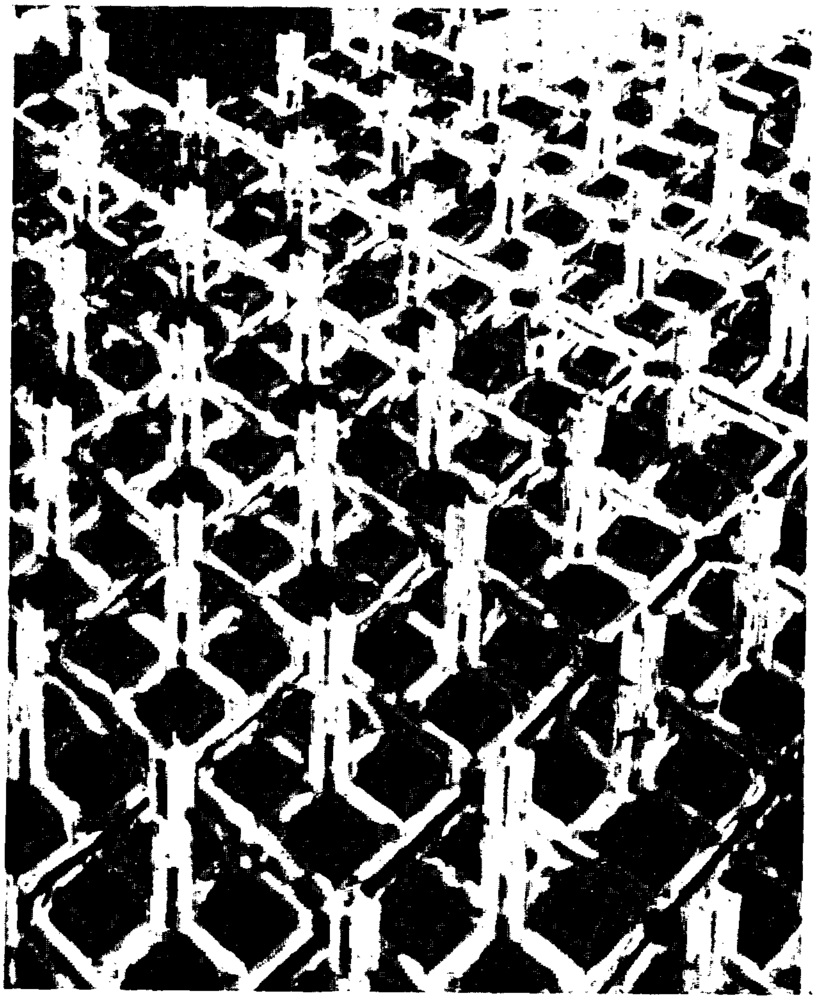
PNL-6049 Vol. III
UC-85

COBRA-SFS: A Thermal-Hydraulic Analysis Computer Code

Volume III: Validation Assessments



December 1986

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

PNL-6049 Vol. III

PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

NTIS Price Codes
Microfiche A01

Printed Copy

Pages	Price Codes
001-025	A02
026-050	A03
051-075	A04
076-100	A05
101-125	A06
126-150	A07
151-175	A08
176-200	A09
201-225	A010
226-250	A011
251-275	A012
276-300	A013

PNL-6049 Vol.111
UC-85

COBRA-SFS: A THERMAL-HYDRAULIC ANALYSIS COMPUTER CODE

VOLUME III: VALIDATION ASSESSMENTS

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the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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ABSTRACT

This report presents the results of the COBRA-SFS (Spent Fuel Storage) computer code validation effort. COBRA-SFS, while refined and specialized for spent fuel storage system analyses, is a lumped-volume thermal-hydraulic analysis computer code that predicts temperature and velocity distributions in a wide variety of systems. Through comparisons of code predictions with spent fuel storage system test data, the code's mathematical, physical, and mechanistic models are assessed, and empirical relations defined. The six test cases used to validate the code and code models include single-assembly and multiassembly storage systems under a variety of fill media and system orientations, and include unconsolidated and consolidated spent fuel. In its entirety, the test matrix investigates the contributions of convection, conduction, and radiation heat transfer in spent fuel storage systems.

To demonstrate the code's performance for a wide variety of storage systems and conditions, comparisons of code predictions with data are made for 14 runs from the experimental data base. The cases selected exercise the important code models and code logic pathways and are representative of the types of simulations required for spent fuel storage system design and licensing safety analyses. For each test, a test description, a summary of the COBRA-SFS computational model, assumptions, and correlations employed are presented. For the cases selected, axial and radial temperature profile comparisons of code predictions with test data are provided, and conclusions drawn concerning the code models and the ability to predict the data and data trends. Comparisons of code predictions with test data demonstrate the ability of COBRA-SFS to successfully predict temperature distributions in unconsolidated or consolidated single and multiassembly spent fuel storage systems.

ACKNOWLEDGMENTS

The authors would like to thank the Department of Energy for sponsoring this work and validation tests performed in support of this effort. Thanks are also extended to Darell Newman, Dale Oden, and Gordon Beeman of the Pacific Northwest Laboratory Commercial Spent Fuel Management Program Office (CSFM-PO) and to Ron Hall of PNL's Monitored Retrievable Storage Program Office (MRS-PO) for their support of this work and associated validation tests. The authors would like to recognize Jim Creer of the CSFM/Dry Storage System Performance Evaluation Project and Dr. Dennis Kreid of the MRS-PO for their efforts toward the successful completion of this validation assessments effort. Finally, thanks to the editors, A. J. Currie and T. L. Gilbride, and to word processor E. C. Darby for their preparation of this document.

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NOMENCLATURE

A - aspect ratio

A_C - contact heat transfer area

D_r - fuel rod outer diameter

D_h - hydraulic diameter

BWR - boiling water reactor

f - friction factor

Gr - Grashof

GWD - gigawatt days

h - heat transfer coefficient

H_C - thermal contact conductance

k - thermal conductivity

K - loss coefficient

MTU - metric ton of uranium

Nu - Nusselt number

P - pitch-to-diameter ratio

Pr - Prandtl number

PWR - pressurized water reactor

Ra - Rayleigh number

Re - Reynolds number

T - temperature

TC - thermocouple

W - watts

Δx - distance between conducting surfaces

ϵ - emissivity

COBRA-SFS: A THERMAL-HYDRAULIC ANALYSIS COMPUTER CODE
VOLUME III: VALIDATION ASSESSMENTS

1.0 INTRODUCTION

The COBRA-SFS (Spent Fuel Storage) code is a lumped, finite-volume, thermal-hydraulic computer code that predicts the temperature and velocity distributions in a wide variety of systems. COBRA-SFS was evaluated and documented for the U.S. Department of Energy's Commercial Spent Fuel Management Program and has been refined and specialized for spent fuel storage system analyses. One of the program's objectives was the evolution of a mechanistically-based computer code that could be used for accurate analyses of complex spent fuel dry storage systems.

Derived from the COBRA family of codes which have been extensively evaluated against in-pile and out-of-pile data, COBRA-SFS retains all the important features of the parent COBRA codes (Rowe 1973; Wheeler et al. 1976; Stewart et al. 1977; and George et al. 1980) and extends the range of application to analyses of spent fuel storage systems. Thus, COBRA-SFS benefits from the validation and assessment efforts of these precursor code versions. The COBRA codes are all based on the subchannel modeling philosophy, which allows complex three-dimensional geometries to be simulated relatively easily and accurately.

To demonstrate the credibility of COBRA-SFS as a computational thermal-hydraulic tool, a significant effort was extended to assess the code's performance and the validity of the computed results. Validation results using earlier versions of COBRA-SFS are provided in Lombardo et al. 1986; McKinnon et al. 1986a; Wiles et al. 1986; Rector et al. 1986a; Cuta and Creer 1986. Validation of the documented version of the code (Rector et al. 1986b, and Rector, Wheeler and Lombardo 1986) is presented in this report. The assessment is based on comparison of code predictions with spent fuel heat transfer test data. The assessment began with simulating simple phenomena in simple geometries and proceeded systematically to complex phenomena and geometries. Fourteen case comparisons were made with the results from six unique spent fuel storage tests. The tests used in the comparisons include all of the combined heat transfer effects expected to occur within spent fuel storage systems.

Select cases were chosen from each test to exercise the important code models and logic pathways. For each test, a test description, and descriptions of the COBRA-SFS computational model and assumptions are given. Comparisons of predictions with data are then presented and the results evaluated. These comparisons, along with pre- and post-test data comparisons presented in other COBRA-SFS application reports, satisfy the objective of the code validation effort: to demonstrate that the coding logic is working correctly, that the physics are modeled properly, and that the code operates as advertised.

This validation assessment volume is the third of a series of three COBRA-SFS documentation volumes. The first volume, Volume 1: Mathematical Models and Solution Method is a description of the theory behind the code. Volume II: User's Manual provides input instructions and guidance in applying the code.

2.0 CONCLUSIONS AND RECOMMENDATIONS

The ability of the COBRA-SFS computer code to predict the thermal performance of spent fuel storage systems was investigated through comparisons of predictions with experimental test data. Fourteen case comparisons from six unique spent fuel storage system tests are presented in this report to assess the code's performance and the validity of the computed results. Comparisons of code predictions with data were made for single and multiassembly storage systems, and a single consolidated test canister. The cases selected for inclusion in this report exercise the important code models and logic pathways and are representative of the type of simulations required for design or licensing applications. The major conclusions and recommendations from this validation effort are presented below.

2.1 CONCLUSIONS

The following conclusions are based on comparisons offered in this report, as well as those documented in earlier applications reports (Lombardo et al. 1986; Wiles et al. 1986; Rector et al. 1986a; Cuta and Creer 1986; McKinnon et al. 1986a).

- Peak system temperatures predicted for the single and multiassembly tests presented in this report were within ±19 and 23°C, respectively.
- The successful predictions of the thermal performance of single, multiassembly, and consolidated assembly storage systems under a variety of backfills (air, nitrogen, helium, and vacuum), heat loadings, and orientations (vertical, horizontal, and inclined) demonstrate that COBRA-SFS can be used for design and licensing safety analyses.
- For large, multiassembly dry storage casks located outdoors, existing standard correlations for cask surface-to-ambient natural and forced convection heat transfer consistently underpredict the actual heat transfer by 20% to 50%. Use of these standard correlations will result in conservatively high predictions of cask surface temperature (and, hence

internal temperatures) for mixed (natural and forced) convection atmospheric conditions.

- Although the majority of cases presented in this report reflect post-test simulations, the ability to make accurate predictions prior to the availability of test data depends heavily on the accuracy and reliability of the geometry, material, and heat generation data provided to the modelers. Generally speaking, the modifications made for the post-test predictions represent refinements in the above parameters, or their uncertainties, which are physically defensible, and do not constitute mere "tuning" or "force fitting" of the code to the data.
- Little effort was devoted to improving the data comparisons except for identifying and correcting obvious input and modeling deficiencies. In some cases the data comparisons might be improved by better noding, and by adjusting heat transfer and friction factor correlations, etc. Most of the comparisons were made in a way that an unfamiliar user might be expected to pursue and therefore are believed to be representative of the code's predictive capabilities.
- Additional refinements in the modeling of fluid-to-fluid heat transfer, and in the modeling of heat transfer and fluid flow in the plenum regions would be expected to further improve the code's predictive capabilities.
- Conduction is the primary mode of heat transfer in consolidated fuel assembly tests. To accurately (±10 to 20°C) predict the temperature distribution in consolidated assemblies, accurate estimates of rod-to-rod and rod-to-wall contact conductances are required. The contact conductance values used in the simulation of the single assembly consolidated spent fuel test (electrically heated model fuel rods straightened to a tolerance of 0.083 mm/m (0.001 in./ft)) may not be representative of conductance values in actual consolidated fuel. However, when modeling consolidated rods, the assumption of uniform rod-to-rod and rod-to-wall gaps will not result in an excessively high (±20°C) overprediction of fuel rod temperatures.

- The 14-case comparison presented in this report, along with 54 other case comparisons documented in earlier applications reports, satisfies the objective of the code validation effort: to demonstrate that COBRA-SFS is capable of accurately predicting the thermal performance of spent fuel storage systems over a wide range of conditions, that the code logic is working correctly, and that the physics are modeled properly.
- To properly assess code predictions, comparisons of peak temperature, axial temperature profiles, and radial temperature profiles should be made.

2.2 RECOMMENDATIONS

Based on the case comparisons presented in this report and the other COBRA-SFS comparisons with data reported in the various applications reports, the following recommendations are offered.

- COBRA-SFS should continue to be used to predict temperature distributions in spent fuel storage systems and, when available, additional comparisons with measured data should be made.
- If accuracy better than approximately 20°C to 30°C is required, the following, in order of importance, should be pursued:
  - System geometries, especially as-built gap widths and characteristics of contacting surfaces (contact coefficients) should be known.
  - The surface conditions of the components (material emissivities) should be known.
  - The effects of atmospheric turbulence on the surface convective heat transfer for casks located outdoors should be modeled. Existing correlations do not adequately model these effects.
  - Detailed in-reactor radiation scans or spent fuel assembly gamma scans should be used to determine or calculate axial decay heat profiles.
  - COBRA-SFS models of heat transfer and fluid flow in the cask plenum regions should be refined to include radially varying inlet

conditions, a computed velocity field, and multidimensional heat transfer between solid structures.

- To enhance the prediction accuracy of convection heat transfer dominated systems, velocity fields should be measured in simulated casks or future cask tests for comparison with COBRA-SFS predictions.

3.0 COBRA-SFS DESCRIPTION

The COBRA-SFS code is a generalized, steady-state, finite-volume computer code that predicts flow and temperature distributions in spent fuel storage systems and fuel assemblies under mixed and/or natural convection conditions. Derived from the COBRA family of codes that have been extensively evaluated against in-pile and out-of-pile data (Stewart et al. 1977, Khan et al. 1981), COBRA-SFS retains all the important features of the parent COBRA codes and extends the range of application to problems with two-dimensional radiation and conduction heat transfer. This capability permits analyses of single- and multiassembly spent fuel storage systems with unconsolidated or consolidated fuel in both the vertical and horizontal orientations, using a variety of fill media.

In the following sections, COBRA-SFS background modeling capabilities and modeling philosophy are discussed. Detailed discussions of the code and its use are presented in Volumes I and II of this document (Rector, Wheeler and Lombardo, 1986, and Rector et al. 1986b).

3.1 COBRA-SFS BACKGROUND

COBRA-SFS was evolved on the strengths of the COBRA code series. COBRA-IIIC (Rowe 1973), COBRA-IV-I (Wheeler et al. 1976), COBRA-IV (Stewart et al. 1977), and COBRA-WC (George et al. 1980) were developed by the Pacific Northwest Laboratory under sponsorship of the Atomic Energy Commission, the Nuclear Regulatory Commission, and the Department of Energy as part of the reactor safety research effort. The basic computational philosophy of COBRA-SFS comes from COBRA-WC, which included the capability of predicting recirculating (natural convection) flows.

To extend the range of applicability of COBRA-WC to address the expected radiation and conduction heat transfer components in a spent fuel storage system, a wall conduction model and fuel rod and wall radiation heat transfer models were incorporated into COBRA-WC to form the earliest versions of COBRA-SFS. These somewhat crude versions of COBRA-SFS were used to make prelook predictions for the pressurized water reactor (PWR) single assembly spent fuel test described in Section 4.1 of this report. The success of these predictions suggested that further comparisons of the code with data be performed to fully evaluate the models contained in COBRA-SFS. As new data were made available, COBRA-SFS was refined to provide additional heat transfer and fluid modeling capabilities to facilitate the modeling of different spent fuel storage systems.

Specifically, the documented version of the code (Rector et al. 1986b; Rector, Wheeler and Lombardo 1986) used to perform the simulations presented in this report contains:

- a numerical procedure to internally iterate to a zero-net flow solution
- upper and lower plenum heat transfer models
- a structural member axial conduction model
- a more flexible boundary heat transfer model
- a generalization of the input for the radiation exchange model.

3.2 MODELING CAPABILITIES

A wide range of spent fuel storage systems can be simulated by COBRA-SFS via input instructions. Applications have included analyses of single assembly storage systems (Lombardo et al. 1986; Cuta, Rector and Creer 1984), multiassembly spent fuel storage systems under various orientations and fill media (Wiles et al. 1986; Rector et al. 1986a; McKinnon et al. 1986a), and analyses of both single- and multiassembly consolidated storage systems (Cuta, Rector and Creer 1984; Cuta and Creer 1986; Rector and Wheeler, 1986). The code contains thermal-hydraulic models for pressure drop, turbulent mixing, subchannel diversion crossflow, buoyancy-induced flow recirculation, conduction and radiation heat transfer, and boundary and plenum heat losses. A summary of the code characteristics is presented in the list below.

- Modeling Capabilities
    - quasi three-dimensional
    - steady state
    - triangular, square, or consolidated rod arrays
    - multiple flow regions

  - recirculating flows
  - interassembly and intra-assembly heat transfer
  - mixed coordinate systems
  - variable axial grid spacing
  - fluid conduction and turbulent mixing
  - pressure drop model (network and subchannel)
  - variable rod property
  - variable boundary heat transfer
  - prescribed surface heat flux
  - plenum heat transfer
  - user-prescribed flow
  - variable fluid properties
- Program and I/O Control
  - constant prescribed flow
  - zero-net flow solution
  - restart and post-processing dump
  - decoupled hydrodynamics (no buoyancy)
  - fully coupled hydrodynamics
  - echoed input
  - result execution and time monitoring
  - pressure drop initialization scheme
  - data "roll" option for large problems
- Limitations and Assumptions
  - steady state
  - single phase
  - incompressible but thermally expandable flow
  - lumped parameter approach
  - quasi three-dimensional
  - no free-field capability
  - one-dimensional boundary heat transfer
  - nonparticipating radiation (planar).

3.3 COMPUTATIONAL PHILOSOPHY

The COBRA-SFS code is based on the subchannel modeling philosophy. This method has been used extensively in the nuclear industry in past years because it allows complex three-dimensional geometries to be simulated easily and accurately. In the subchannel approach, the storage system, fuel assembly, or waste form being simulated is divided into a number of quasi two-dimensional flow paths or channels. These channels are characterized mathematically by a flow area and wetted perimeter--the exact shape of the channel is unimportant. The relation of a subchannel control volume to a storage system is depicted in Figure 3.1.

Mass, momentum, and energy can be exchanged between neighboring channels by diversion crossflow and turbulent mixing. A lateral connection between channels is defined mathematically by a gap width and the distance between channel centroids. Since a crossflow exists only between adjacent channels that are connected and since there is no momentum coupling from one crossflow to another, discrete lateral coordinate directions or lateral boundary conditions are not needed.

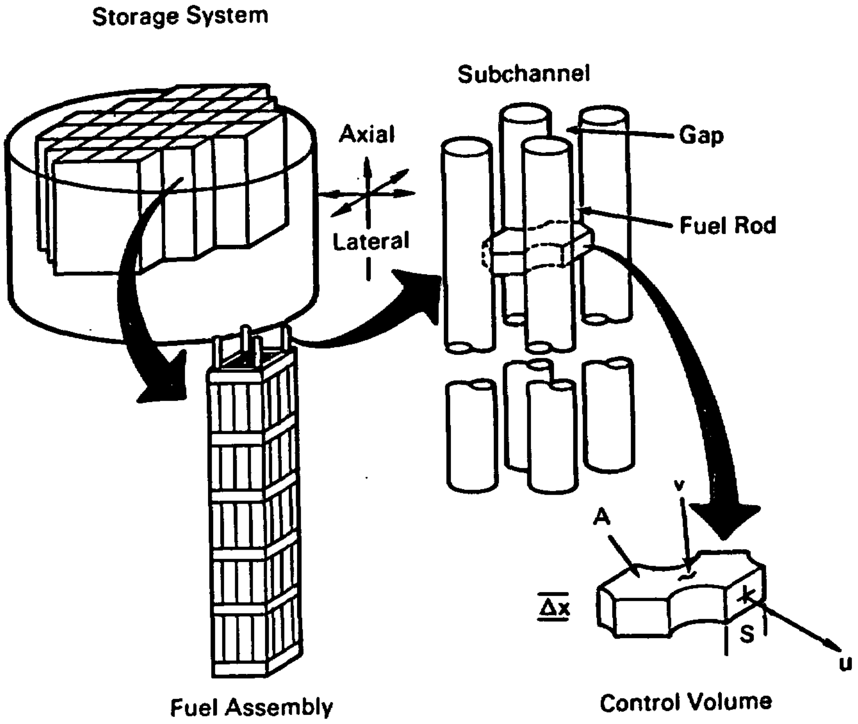


FIGURE 3.1. Relation of Subchannel Control Volume to a Storage System

Subchannels can be used in a variety of ways to describe fluid flow regions. The channel shapes may be quite regular, as in the square array of a fuel bundle, or quite irregular, where large areas of flow are lumped into a single flow channel. In either case, the channels may be connected to an arbitrary number of adjacent channels. Additionally, subchannels may be thermally connected to an arbitrary number of wall or slab nodes; wall nodes can then be thermally connected to any number of other walls by conduction or radiation heat transfer. The overall flexibility of the subchannel approach makes it a very powerful tool in effectively simulating complex geometries.

4.0 SINGLE ASSEMBLY EVALUATION TESTS

The first step in the evaluation of COBRA-SFS was the analyses of single assembly storage systems. Conduction, convection, and radiation heat transfer mechanisms must be properly modeled to accurately predict the thermal performance of these systems. To demonstrate the effectiveness of the COBRA-SFS models for single assembly spent fuel heat transfer, COBRA-SFS predictions of three unique single assembly spent fuel tests, two with an unconsolidated assembly and one with a consolidated assembly, are compared against test data in the following sections. The first test performed and described below was the PWR Single Assembly Spent Fuel Heat Transfer Test, which examines the effect of fill media on thermal performance of an actual PWR spent fuel assembly. Next, the Electrically Heated PWR Single Assembly Test, which examines the thermal response of a model spent fuel assembly under various loadings, orientations, and backfills, is described. Finally, the Consolidated Spent Fuel Test, which examines the heat transfer of model consolidated fuel arrays, is described.

4.1 PWR SINGLE ASSEMBLY SPENT FUEL TESTS

In this test series, the temperature response of a single, instrumented, vertical PWR spent fuel assembly was investigated in atmospheres of air, helium, and a partial vacuum. Experimental axial temperature data were obtained at several radial positions for fixed boundary conditions, thereby quantifying the effect of fill media in the vertical orientation. To examine COBRA-SFS's predicted effect of fill media, simulations of all three test cases were made. In this section, descriptions of the test apparatus, computational model, and modeling uncertainties are provided, along with results of comparisons of predictions with data. Input, representative output, and convergence listings for the cases simulated are presented in Appendix A. Results of prelook simulations made prior to the availability of test data are documented in an earlier applications report (Lombardo et al. 1986).

4.1.1 Test Description

The PWR single assembly test apparatus is shown in Figure 4.1. The test section consisted of a single PWR spent fuel assembly sealed in an instrumented stainless steel canister, which was enclosed in a carbon steel cylindrical liner. The test assembly was maintained in a vertical position by a seismic restraint fixture. The test apparatus and procedures are fully described by Bates (1986), so only a summary of the components is given below.

The PWR spent fuel assembly used in these tests was discharged from the Florida Power and Light Turkey Point Unit Number 3 reactor with a burnup of approximately 28,000 MWD/MTU. The fuel assembly consisted of a 15x15 array with 204 fuel rods, 20 control rod guide tubes, and 1 instrumentation tube. The active fuel length after exposure was assumed to be 3658 mm (144 in.); the overall fuel assembly length was 4097 mm (161 in.). A total of seven spacer grids were located axially over the length of the fuel. A list of relevant fuel assembly parameters is presented in Table 4.1.

Decay heat measurements of the spent fuel assembly were obtained from boiling water calorimetry measurements (Creer et al. 1981; Schmittroth 1984). Decay heat levels of 1.17 kW for the air and vacuum runs and 1.16 kW for the helium run were reported subject to a ±5% accuracy. The axial decay heat profile was inferred from gamma flux measurements of a selected sample of individual fuel pins. It was assumed that the axial decay heat flux is directly proportional to the gamma flux; a plot of the axial decay heat distribution inferred from the measured gamma flux is displayed in Figure 4.2.

During testing, the spent fuel assembly was placed inside the cylindrical, stainless steel test canister. The canister was surrounded by an externally heated, carbon steel pipe which elevated the temperature of the canister wall to values typical of what might be expected in a multiassembly storage system. Welded to the inside of the canister was the fuel assembly vertical support cage, which provided lateral restraint and centered the assembly within the canister. The fuel assembly support cage was fabricated from four 50.8 mm

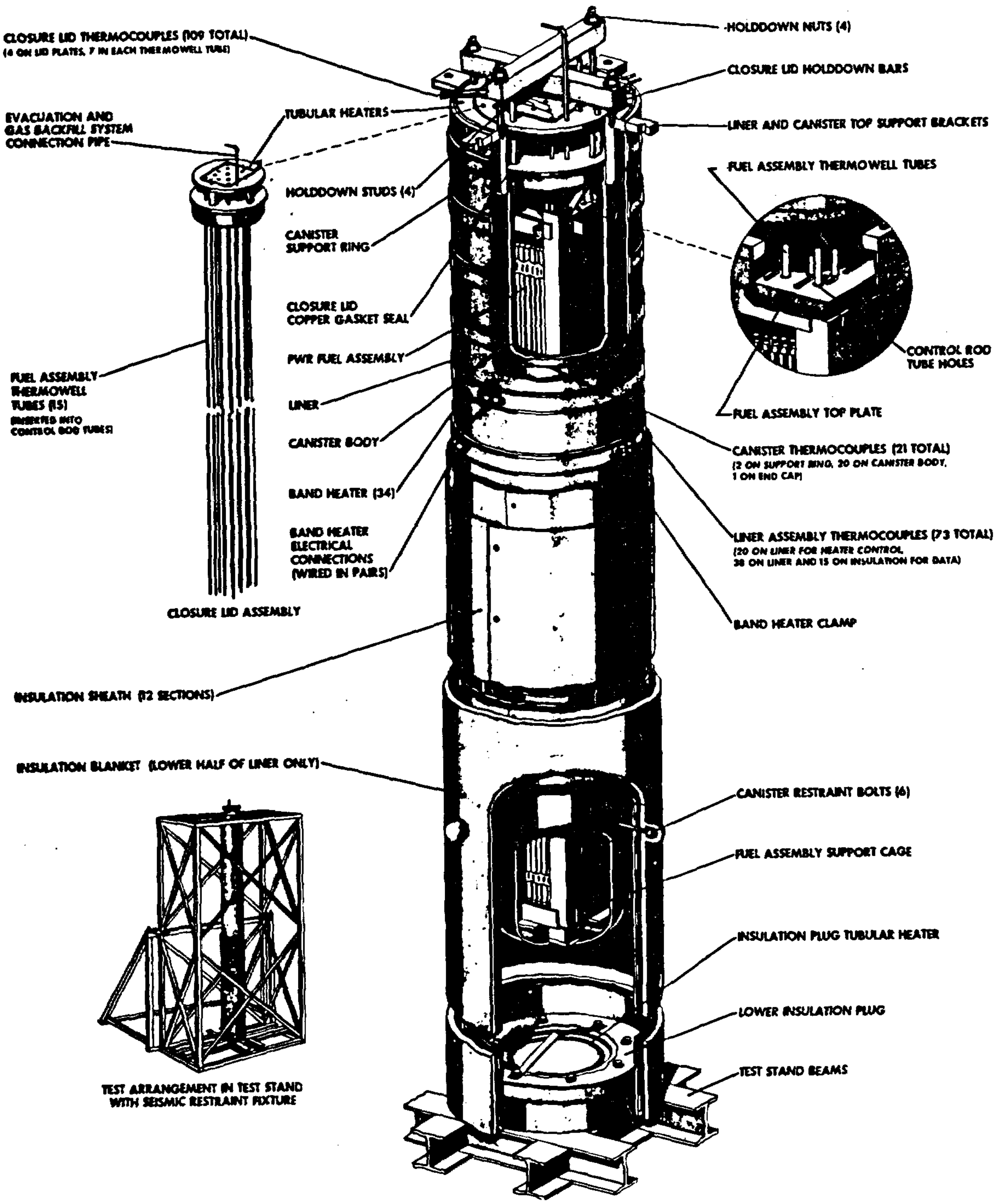


FIGURE 4.1. PWR Single Assembly Spent Fuel Test Apparatus

TABLE 4.1. Turkey Point No. 3 PWR Fuel Assembly Parameters

Vendor	Westinghouse Electric Corp
Type (Rod Array)	15 x 15
Assembly Parameters	
Transverse Dimension	21.4 cm (8.426 in.)
Assembly Weight	652.73 kg (1439 lb)
Assembly Length	409.7 cm (161.3 in.)
Control Rod Guide Thimble Tubes	
Number	20
Upper OD	1.39 cm (0.546 in.)
Wall Thickness	0.43 mm (0.017 in.)
Material	Zr-4
Instrument Tubes	
Number	1
OD	1.39 cm (0.546 in.)
Wall Thickness	0.43 mm (0.18 in.)
Material	Zr-4
Spacer Grids	
Number	7
Material	Inconel 718
Spring Material	Inconel 718
Fuel Rods	
Number	204
Length	386.08 cm (152.0 in.)
OD	1.07 cm (0.422 in.)
Wall Thickness	0.62 mm (0.0243 in.)
Material	Zr-4
Fuel Length	365.76 cm (144.0 in.)
Plenum Springs	
Working Length	17.27 cm (6.80 in.)
Material	Inconel 718
Fuel Pellet	
Material	UO_2
Enrichment	2.559 Weight % U^{235}
Density	92% Theoretical

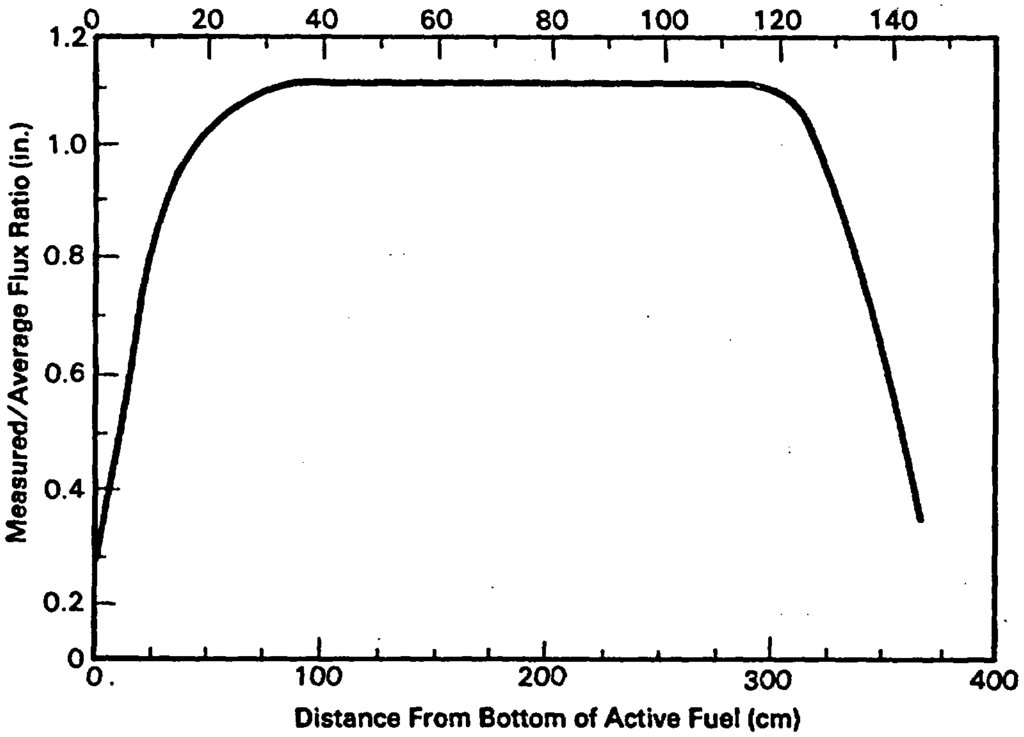


FIGURE 4.2. Turkey Point Spent Fuel Assembly Axial Decay Heat Profile

(2 in.) angle-iron pieces, with each member set upright and positioned adjacent to the assembly corners. Rectangular metal plates were used to join the vertical members of the support cage at six axial levels.

Instrumentation of the canister consisted of 20 thermocouples placed at 5 different axial locations on the outer wall to provide boundary temperature data and heater control. Attached to the canister upper end cap was a tubular heater, also used to maintain elevated boundary temperatures. An axial cross section of the test assembly and canister thermocouple locations is shown in Figure 4.3. Note that the canister was suspended from the liner to minimize the axial heat transfer.

The test assembly was sealed by the canister closure lid assembly. The closure lid assembly was penetrated by 15 instrumentation tubes. The tubes were positioned so that they could be inserted into the existing, hollow

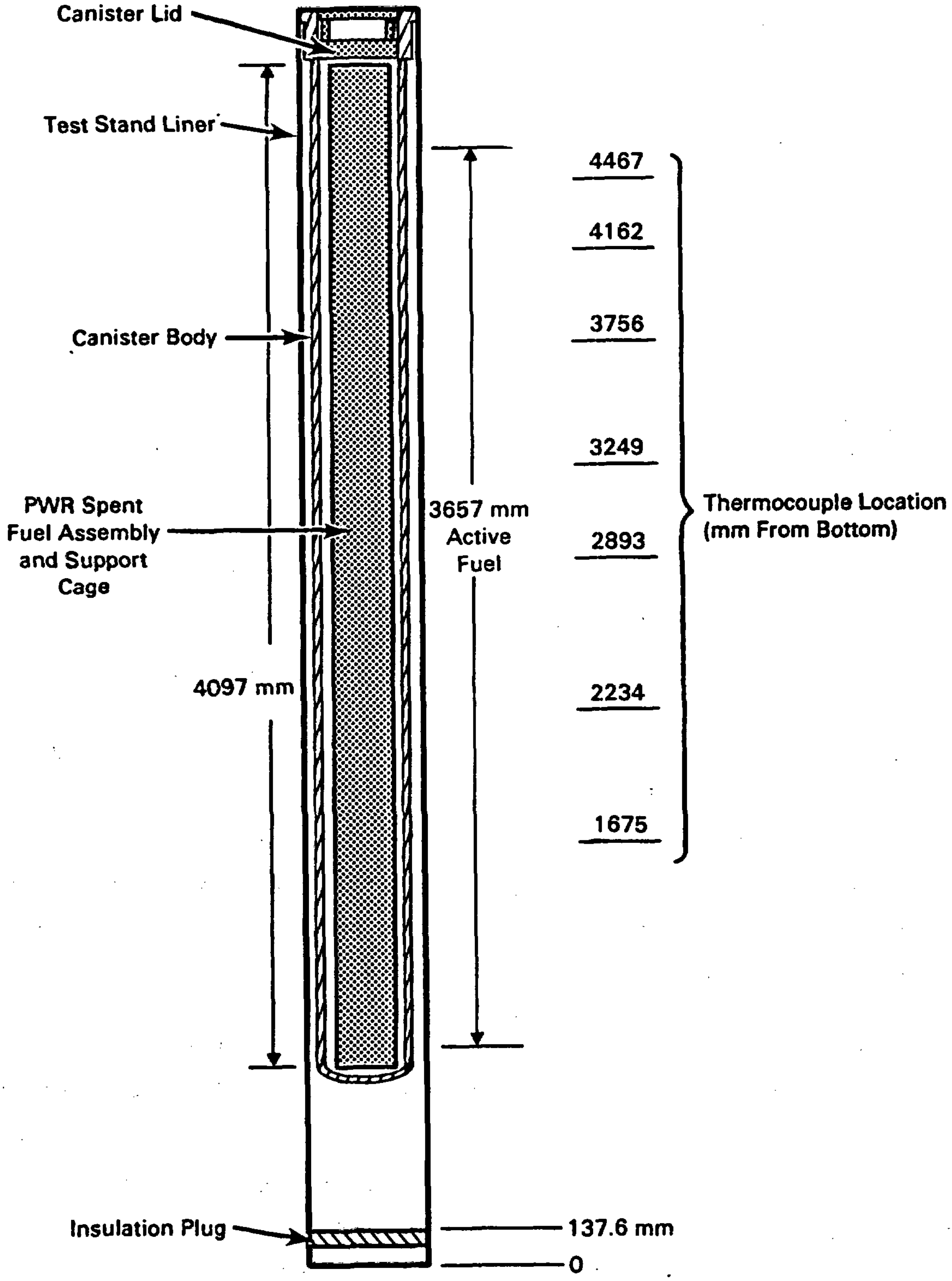


FIGURE 4.3. PWR Single Assembly Spent Fuel Test Apparatus Axial Cross Sections and Thermocouple Locations

PWR fuel assembly control rod guide tubes and center instrumentation tube. Each instrumentation tube contained seven thermocouples and provided fuel assembly temperature data over the length of the bundle. A cross sectional view of the fuel assembly and canister presented in Figure 4.4 illustrates the thermocouple position within the canister. In addition to the instrument tubes, a penetration for gas evacuation and backfill was provided to allow the canister to be filled with various gaseous media for fuel temperature response testing.

Surrounding the canister assembly was a 457.2-mm-(18 in.) diameter carbon steel pipe referred to as the liner. Thirty-four electric-band trace heaters were placed along the liner outside surface to impose an elevated axial temperature distribution along the canister surface. The liner and band heaters were surrounded by a stainless steel insulation sheath; wrapped around the sheath was an insulation blanket to further reduce the test assembly radial heat loss. Additional trace heating was applied in the liner bottom and top plates.

A total of 71 thermocouples were secured to the liner. Of these, 55 provided temperature data; the remaining 18 provided temperature feedback information to the heater controllers. The liner data thermocouples were located midway between the band heaters.

Operation of the test assembly was conducted in atmospheres of air, helium, and a vacuum. For each of the test runs, the liner heater controllers were set to provide a predetermined temperature profile along the canister. Fuel temperature data were taken when thermal stabilization was reached. For the air runs, the vent valve was left open to the atmosphere; in the helium runs the canister was backfilled and pressurized to 1.07 ± 0.03 atmospheres. All vacuum runs were conducted with the vacuum pump running and the cask internal pressure maintained at approximately 0.2 atmospheres. The degree of vacuum imposed in this test represents a low pressure condition, sufficient to eliminate convection, but not low enough for free molecular flow. Thus, the gas thermal conductivity was assumed to be unaffected at these low pressures.

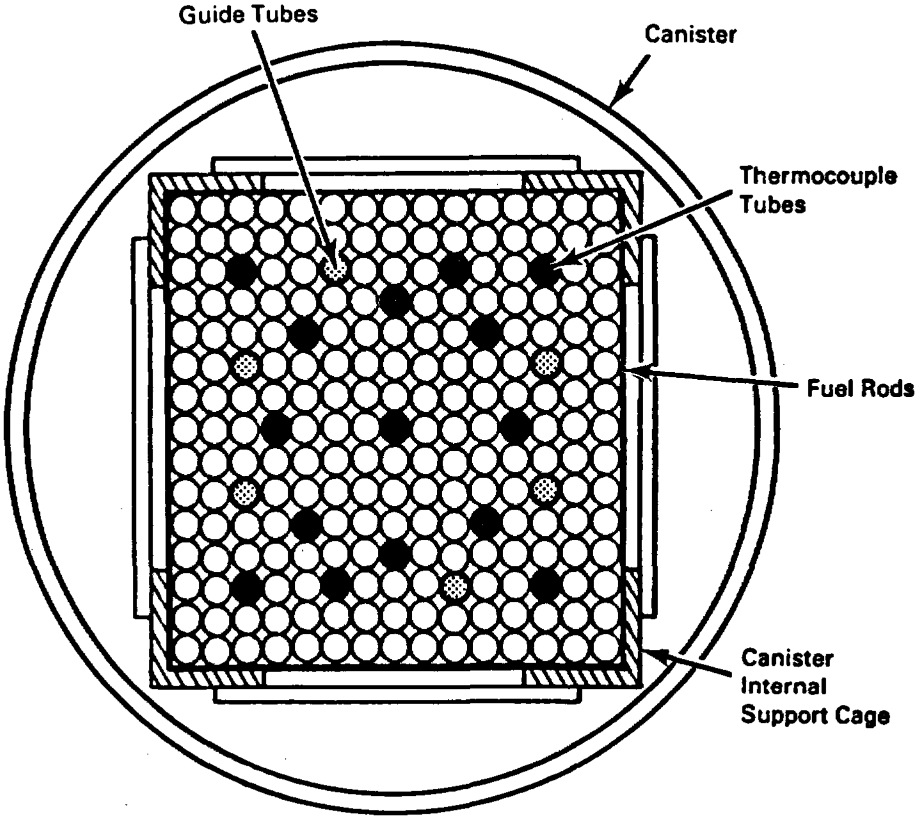


FIGURE 4.4. Transverse Cross Sectional View of PWR Single Assembly Spent Fuel Test Apparatus

4.1.2 Computational Model Description

The computational model used to simulate the PWR Single Assembly Heat Transfer Test is described in this section, along with the modeling parameters and correlations employed. A brief discussion of the modeling uncertainties is also provided. A comparison of code predictions with data is then presented and discussed.

4.1.2.1 Nodal Representation

A three-dimensional model of the PWR Single Assembly Spent Fuel Test Apparatus was used for this analysis. A transverse cross sectional view of the computational cell arrangement illustrating the subchannel and wall noding employed is displayed in Figure 4.5. A total of 34 axial levels were used in the model.

The test apparatus was modeled using a single assembly, segregated into two distinct regions. The inner, or fuel assembly region, consisted of 31 fuel rods, 4 control rod guide tubes, a center instrumentation guide tube, and 28 fluid subchannels. The second, or downcomer region, consisted of the large flow area defined between the outer row of rods and the canister wall and was modeled as a single channel. Boundary temperatures were specified at the canister wall via input instructions.

Each rod in the interior assembly was individually modeled and divided into five, uniform radial nodes: four for the fuel, and a single node for the cladding. No circumferential rod effects or rod axial heat transfer were modeled. Only the fuel rods were assumed to produce any heat; the measured axial heat profile presented in Figure 4.2 was applied uniformly at each radial position. No flow through the hollow guide or instrumentation tubes was allowed. Appropriate fuel and guide tube diameters were used for the rod and subchannel models.

Two-dimensional rod-to-rod and rod-to-wall radiation heat transfer in a plane was modeled from graybody exchange factors that were provided as input to the code. The exchange factors were developed using the following assumptions:

- isothermal, gray surfaces
- non-participating media
- diffusely reflecting and emitting surfaces
- uniform radiosity over an exchanging surface.

For the fuel rods, the minimum area used to calculate black body view factors was a one-quarter rod surface segment. The evaluation of black body viewfactors based on one-quarter pin surface segments has been shown previously to provide accurate modeling of radiation heat transfer in a fuel rod bundle (Lombardo et al. 1986; Cox 1977). The assembly support cage was ignored when calculating the graybody exchange factors, and it was further assumed that the fuel rods,

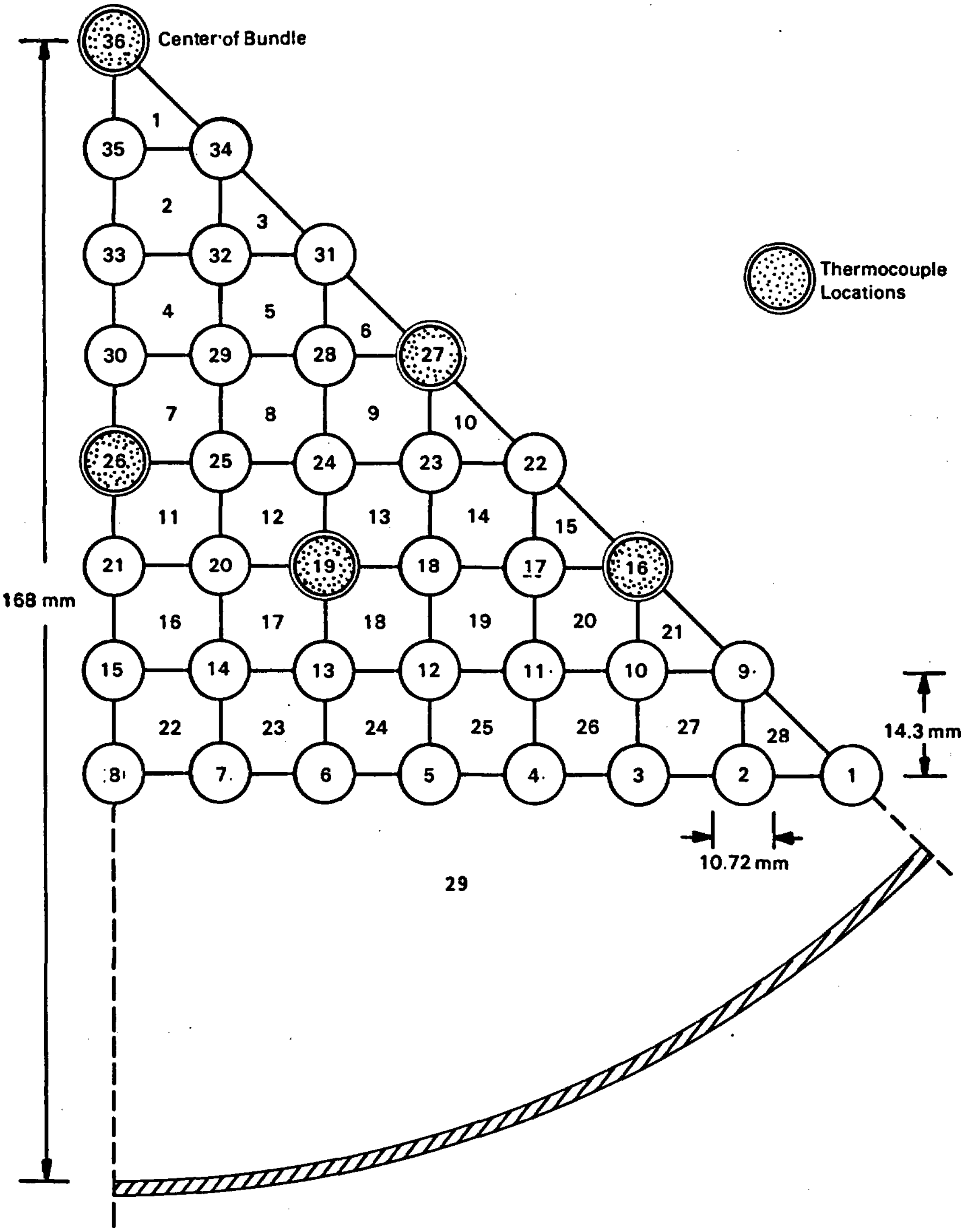


FIGURE 4.5. Transverse Cross Section of COBRA-SFS Computational Model for the PWR Single Assembly Test Apparatus

guide tubes, and instrumentation tube all had the same diameter and emissivities.

4.1.2.2 Modeling Parameters and Correlations

The material properties used in the computational model, with the exception of emittances, were well defined. Solid properties were assumed to be independent of temperature, while fluid properties were input as functions of temperature and were continuously updated during the simulation. The emissivity values used for the highly oxidized zircaloy clad fuel rods and stainless steel canister inner wall were best-estimate values, selected at 0.8 and 0.3, respectively (Peterson 1975, Siegel and Howell 1972).

Fluid conduction was included for all fill media, but was most important for helium. Conduction lengths similar to the fuel rod pitch were used within the fuel rod array.(a) Fluid conduction between the subchannels adjacent to the outer row of rods and the large downcomer subchannel was also accounted for.

The flow resistance of the test section is important in defining the overall contribution of convection heat transfer within the cask. Rod and wall friction losses were modeled using an analytical solution for fully developed laminar flow along cylinders arranged in a square array; $f = 100/Re$ (Sparrow and Loeffler 1959). Loss coefficients for grid spacers, entrance, and exit losses were assumed to be negligible.

Heat transfer from the rods and walls to the coolant was prescribed using the film coefficient $Nu = 3.66$ (Kays and Crawford 1980). This formulation is an exact solution of the energy equation for a circular tube with a constant surface-temperature and fully developed velocity and temperature profiles. The film coefficient was evaluated as a function of temperature at each location and was applied to both the fuel assembly and downcomer assemblies. For the vacuum case (low pressure air), no enhancement of the heat transfer by convection was assumed; thus, $Nu = 1.0$.

(a) Conduction length is the distance used to define the temperature gradient when calculating the heat transfer between adjacent subchannels.

4.1.2.3 Modeling Uncertainties

The computational model used in the analysis was based on information provided by Westinghouse, Advanced Energy Systems Division (Unterzuber 1981) and summarized by Bates (1986). In developing the model, significant uncertainties were associated with the following important heat transfer and fluid flow parameters:

- material emissivities
- radiation heat transfer shielding effects
- contact heat transfer
- flow resistances
- axial decay heat generation profiles.

The rod and canister wall emissivities are key parameters in the radiation model. A wide range of emissivity values was observed in the literature for these components and was found to be dependent upon oxidation buildup, fabrication technique, and temperature. The values used for the fuel rods and canister wall, 0.8 and 0.3, respectively, are best estimates. Confidence in these values is not absolute, and variations in emissivity from rod to rod may exist. Axial variations in rod emissivity may exist as well.

The heat transfer shielding effect of the fuel assembly support cage is another uncertainty in the radiation model. The angle-iron structures and horizontal support plates of the support cage act as an intermediate radiation shield; however, that effect was ignored for simplicity of model setup. The consequences of ignoring the shielding effects of the support cage are expected to be most severe for the vacuum run.

The unmodeled contact between the fuel assembly and the support cage is another uncertainty. The effect of contact would be to slightly lower and/or skew the fuel rod temperature distribution within the bundle. Since the existence and type of contact were not well defined, the fuel assembly was assumed centered vertically within the canister. Some contact between the spent fuel assembly bottom inlet nozzle and the canister bottom was also expected. Again, specific details of this contact are not known and were not modeled.

Thus, an additional source of uncertainty exists in the unmodeled axial heat transfer from the lower regions of the fuel assembly to the canister bottom.

A good deal of uncertainty exists in the modeling test section flow resistances. Unmodeled flow resistances include those of the grid spacers, and the fuel assembly inlet and outlet nozzles. The unmodeled losses from these components should enhance the natural convection predicted within the cask. The form drag correlation used for the fuel rods was assumed to apply in the open downcomer region; application of this correlation to the geometry of the downcomer region thus represents another uncertainty.

The assumption of symmetry in fuel loading and geometry allowed simulation of the test apparatus using a one-eighth sector model. Some uncertainty may be attributed to this assumption, since the radial heat distribution within a spent fuel assembly can be significantly asymmetric depending on its exposure history. A small uncertainty exists in the measured axial decay heat profile as well.

4.1.3 Comparisons of Predictions to Data

Representative predicted axial temperature profiles for the peak temperature instrumentation tube are plotted with the experimental test data for the three fill media cases in Figures 4.6 through 4.8. The data are presented for rod number 36 (center tube) as a function of elevation from the cask bottom for each fill media. Radial profiles are also plotted with the data at an elevation of 185 cm (72.8 in.) above the cask bottom in Figure 4.9 through 4.11. Both the axial and radial plots are presented in order of increasing system temperature, i.e., helium, air, and vacuum backfills.

Rod temperature data were obtained from thermocouples located inside an instrument tube inserted into the hollow instrumentation tube of the spent fuel assembly. The two cylinders surrounding the thermocouples act as thermal radiation shields so the recorded temperature is slightly lower ($<$ 5°) than the surface temperature (Unterzuber 1982). Code predictions represent surface or cladding temperatures, which should be slightly higher than the internally measured data.

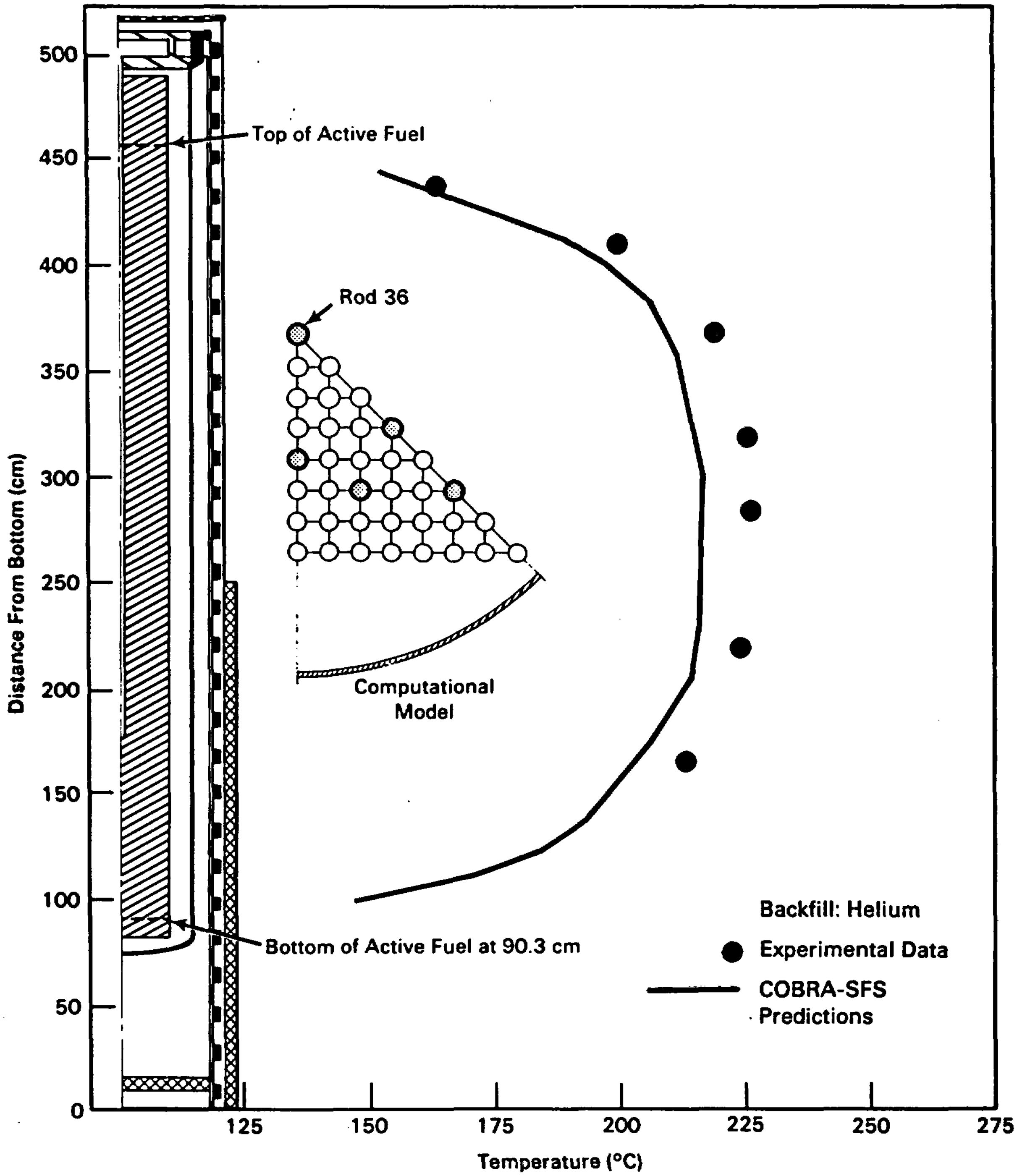


FIGURE 4.6. Predicted Axial Temperature Profile Compared to Rod No. 36, PWR Single Assembly Helium Test Data

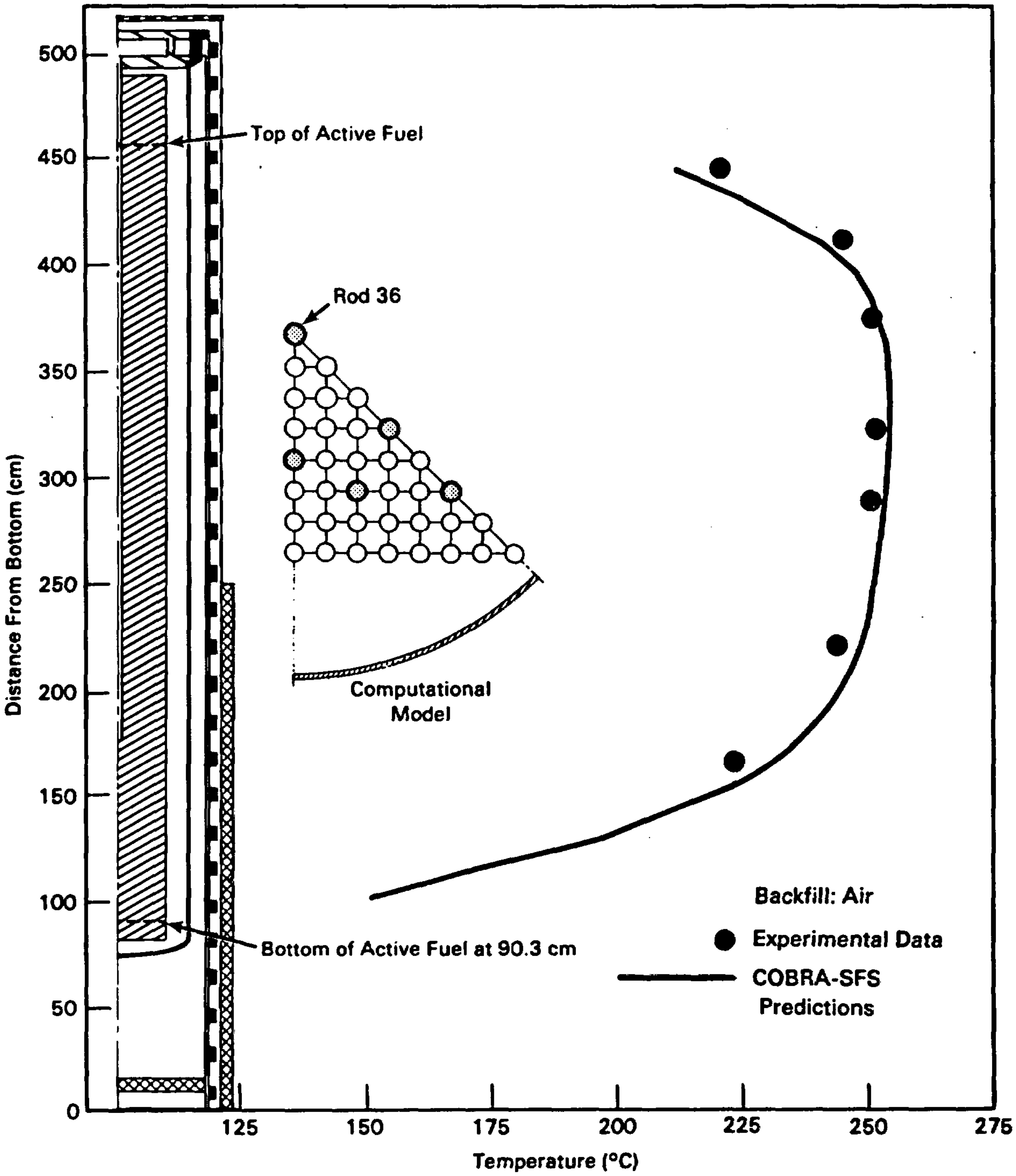


FIGURE 4.7. Predicted Axial Temperature Profiles Compared to Rod No. 36, PWR Single Assembly Air Test Data

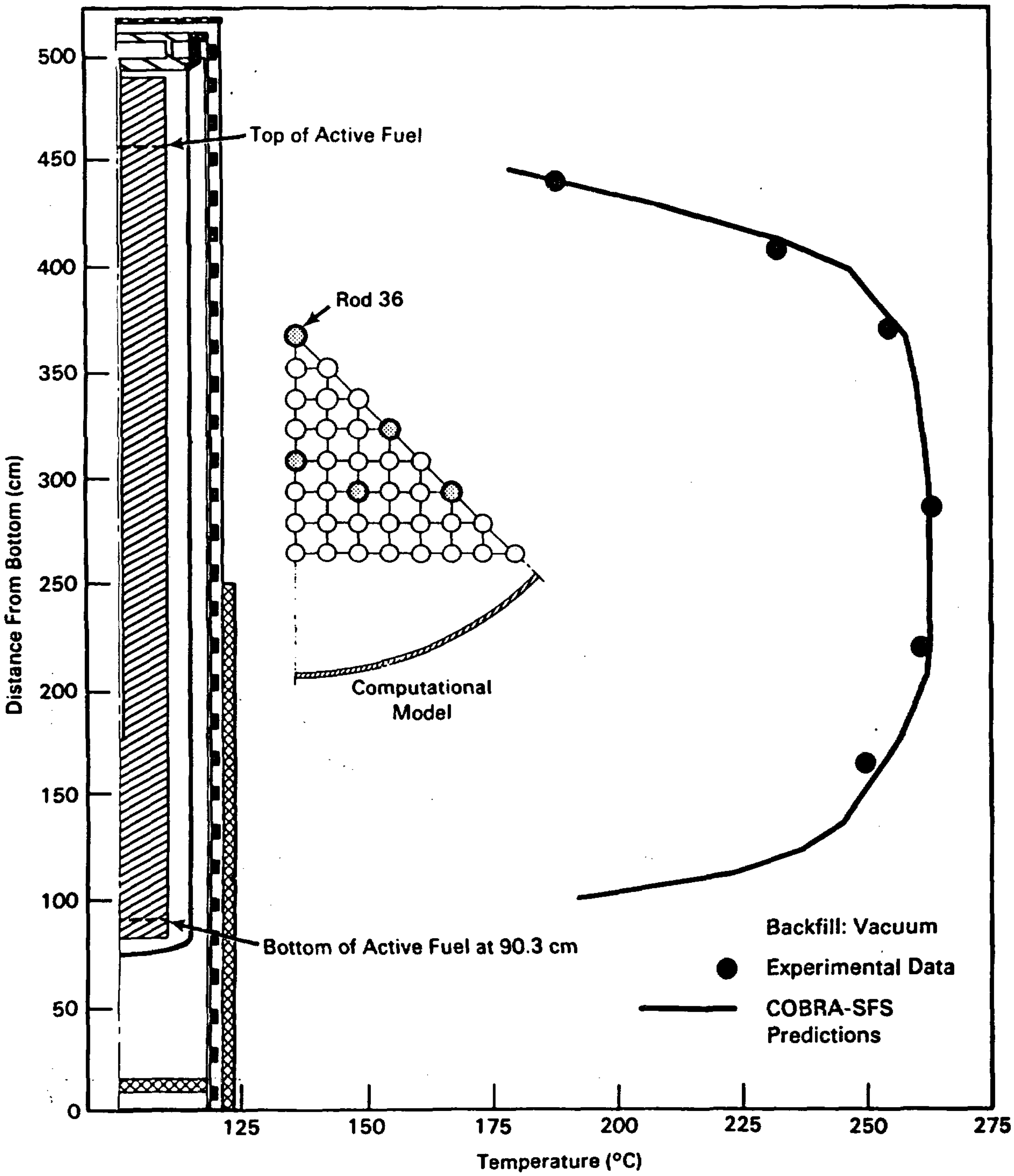


FIGURE 4.8. Predicted Axial Temperature Profile Compared to Rod No. 36, PWR Single Assembly Vacuum Test Data

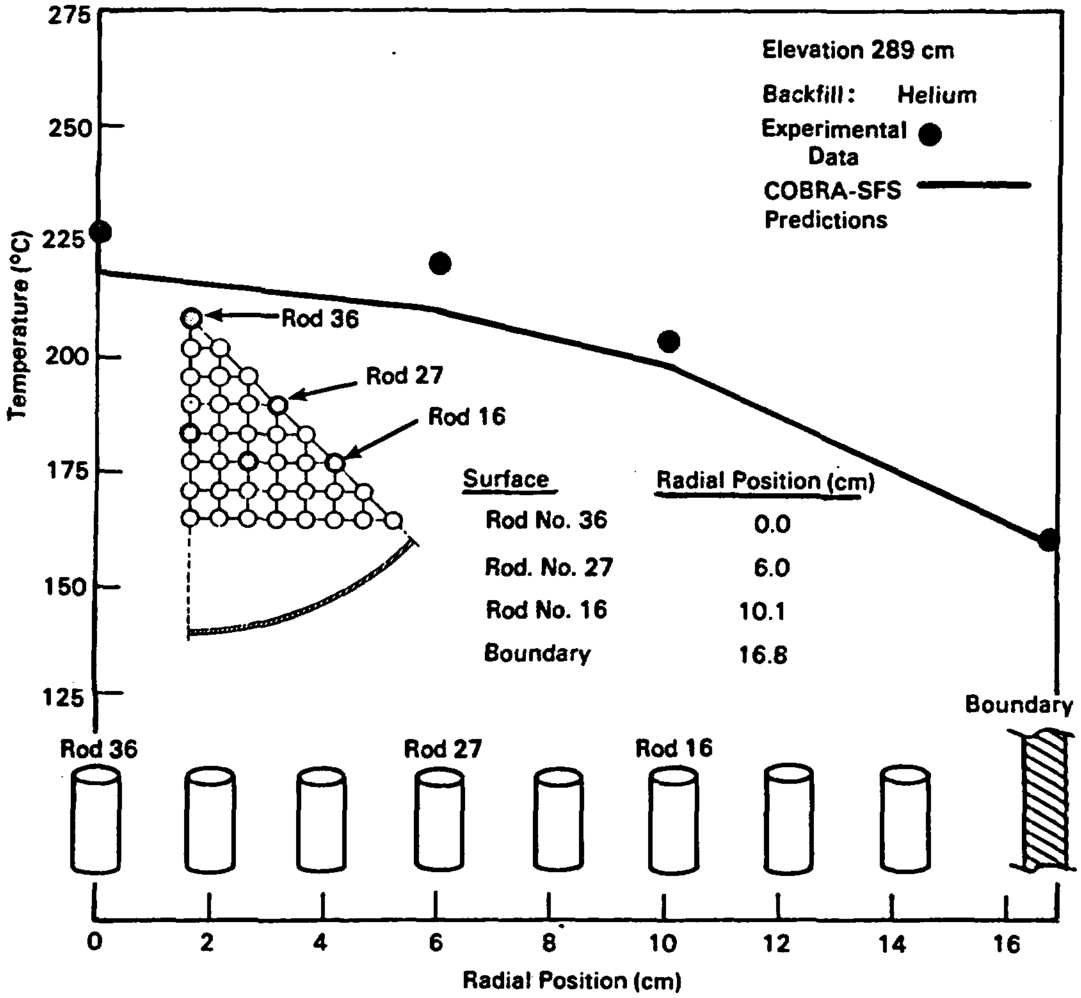
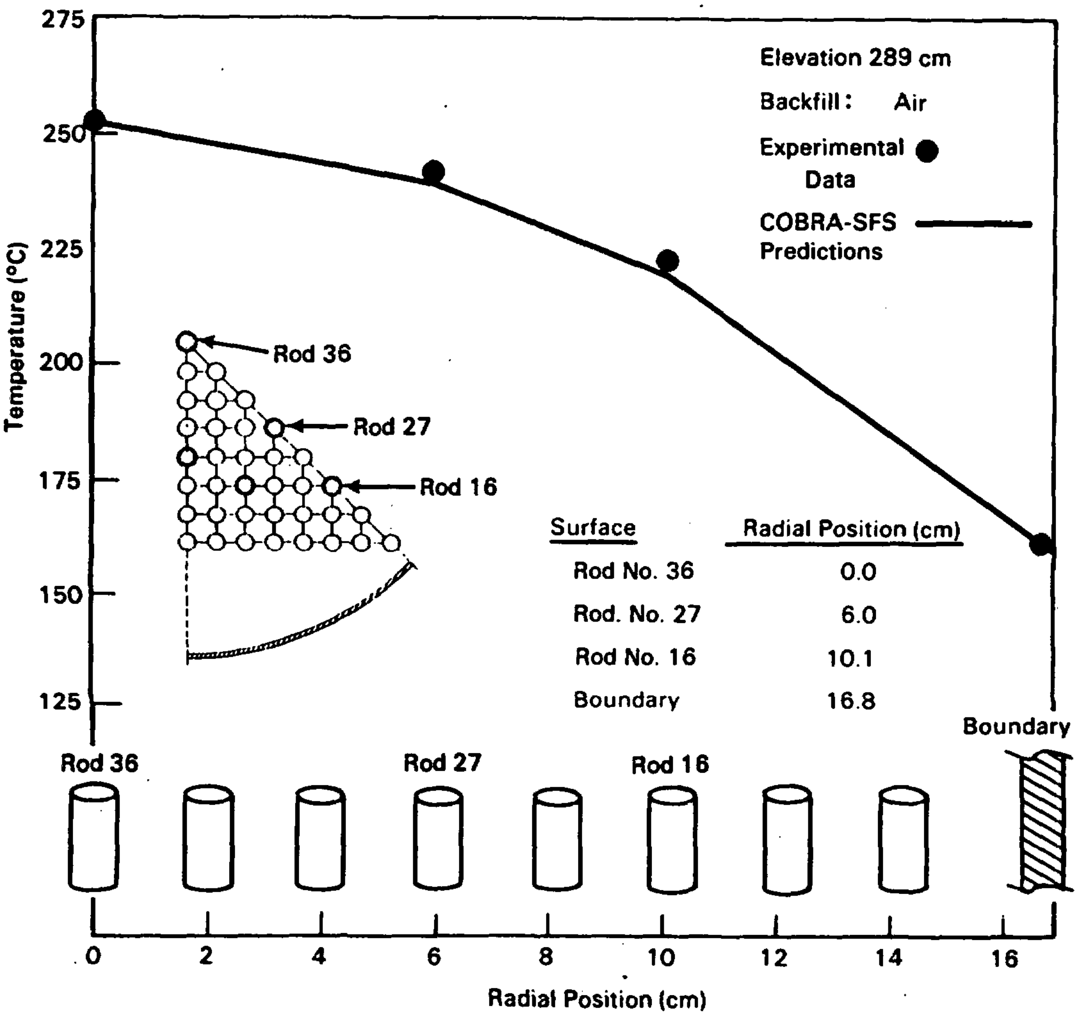


FIGURE 4.9. Predicted Radial Temperature Profile Compared to PWR Single Assembly Helium Test Data at Elevation 185 cm

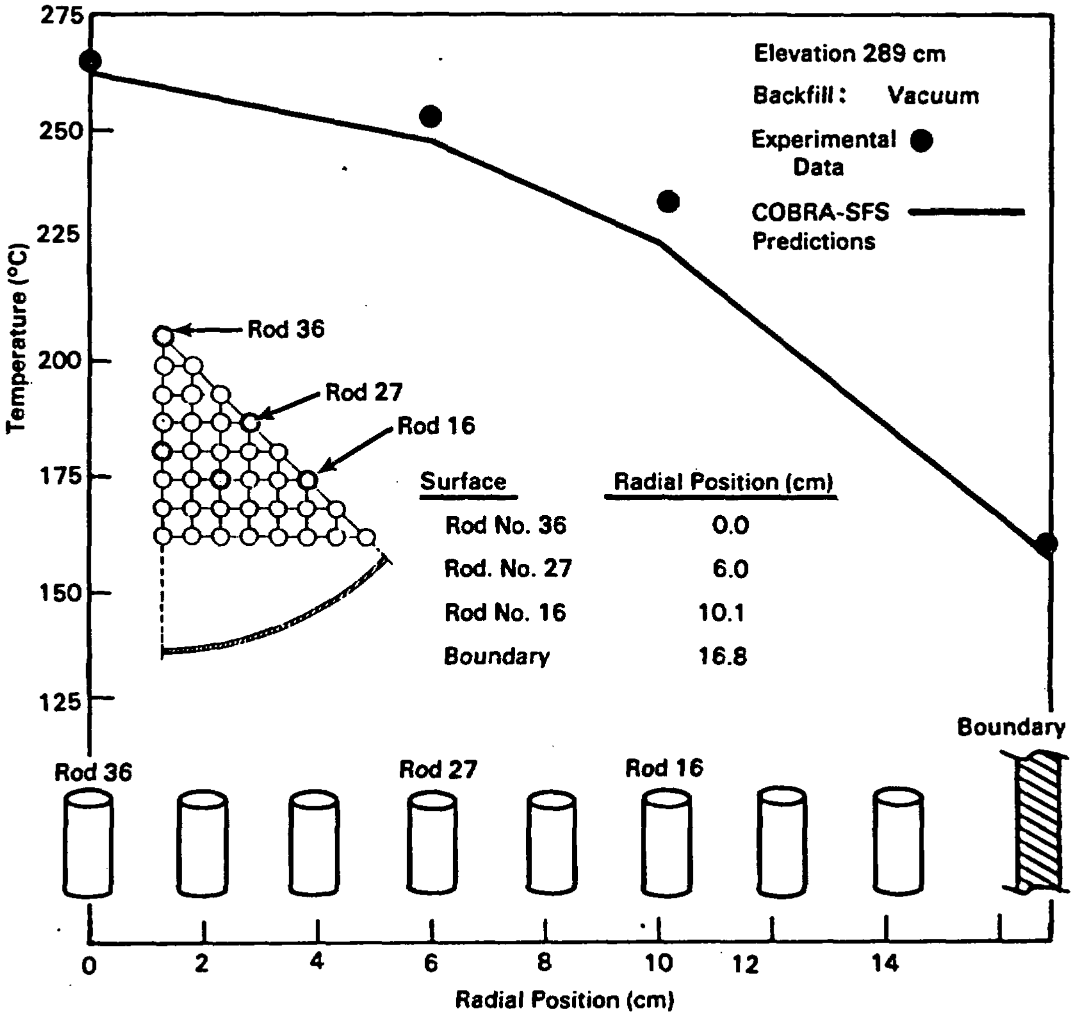
As indicated in the hot rod axial profile displayed in Figures 4.6 through 4.8, excellent agreement (±3°C) in peak rod temperature for the helium, air, and vacuum runs was obtained. The agreement between predictions and data is approximately equal to the data scatter, estimated at ±3°C (Bates 1986). The exception to this is the helium run, which underpredicted the data by 9°C. The overall agreement with the axial profiles is also seen to closely match the data.



Surface	Radial Position (cm)
Rod No. 36	0.0
Rod. No. 27	6.0
Rod No. 16	10.1
Boundary	16.8

FIGURE 4.10. Predicted Radial Temperature Profile Compared to PWR Single Assembly Air Test Data at Elevation 185 cm

The excellent agreement with data is further supported by the radial temperature profiles shown in Figures 4.8 through 4.11. The air predictions are shown to be within the data scatter at this elevation, although somewhat less agreement is seen in the vacuum predictions, especially towards the outer regions of the fuel assembly. Again, the slight overprediction in this case may be due to the unmodeled radiation heat transfer shielding effects of the fuel assembly support cage. The results for the helium backfill indicate that the assembly thermal resistance is slightly underpredicted, although the predictions are still within 10°C of the data at this elevation. The good



Surface	Radial Position (cm)
Rod No. 36	0.0
Rod. No. 27	6.0
Rod No. 16	10.1
Boundary	16.8

FIGURE 4.11. Predicted Radial Temperature Profile Compared to PWR Single Assembly Vacuum Test Data at Elevation 185 cm

agreement with the data for the three different fill media supports the conclusion that the conduction, convection, and radiation models implicitly contained within COBRA-SFS are performing adequately.

4.2 ELECTRICALLY HEATED PWR SINGLE ASSEMBLY SPENT FUEL TEST

The temperature response of an electrically heated model PWR assembly was investigated at two heat generation levels in atmospheres of air, helium, and vacuum, while oriented in horizontal, vertical, and inclined (25° from horizontal) positions. Experimental temperature data were recorded at several axial and radial positions in the test assembly, thereby providing complete information on the separate effects of media, heat generation level, and orientation. COBRA-SFS predictions for the entire 14 run test matrix, including comparisons of prelook and post-test predictions with data, have been documented in an earlier applications report (Lombardo et al. 1986), and will therefore not be repeated here. To demonstrate the ability of COBRA-SFS to predict one of the more unique aspects of these tests, that is, the effect of orientation, simulations of runs with nitrogen backfill were made for the three orientations examined. In the following sections, a description of the test apparatus, computational model, and modeling uncertainties are provided. Comparisons of code predictions with test data from the test cases selected are then presented. Listings of the input, representative output, and convergence data for the runs presented herein are contained in Appendix B.

4.2.1 Test Description

The test assembly used to investigate the effects of gas backfill, orientation, and heat generation levels on the thermal performance of an electrically heated model spent fuel assembly is illustrated in Figure 4.12. Major components of the test assembly consisted of: 1) contaminated vessel body, 2) model fuel assembly and fuel tube, 3) fuel-tube transition piece, and 4) closure lids. A brief description of each of the major components is given below; detailed descriptions are given by Bates (1986).

The containment was a cylindrical vessel formed from two concentric steel pipes. Mating flanges were welded to each end of the vessel for the closure lids. The resulting interior cavity of the vessel was 444.5 mm (17.5 in.) in diameter and 4826 mm (190 in.) long. In this test series the vessel annulus contained air at one atmosphere. Natural convection within this annulus was observed as expected.

Encircling the vessel exterior wall were three electrical resistance strip heaters that were spirally wound in parallel along the length of the containment

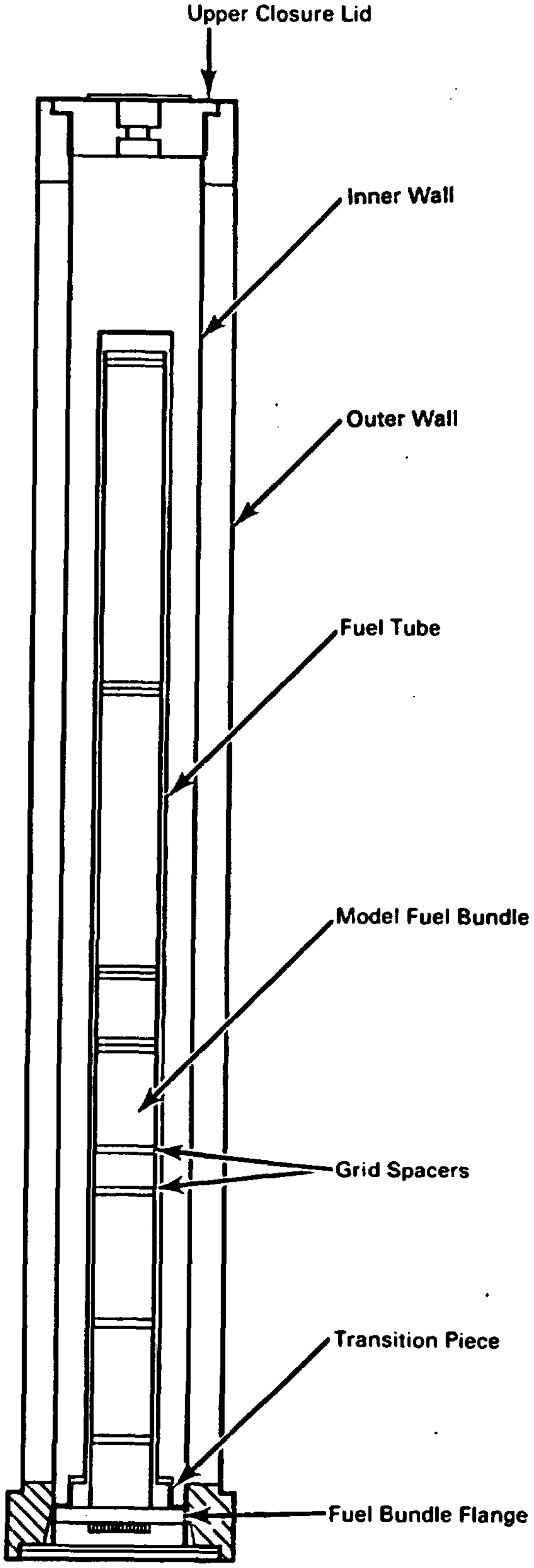
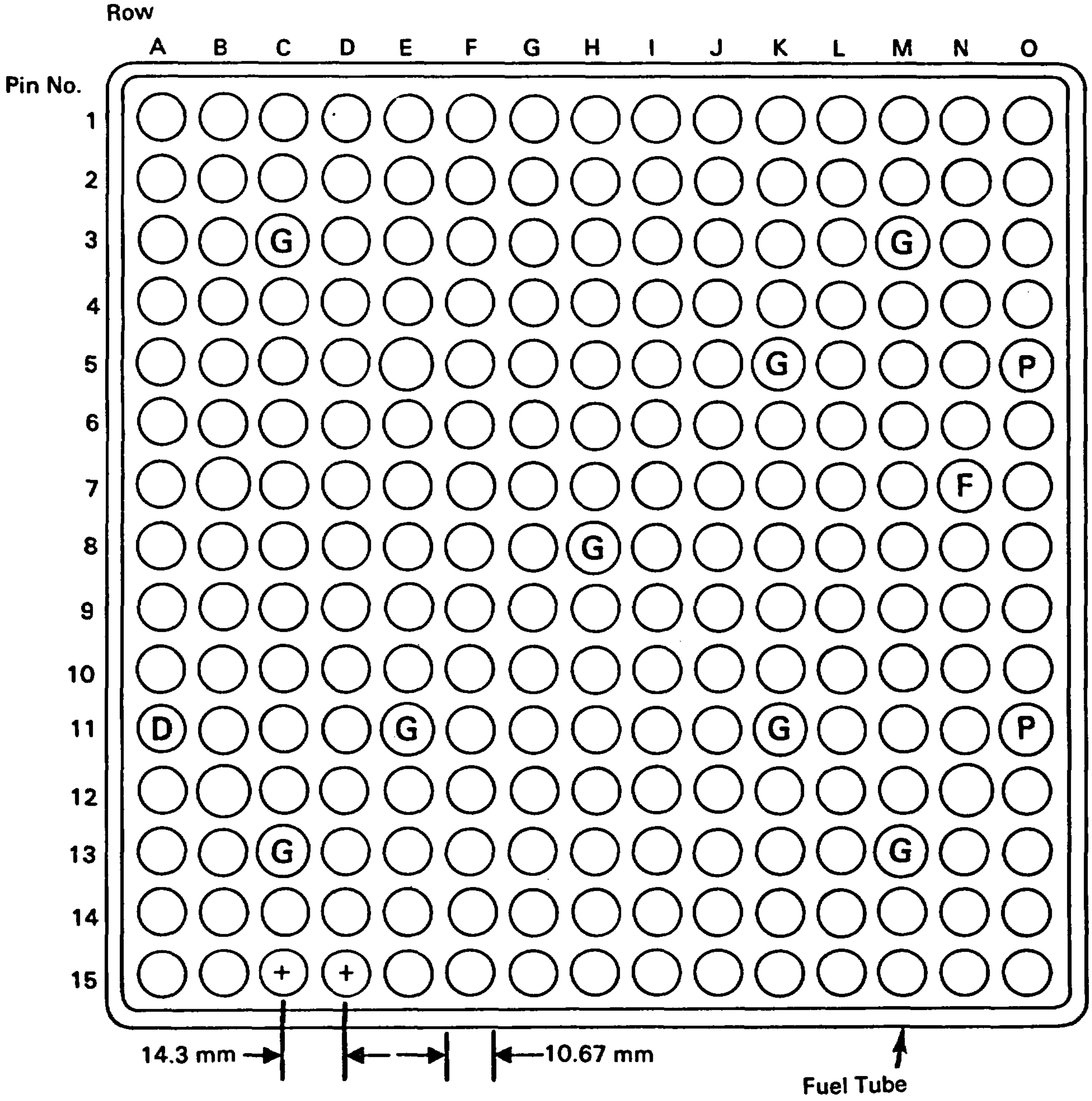


FIGURE 4.12. Electrically Heated PWR Single Assembly Test Apparatus

barrel. The heaters provided elevated boundary temperatures for the model fuel assembly, typical of what may be expected in a multiassembly storage system. The heaters were controlled by means of an "off-on" adjustable setpoint thermostat to establish the desired axial temperature profile on the cask inner wall. A 50.8-mm (2-in.) thick insulation blanket covered the cask barrel and strip heaters to minimize heat losses. Twenty thermocouples were located on the annulus inner wall to determine the cavity temperatures. The thermocouples were attached to flexible, stainless steel bands that fit into the cask I.D. at five axial positions. An additional thermocouple was used for temperature feedback control of the cask strip heaters.

Enclosed within the cask cavity was the electrically heated model fuel assembly and fuel tube. The fuel assembly was designed to simulate a 15x15 light water reactor PWR fuel assembly--the fuel tube was an actual spent fuel assembly storage tube as used in reactor pools. The model fuel bundle was composed of 214 heater rods and 11 unheated (water) rods. In addition to the unheated water rods, five of the model fuel rod leads were shorted out or disconnected, and thus, did not generate heat. A transverse cross section of the model fuel assembly showing the heater, water, and zero-power rods is displayed in Figure 4.13. Not shown on this figure are the four "egg-crate" spacers and the four "bar" grid spacers that maintained the fuel rod array in a fixed orientation. (The bar-type spacer refers to a grid spacer fabricated from stainless steel bars; the egg-crate spacers were prototypic of those found in actual PWR fuel assemblies.)

The heater rods were assumed to produce a uniform axial heat generation profile over their 3658-mm (144 in.) active length; the total rod length was 4216 mm (166 in.). The model fuel rods extended through a 51-mm (2 in.) thick flange plate at the test section bottom that was bolted to the transition piece. A uniform radial heat generation profile was obtained by matching rod electrical resistance values. Total assembly power was measured by calibrated watt transducers. Sixty type "T" thermocouples were located at strategic radial and axial positions along the rod assembly. The thermocouples were



G = Unheated Guide Tubes

F = Failed Heater Element

D = Power Leads Disconnected

P = Pressure Tap Tube

FIGURE 4.13. Transverse Cross Sectional View of Electrically Heated Single Assembly Test Section

positioned and locked midway between two adjacent heater rod sheaths by means of a thermocouple "pad", or positioned directly on the rod surface by means of a thin steel band.

Enclosing the model fuel assembly was the fuel tube, a square walled, stainless steel-clad Boral tube with rounded corners. The fuel tube was approximately 4089 mm (161 in.) in length and was corrugated with 1.27-mm- (0.05 in.) high dimples spaced uniformly along the length of the tube. The fuel tube acted as a thermal radiation shield for the assembly and defined two distinct flow regions within the cask interior.

The lower end of the fuel tube was welded to the fuel tube-transition piece, a stepped, perforated, cylindrical pedestal that supported the model fuel assembly and allowed for flow communication between the interior and exterior regions of the fuel tube. The transition piece, shown in Figure 4.14, contained two rows of 25.4-mm- (1 in.) diameter holes in the upper pedestal (50 total) for flow recirculation, which approximated the flow area of a prototypic fuel assembly end fitting. The base of the transition piece was bolted to the cask bottom end piece to form the lower end seal. Penetrations in the lower flange included instrument leads and vent lines for cask internal atmosphere control. Additional thermocouple leads exited through the upper closure lid, a flanged, metal cylinder that was bolted to the cask body to form a pressure tight seal.

The assembled test section was used to investigate the thermal performance of the model fuel assembly with backfill gases of air, helium, and a vacuum in vertical, horizontal, and inclined orientations (25 degrees from horizontal). Test runs were performed at assembly heat generation levels of 0.5 and 1.0 kW. Additional runs were to determine characteristic test section boundary conditions and experiment repeatability. For all runs, the annular space between the test section inner and outer walls was air-filled and sealed. For runs with an air environment, the test section interior was vented to the atmosphere. With the test section sealed, the vacuum tests were operated at a pressure of 0.1 atmospheres; a minimum low pressure of 0.04 atmospheres was reached to investigate the effect of the vacuum level on the assembly thermal

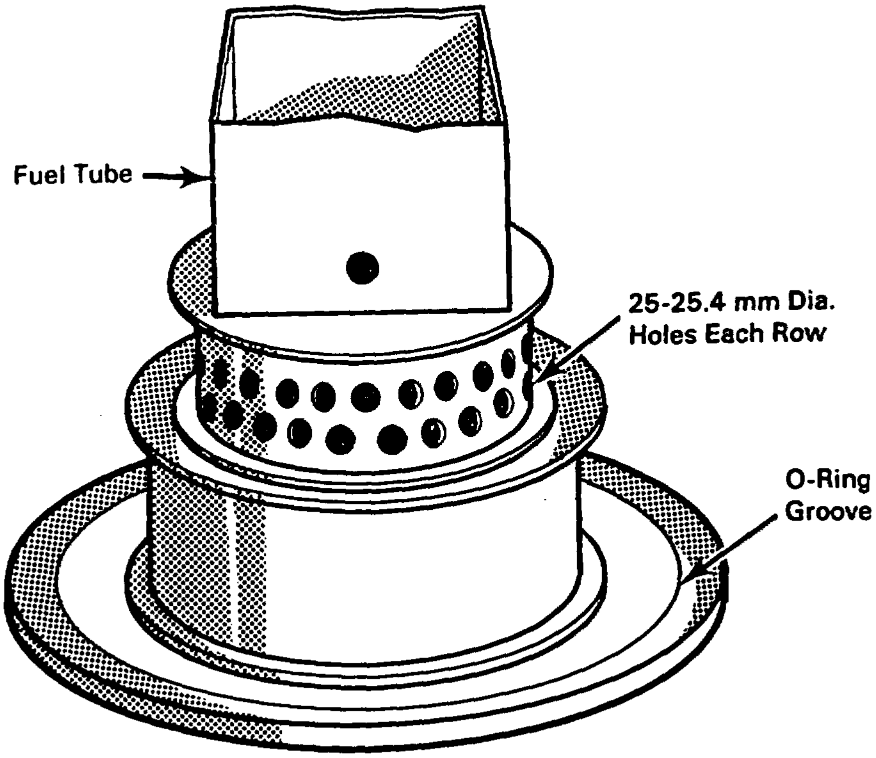


FIGURE 4.14. Fuel-Tube Transition Piece

response. For the helium test runs, the test section was sealed, evacuated, and repressurized with helium to approximately 1.1 atmospheres with a pressurized helium supply. An outline of the test matrix is presented in Table 4.2.

4.2.2 COBRA-SFS Computational Model Description

The COBRA-SFS computational model used to simulate the Electrically Heated Single Assembly Heat Transfer Test is presented in this section along with the modeling parameters and correlations employed. A brief discussion of the modeling uncertainties is also provided.

TABLE 4.2. Electrically Heated PWR Single Assembly Test Matrix

Test No.	Attitude	Nominal Power (kW)	Actual Power (kW)	Environment	Pressure (Atmospheres)	Ambient Temperature
1	25°	1.0	.951	AIR	0.98	28°C
2	25°	1.0	.940	VAC	0.11	30°
3	25°	1.0	.956	He	1.04	27°
4	25°	0.5	.501	He	1.04	23°
5	25°	0.5	.484	VAC	0.11	28°
6	25°	0.5	.477	AIR	0.98	24°
7	H	0.5	.487	AIR	0.98	23°
8	H	0.5	.486	VAC	0.12	26°
9	H	0.5	.500	He	1.04	21°
10	H	1.0	.964	He	1.03	23°
11	H	1.0	.949	VAC	0.11	23°
12	H	1.0	.943	AIR	0.98	27°
13	V	1.0	.994	AIR	0.98	19°
14	V	1.0	.977	VAC	0.10	17°
15	V	1.0	.995	He	1.03	21°
16	V	0.5	.501	He	1.03	21°
17	V	0.5	.496	VAC	0.11	22°
18	V	0.5	.515	AIR	0.98	22°

VAC = vacuum
H = horizontal
V = vertical

4.2.2.1 Nodal Representation

A three-dimensional model of the electrically heated single assembly test section was developed for the COBRA-SFS analysis. A transverse cross section of the computational cell arrangement is presented in Figure 4.15 that illustrates the subchannel and wall noding employed. A total of 24 uniform axial nodes were used to model the axial direction. Only the interior components were modeled since the inner wall temperatures were provided as boundary conditions.

The test section was modeled as two assemblies: the interior, or rod assembly, and the exterior, or downcomer assembly. In the interior assembly,

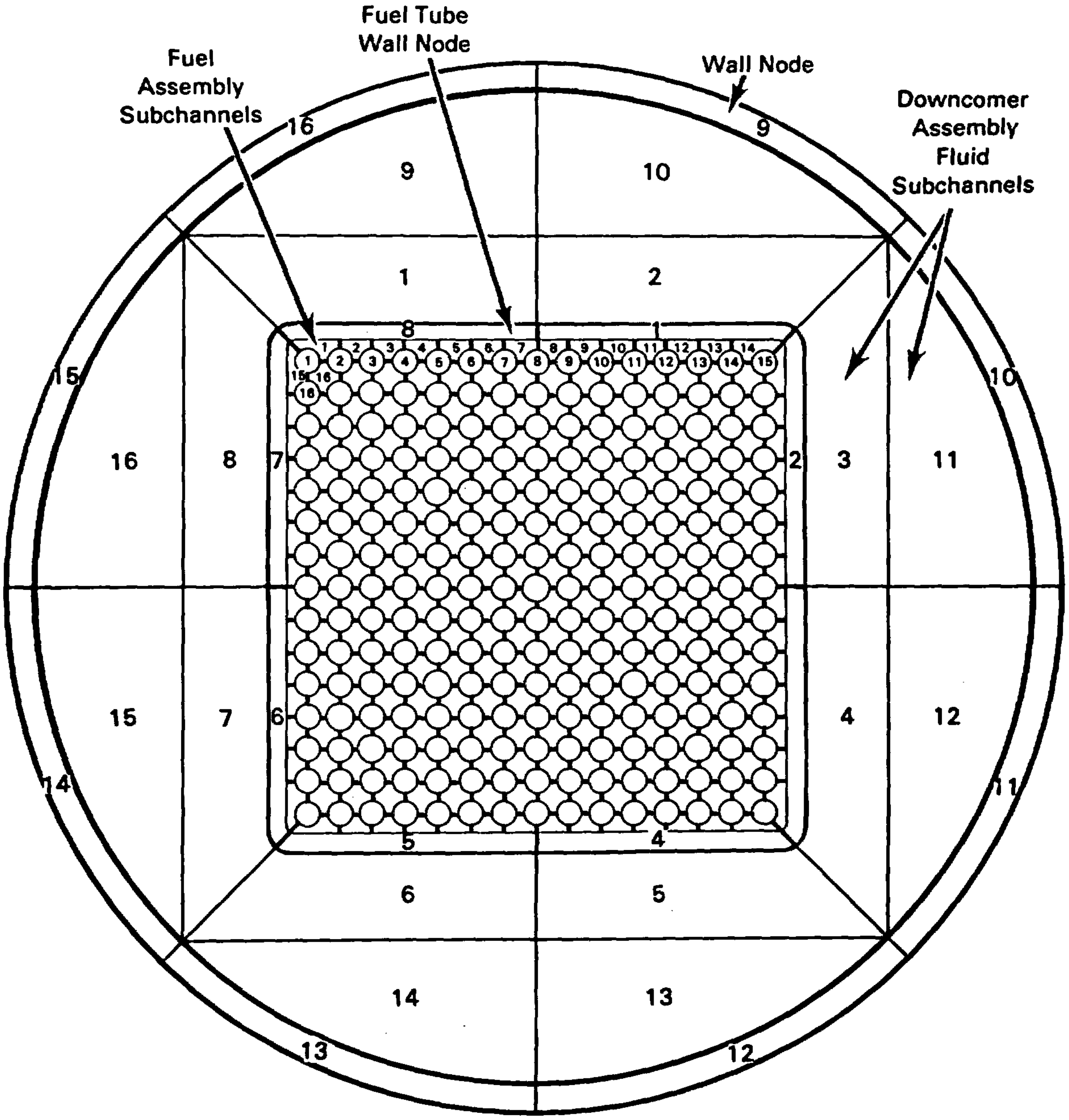


FIGURE 4.15. Transverse Cross Section of COBRA-SFS Computational Model for the Electrically Heated PWR Single Assembly Test

256 subchannels were used to describe the flow paths at each axial level; an additional 16 subchannels defined the downcomer flow paths. Conduction between fluid subchannels was accounted for in both assemblies. Rod and wall surface

drag, spacer grid losses, and fuel tube inlet and exit losses were all accounted for in the model.

Each of the 225 heater rods in the interior assembly was individually modeled and was divided into five radial nodes: four for the fuel, and a single node for the cladding. In the prelook model, no circumferential rod effects or rod axial heat transfer effects were included. Uniform axial and radial heat power generation profiles were assumed. A total of 15 rods failed and did not produce any heat. The diameter difference of the water and heater rods was properly accounted for in the subchannel model, but the radiation heat transfer model assumed all rods to be equal in diameter. Flow through the water rods was not modeled.

The fuel tube and test section inner wall were each modeled with eight uniform nodes. The eight test section wall nodes were used to represent the temperature boundary conditions set during testing. In the horizontal and inclined positions, a circumferential gradient in the test section wall was measured due to the natural convection occurring within the air-filled annulus of the vessel body. To accommodate the circumferential boundary temperature distribution, eight wall nodes were used to model the test section outer wall. Because the circumferential variations in boundary temperatures were expected to influence fuel tube and fuel assembly temperatures, eight wall nodes were used to model the fuel tube as well. The composite fuel tube wall was modeled using a single radial node. Both axial and circumferential heat transfer were accounted for in the fuel tube and vessel wall nodes. Radiation heat exchange between the walls and rods on a plane was determined from graybody exchange factors prescribed for the interior and exterior assemblies.

In the interior assembly, the exchange factors were derived from one-quarter rod surface segments, a more exact approach than the assumption of uniform radiosity over a surface. Proper subdivision of the fuel rod surface was determined in the PWR Single Spent Fuel Assembly Test comparisons to be significant in determining the proper radiative heat exchange within an enclosed assembly (Lombardo et al. 1986). The graybody exchange factors specified for the downcomer assembly were based on wall node surface areas equal to one-eighth of the total heat transfer area. All gaseous fill media were considered nonparticipating with respect to radiation heat transfer.

As-measured temperatures along the test section interior wall were applied in the model by use of specified boundary temperature profiles in the downcomer assembly. Additional temperature measurements in the upper and lower plenums completed the prescribed boundary temperature field of the test section cavity.

Upper and lower plenums were employed to model the large mixing volumes and heat transfer areas that existed in the test section cavity above and below the model fuel assembly. The plenum models allowed for mixing of the upflow and down-flow channels and provided a means of adding or removing heat from these regions. No flow field was calculated within the plenums; however, one-dimensional radial and axial heat losses were modeled. Heat transfer from the upper and lower closure lids was simulated using this approach. Axial heat transfer from the fuel tube walls to the plenum region was also modeled.

4.2.2.2 Modeling Parameters and Correlations

The material properties used in the computational model, with the exception of emittances, were well defined. Fluid properties were input as functions of temperature and were updated continuously during the simulation. A range of emissivity values was identified for the solid structures within the test section. Emissivity is known to be dependent upon fabrication technique, oxidation buildup, and temperature. Unique values of emissivity were used for each of the stainless steel components: an emissivity of 0.25 was assumed for the stainless steel-clad fuel tube; whereas an emissivity of 0.6 was assumed for the heater rods. The larger value of emissivity chosen for the heater rods reflects the many hours of high-temperature operation in an oxidizing environment. The emissivity value used for the fuel tube lies in the range of experimental data previously obtained from a similarly constructed fuel tube (Taylor 1983) prior to exposure to high temperature. Allowing for some oxidation of the vessel stainless steel inner liner, an emissivity value of 0.6 was assumed.

Heat transfer from the rods and walls to the coolant was prescribed through use of a film heat transfer coefficient of the form Nu = 3.66 (Kays and Crawford 1980). This formulation is an exact solution of the energy equation for a constant surface temperature and fully developed velocity profiles in a circular tube. The film coefficient was evaluated as a function of temperature at each location. For the vacuum (low pressure air case), no enhancement of the heat transfer by convection was assumed; thus, Nu =1.0.

The overall flow resistance of the test assembly was assumed to be a combination of:

- rod and wall surface drag
- spacer losses
- fuel tube inlet and exit losses
- model fuel assembly inlet and exit losses.

For the interior assembly, rod and wall friction were modeled from an analytical solution for fully developed laminar flow along cylinders arranged in a square array; f = 100/Re (Sparrow and Loeffler 1959). This correlation was found to provide the best estimates of wall friction as determined in the PWR Single Assembly Spent Fuel Test post-test analysis (Lombardo et al. 1986). This estimate of form friction was also used in the downcomer for the helium and vacuum cases, but was not applied in the air case, as discussed below.

A substantially larger value of friction was required for the downcomer assembly in the air case to lessen the magnitude of numerically induced flow oscillations. Small changes in the system pressure drop produced corresponding large changes in the downcomer velocity field. The favorable buoyant properties of air and the large subchannel areas in the downcomer are thought to be responsible for the oscillations observed. To stabilize the flows, a friction factor of 100 was applied in the downcomer region. Evaluation of the effect of the increased downcomer flow resistance indicated a ±10°C change in peak clad temperature.

Spacer pressure losses were defined for both the egg-crate and bar-type spacers as K = 1 and K = 8, respectively. Losses due to the area changes at the model fuel assembly exit were modeled by a loss coefficient of 1.0. Losses at the model fuel assembly inlet included losses due to area change as well as losses from the fuel tube-transition piece (Figure 4.14). A loss coefficient of 18 was used for the downcomer and model fuel assembly inlet (Idel'Chik 1966).

Heat losses from the plenum regions to the boundary required the specification of the thermal resistance from the bulk mixed-mean fluid temperature to the film boundary layer. For the air cases, a correlation of the form Nu = 50 was used to define this resistance for both plenum regions, and was based on results for air flowing in a pipe (Kreith 1965). A correlation of the form Nu = 10 was used in the helium backfill cases which incorporates an increase in the bulk-to-film thermal resistance due to the reduced natural convection characteristics of helium.

4.2.2.3 Modeling Uncertainties

The computational model developed for the analysis was based on drawings supplied by Allied General Nuclear Services, fabricators of the test assembly, and descriptions of the components, instrumentation, and test operation provided in the data report (Bates 1986). In developing the model, significant uncertainties were associated with the following important heat transfer and fluid flow parameters:

- material emissivities
- model fuel rod pitch
- plenum thermal resistance
- test section flow resistance.

Each of these uncertainties is addressed below.

The surface emissivity values were a major source of uncertainty in these simulations. A wide range of emissivity values was observed in the literature for the test section components and was found to be dependent upon oxidation buildup, fabrication technique, and temperature. Values used were 0.6 for the stainless steel cask inner wall, 0.25 for the stainless steel-clad fuel tube, and 0.6 for the stainless steel-clad heater rods. The values chosen represent best estimates. Confidence in these values is low, and variations of emissivity from rod to rod probably exist. Uncertainty of the graybody assumption exists for all surfaces.

It is interesting to note that uncertainty in the fuel tube emittance affects the thermal resistance of both the rod assembly and downcomer region, whereas errors in the heater rod or test section inner wall emittance alters the thermal resistance for that region only. Additionally, because of the relatively low value of fuel tube emittance, 0.25, a small change in this parameter represents a large change in the radiative heat transfer to and from the fuel tube. Thus, the fuel tube emittance is a critical parameter in determining the proper radial temperature profile through the test section.

An additional parameter that influences the radiation and convection heat transfer within the test section is the model fuel rod pitch. Use of the bar-type grid spacers, in conjunction with the larger diameter guide tubes, effectively spreads the fuel assembly cross section so that the rod pitch is altered. The concentration of bar-type spacers in the upper elevations of the fuel assembly suggests that axial variation of the fuel rod pitch may exist. In fact, measurement of the as-built fuel rod pitch in the upper elevations indicates an increase from the nominal value of 14.3 mm (0.563 in.) to 14.76 mm (0.581 in.). The uncertainty in the fuel rod pitch is significant because radiation heat transfer within the enclosure is a function of the "view" each rod has of adjacent rods and the walls. When the pitch is increased, the views increase as well, enhancing the radiative heat removal. Uncertainty in the rod pitch also affects the convection established within the cask as the film coefficient and the friction factor are both functions of the equivalent hydraulic diameter. Thus, uncertainty in the rod pitch can affect the radiation and convection heat transfer within the cask. Other uncertainties resulting from the use of the bar-type spacers are the localized flow blockage, thermal radiation shielding, and radial conduction effects. No attempts were made to model these details. Elimination of these effects from the computational model represents another uncertainty.

A large degree of uncertainty existed in defining the plenum region heat transfer, due in part to the many simplifying assumptions that were made. Most importantly, it was assumed that the heat transfer from the plenums is a function of the natural convection established; that is, backfill gasses with good buoyant properties are expected to produce higher fluid velocities, and thus, improved heat transfer. Values of the plenum bulk-to-film resistance were employed globally over the plenum surfaces, neglecting any local effects. The effect of solid structures within the plenums was also ignored. To complete the thermal model of the plenum regions, a plenum boundary temperature must be prescribed. Identifying a proper plenum boundary temperature was complicated because the cask closure pieces were not insulated and the cask heaters did not extend over the entire length of the test assembly. Therefore, very severe axial temperature gradients occurred within the plenum regions. The nonuniform plenum surface temperatures were approximated by an integrated temperature for the boundary, which represents another approximation.

The major uncertainty in flow resistances is associated with the fuel tube-transition piece. The complex geometry and multiple flow paths of this structure make specification of actual flow resistances difficult. Additional uncertainty exists with the loss coefficients applied to the bar-type grid spacers, and to the fuel tube exit. As discussed earlier, the artificially high flow resistance applied in the downcomer assembly to aid in the computational stability of the air backfill cases is also a cause of uncertainty.

One mode of heat transfer not well defined in these simulations is the rod axial conduction from the lower regions of the model rod to the heater rod flange. Large uncertainties exist in the heater rod-to-flange contact resistance as well as the contact heat transfer area. The version of COBRA-SFS used in this analysis does not include the capability of transferring heat axially from the rods to a plenum structure (the heater rod flange), so it was not modeled.

The electrically heated assembly was assumed to have uniform radial and axial heat generation profiles. Uniformity of the radial heat generation distribution was assured by individual electrical resistance measurements of all rods. However, the axial heat generation profiles of the heater rods were not verified. Therefore, by assuming a uniform heat generation profile over the heated length, the effects of heater element resistance temperature dependence were ignored.

For this analysis, it was assumed that there was no fuel assembly/fuel tube contact, and that the fuel assembly remained centered within the fuel tube for all orientations. Both assumptions represent additional uncertainties in the simulation of the horizontal and inclined cases.

In addition to the major uncertainties described above, uncertainties exist in the heater rod and wall film coefficients, rod and wall friction, and in the test section geometry. Uncertainties in the graybody radiation model, and the finite difference treatment of the axial and transverse momentum equations, are implicitly contained within the COBRA-SFS code.

4.2.3 Comparisons of Predictions to Data

Predicted axial temperature profiles for selected instrumented model fuel rods and the test section wall are plotted with the experimental test data in Figures 4.16 through 4.18 for 3 of the 18 test cases. The cases presented illustrate the effect of orientation with an air backfill. In each figure, four axial profiles are presented which provide the cask radial temperature distribution along the fuel tube diagonal: a center heater rod (Row H, Pin 9, Figure 4.13), a corner rod (Row A, Pin 1), the fuel tube, and the test section inner wall. In all figures, the data are plotted as a function of elevation from the cask bottom.

All temperature data with the exception of center rod H9 were obtained from thermocouples welded directly onto the measurement surface. Data for rod H9 were obtained using thermocouple pads that measure the average temperature of two adjacent, neighboring rods. The code predictions represent temperatures of rod H9 only and, thus, should be slightly higher than the data. Additionally, data comparisons were complicated by the sparseness of temperature data at the lower elevations of the test assembly. Faulty and dislocated thermocouples eliminated four of the axial temperature data points for the hot center rod, leaving just three axial temperature measurements for comparison, all of which are above the 2.5 m (8 ft) elevation.

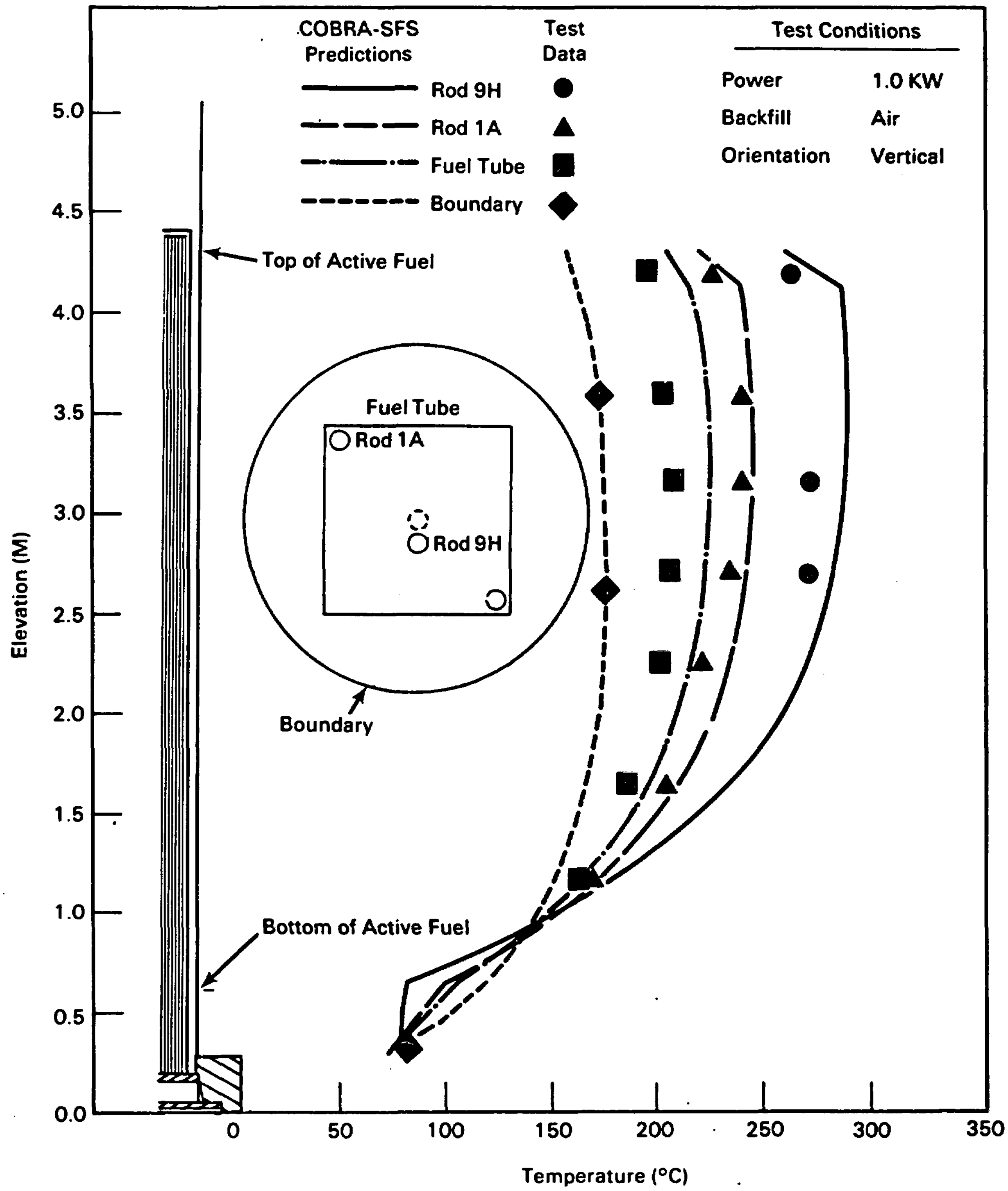


FIGURE 4.16. Predicted Axial Temperature Profile Compared to Electrically Heated PWR Single Assembly Vertical, 1 kW, Air Test Data

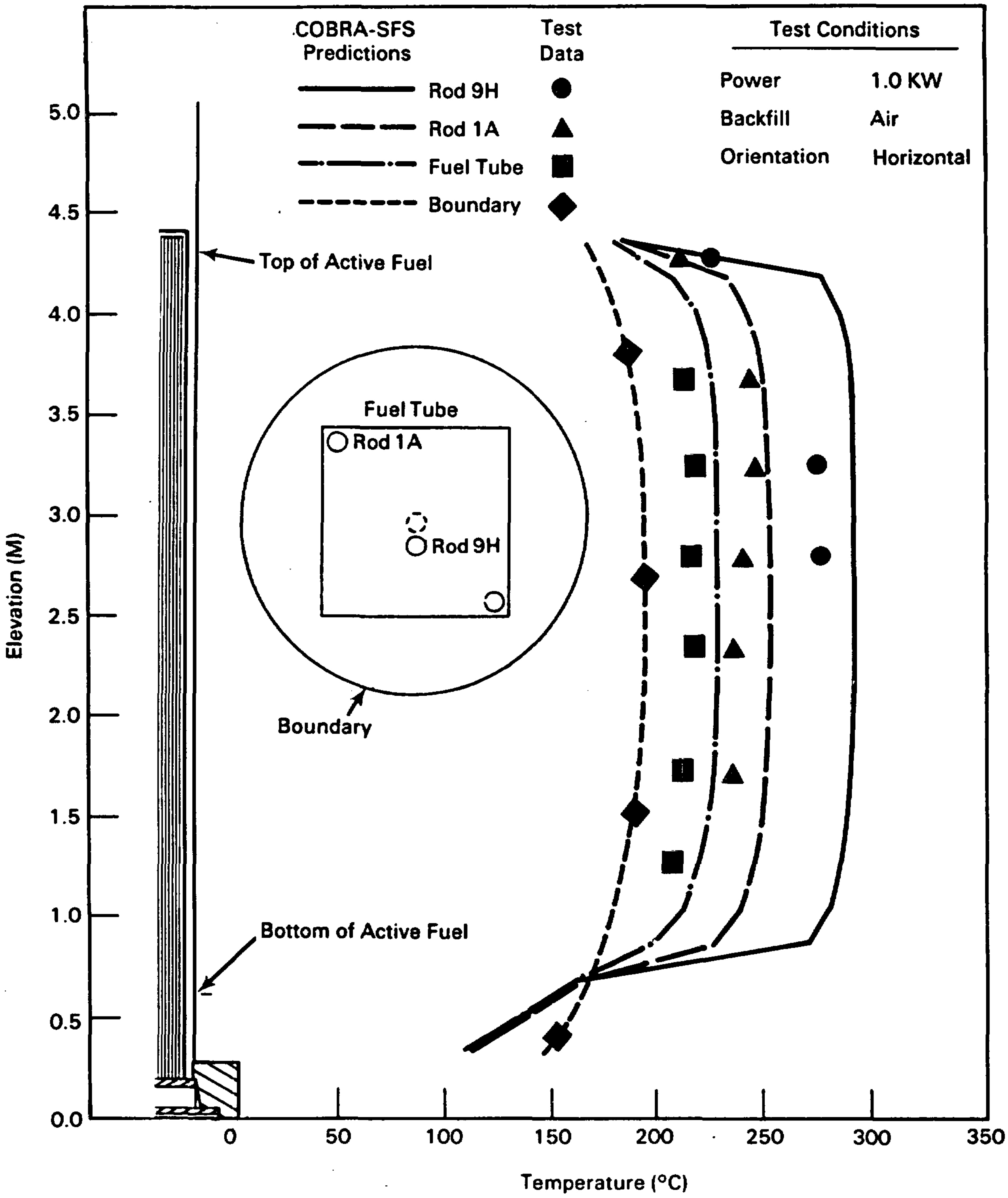


FIGURE 4.17. Predicted Axial Temperature Profile Compared to Electrically Heated PWR Single Assembly Horizontal, 1 kW, Air Test Data

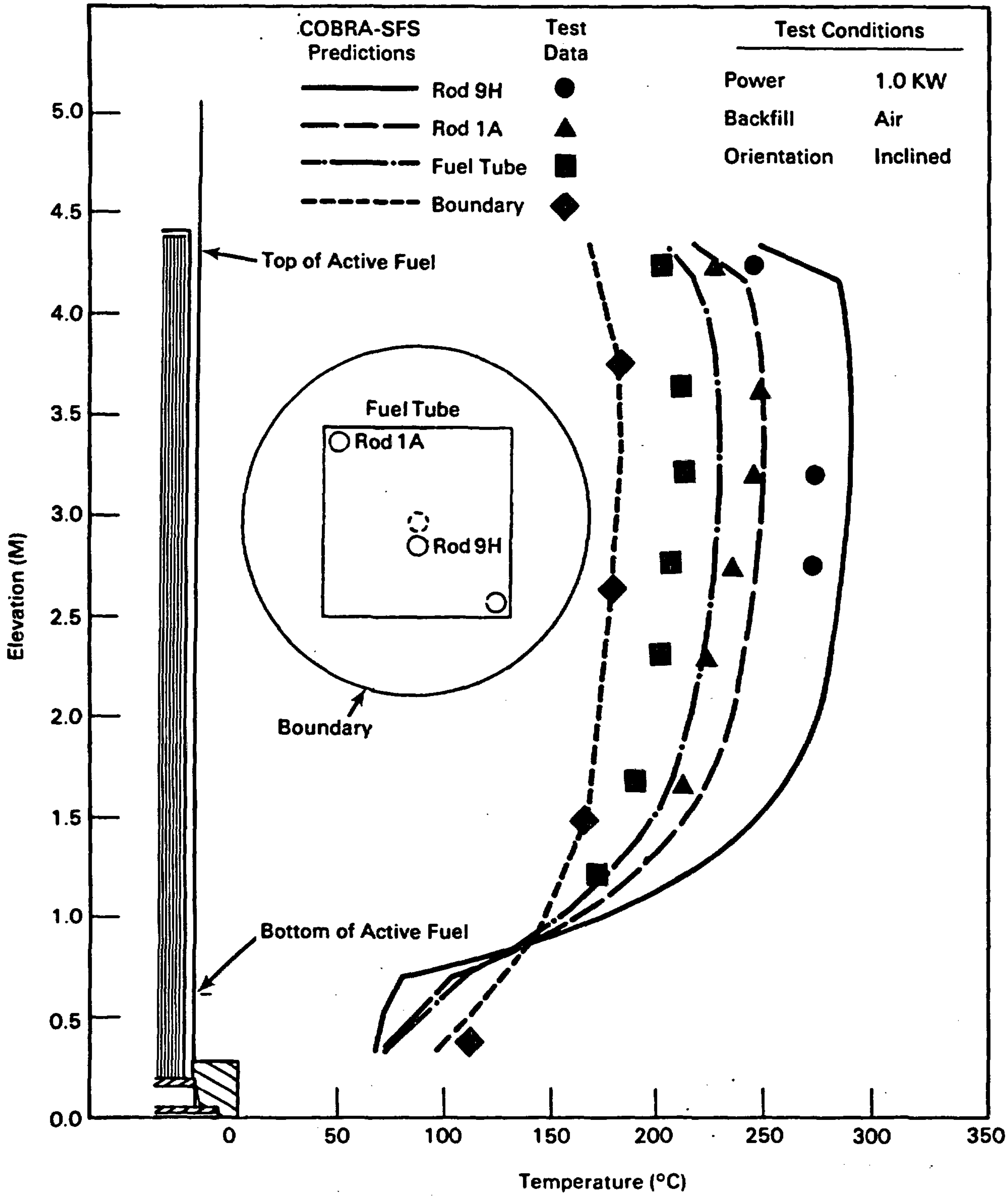


FIGURE 4.18. Predicted Axial Temperature Profile Compared to Electrically Heated PWR Single Assembly Inclined, 1 kW, Air Test Data

Results of the air-filled vertical test comparisons are displayed in Figure 4.16. Reasonable agreement with the measured test data was achieved with the peak clad temperature overpredicted by 15°C. Good agreement in the axial temperature profiles was observed, although the data comparison was complicated by the sparseness of data at the lower elevations of the test assembly. The overpredicted fuel tube temperature is in part responsible for the overpredicted rod peak temperature. This overprediction may be due to uncertainty in the fuel tube and canister wall emissivity values, the uncertainty in the convective heat transfer coefficient in the downcomer region, and the difficulty in defining the fluid-to-fluid conduction heat transfer across the open area of the downcomer region (believed to be a function of the number of radial fluid subchannels).

The horizontal orientation results are presented in Figure 4.17. Relatively good agreement is seen between the predictions and data. Comparisons of data and predictions between the vertical and horizontal orientations for the 1.0 kW air case, displayed in Figure 4.16 and Figure 4.17, respectively, show the measured and predicted results to be little influenced by orientation.

The uniformity of results with respect to orientation is due to the fact that the fuel tube and assembly geometry are essentially fixed at the lower elevation by the fuel tube-transition piece and heater rod flange. Thus, fuel tube/assembly contact is avoided, a phenomena which has been shown to provide significant reductions in peak temperature and radially skewed temperature profiles across an assembly (Wiles et al. 1986; Cuta, Rector and Creer 1984).

With this somewhat fixed test section geometry, the test series provides an independent evaluation of buoyancy-induced effects (natural convection and thermal stratification) in the horizontal orientation. Flow recirculation in the horizontal orientation is not expected along the fuel assembly centerline, but is expected circumferentially about the fuel and downcomer assemblies. The effect of this limited convection, as with the case of flow stratification, is to enhance the cask heat removal and impose a transverse fuel assembly temperature gradient. This effect is found to be minor as evaluated from a comparison of center rod temperature data for the horizontal air and vacuum test cases. The peak rod temperature differences between these runs ranged from 8°C to 15°C for the 0.5 and 1.0 kW test series, respectively. Therefore, only modest thermal benefit is derived from the buoyancy-induced effects in this test. Thus, the limited effects of buoyancy and fuel tube/assembly contact greatly reduce the influence of orientation in this experiment. This trend was correctly predicted by COBRA-SFS.

Neither the predictions or data for the inclined orientation cases, displayed in Figure 4.18, differ significantly from the horizontal results. This effect is demonstrated by a comparison of the 1.0 kW inclined air case, displayed in Figure 4.18, with the horizontal air case shown in Figure 4.17. The differences in the modeling of horizontal and inclined orientations lie in the treatment of buoyancy effects which was possible in the inclined simulations. In the axial direction, the buoyancy term in the momentum equations was reduced by the direction cosine, whereas buoyancy effects in the transverse direction were not modeled. As a result, only an axial velocity component is modeled in this orientation. In spite of the longitudinal natural convection, very little difference in peak temperature was observed between the horizontal and inclined predictions, a trend also seen in the data. As in the horizontal simulations, the skew in the predicted transverse assembly temperature profile is a direct result of the asymmetric boundary temperatures assigned to the cask inner wall. Again, the relatively modest effect of buoyancy-induced flows observed in the horizontal and inclined runs suggests that buoyancy-induced effects can be eliminated in these orientations without the introduction of significant errors.

4.3 SINGLE CANISTER CONSOLIDATED SPENT FUEL TEST

In this test series the thermal performance of test sections modeling consolidated and unconsolidated spent fuel rods was investigated. The data used in this study were obtained by Ridihalgh, Eggers, and Associates (REA) (1983) and Eggers, Ridihalgh Partners, Inc. The data are derived from three test sections (one unconsolidated and two consolidated) containing electrically heated rods simulating fuel from 8x8 boiling water reactor (BWR) assemblies (Eggers 1985). The test sections were 61 cm (24 in.) long with the rods oriented horizontally. Measurements were taken with air and helium as fill gases. In addition, two test runs were conducted with the unconsolidated test section evacuated to 10^{-2} mm Hg, and one vacuum case was run with one of the consolidated rod test sections.

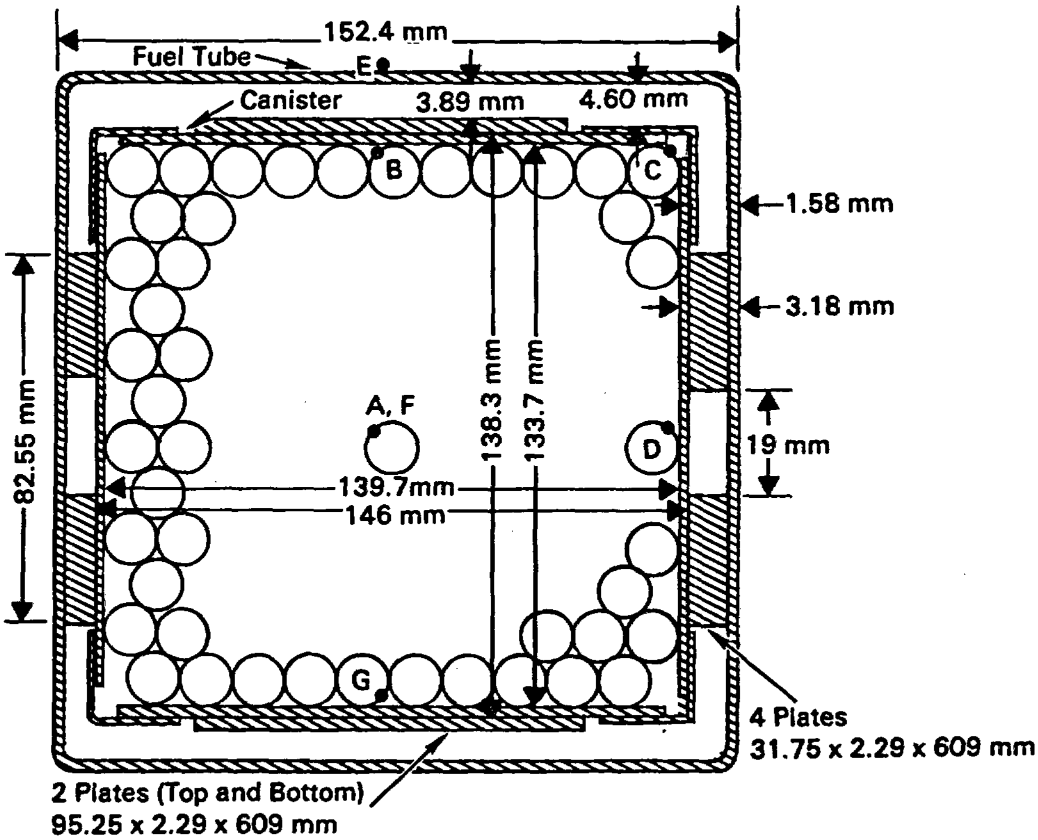
Measured temperatures were obtained in these test sections for 28 test runs. Seven of the runs were in the unconsolidated test section. Of the other 21, 5 were run in the consolidated assembly with the rods separated by a uniform gap of 0.254 mm (0.010 in.), and 16 were run in the consolidated assembly with zero gap between the rods.

For the purposes of this study, however, runs with consolidated fuel (zero gap) will be highlighted, as these runs provide unique insights into the capabilities of COBRA-SFS for consolidated spent fuel analysis. Comparisons of predictions with data are presented for the consolidated assembly with backfills of air and helium, showing the effect of fill media. For details on the other two test runs and the complete comparisons of COBRA-SFS predictions to data, refer to the applications report by Cuta and Creer (1986); the test procedure and data are discussed in detail in two reports by Eggers (1985). In the following sections, descriptions of the test apparatus, the COBRA-SFS computational model, and comparisons of predictions to data are presented. Input, representative output, and convergence listings of the cases presented herein are presented in Appendix C.

4.3.1 Test Description

A cross section at the midplane of the consolidated assembly with zero gaps between the rods is shown in Figure 4.19. The canister was positioned in the fuel tube by means of small steel shims under the four corners of the canister's bottom face. In addition, four plates, 3.18 cm (1.25 in.) by 0.23 cm (0.090 in.) by 61 cm (24 in.) were inserted in the vertical sides of the annulus, two on each side, as illustrated in Figure 4.19. The plates were intended to prevent any possibility of natural convection in the annulus.

The dimensions given in Figure 4.19 are based on a "perfect fit" of the rods into the triangular array. The as-built dimensions of the test section, however, indicate that it is not all that easy to stack rods precisely in a



A,B,C,D,E,F,G Thermocouple Locations
Note: Drawing is Not to Scale

FIGURE 4.19. Cross Section of Consolidated Fuel Test Assembly

triangular array inside a rectangular box. The measured width of the annular gap between the canister and the fuel tube was 0.51 to 1.02 mm (0.020 to 0.040 in.) on the sides, in contrast to the calculated value of 1.58 mm (0.0625 in.) in the unblocked segment of the annulus. The measured width of the gap at the top and bottom was 2.54 to 3.05 mm (0.100 to 0.120 in.), compared to the calculated value of 3.88 mm (0.153 in.). In spite of these differences, however, the calculated temperature gradient across the annulus was in every case too small to be significantly affected by such a small difference in the geometry, so the calculated values were used in the COBRA-SFS geometry model.

The rods for the consolidated test runs were stainless steel 304 tubing with a nominal OD of 12.7 mm (0.500 in.), and wall thickness of 0.89 mm

(0.035-in.). The tubes were filled with 2-hole ceramic insulators containing nichrome heater wire to provide a uniform heat generation profile along the full 61 cm (24 in.) length. The insulator material was mullite, an aluminum silicate ($3Al_2O_3$-SiO_2). Wire wraps at each end of the tube centered the mullite in the tube with a nominal gap of 12.7 mm (0.050 in.) between the ceramic and the inner surface of the tube. The emissivity of the outer surface of the stainless steel tube was altered by black nickel plating. This produced a surface emittance of approximately 0.8, a value consistent with the emissivities of actual spent fuel rods.

The radial locations of the thermocouples used to make the temperature measurements are shown in Figure 4.20. The desired boundary temperature was imposed on the test section by means of an electric heater wrapped around the outer surface of the insulated fuel tube. The boundary temperature thermocouples were located at Planes A, B, and C--where Plane A was 5.1 cm (2 in.) from one end of the test section, Plane B was the midplane, and Plane C was 5.1 cm (2 in.) from the other end of the test section. Boundary

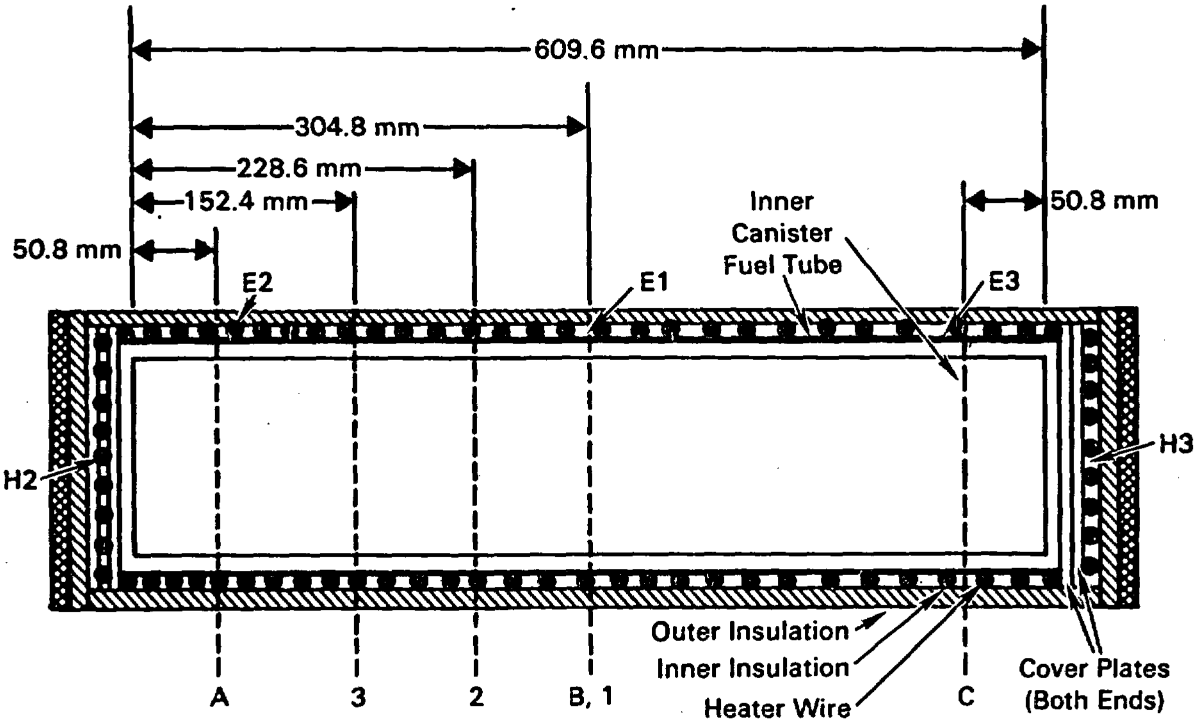


FIGURE 4.20. Consolidated Assembly Test Section E_1, E_2, E_3, H_2, H_3 Thermocouple Locations

temperatures were also measured on the top surface of the test section, (E), and at the center of each end of the test section (thermocouples H2 and H3). The rod thermocouples were located at three different axial positions in one half of the test section. Plane 1 was the midplane of the test section, Plane 2 was 22.9 cm (9 in.) from the end of the test section, and Plane 3 was 15.2 cm (6 in.) from the same end of the test section. The diagram in Figure 4.20 shows the relative axial locations of the rod and boundary measurement planes.

A total of sixteen test runs were conducted with the zero rod gap geometry. Seven runs were performed with the canister axisymmetric in the fuel tube with air and helium backfills at equivalent decay heat levels of 100 W, 400 W, and 800 W. One vacuum test run was also performed with this geometry, with an equivalent decay heat of 400 W. Four test runs were conducted with the canister off-center in the fuel tube, so that the annulus was 2.03 to 0.254 mm (0.08 to 0.10 in.) wide on the left side, 0.54 to 1.04 mm (0.02 to 0.04 in.) wide on the right side, 0.61 to 0.66 mm (0.24 to 0.26 in.) wide on the bottom, and 0.54 to 1.04 mm (0.02 to 0.04 in.) on the top. Four additional test runs were performed with the canister axisymmetric within the fuel tube, but painted with a high emissivity paint on its outer surface.

To demonstrate how well COBRA-SFS predicts the consolidated fuel data, simulations of the zero rod gap assembly centered within the canister were performed for the air and helium backfills at the 800 W heat generation level. Comparisons were made at the highest decay heat level to provide larger rod-to-rod temperature gradients across the assembly, thereby reducing some of the experimental error. Predictions were made with both the air and helium backfills to demonstrate the effect of fill media on consolidated assembly heat transfer. Prelook COBRA-SFS predictions and test data for all 28 cases with both the zero rod gap assembly and the 0.254-mm rod gap assembly have been reported earlier (Cuta and Creer, 1986) and will not be repeated here. A description of the zero-rod gap assembly model and comparisons of predictions using the document version of COBRA-SFS with data are presented below.

4.3.2 Computational Model Description

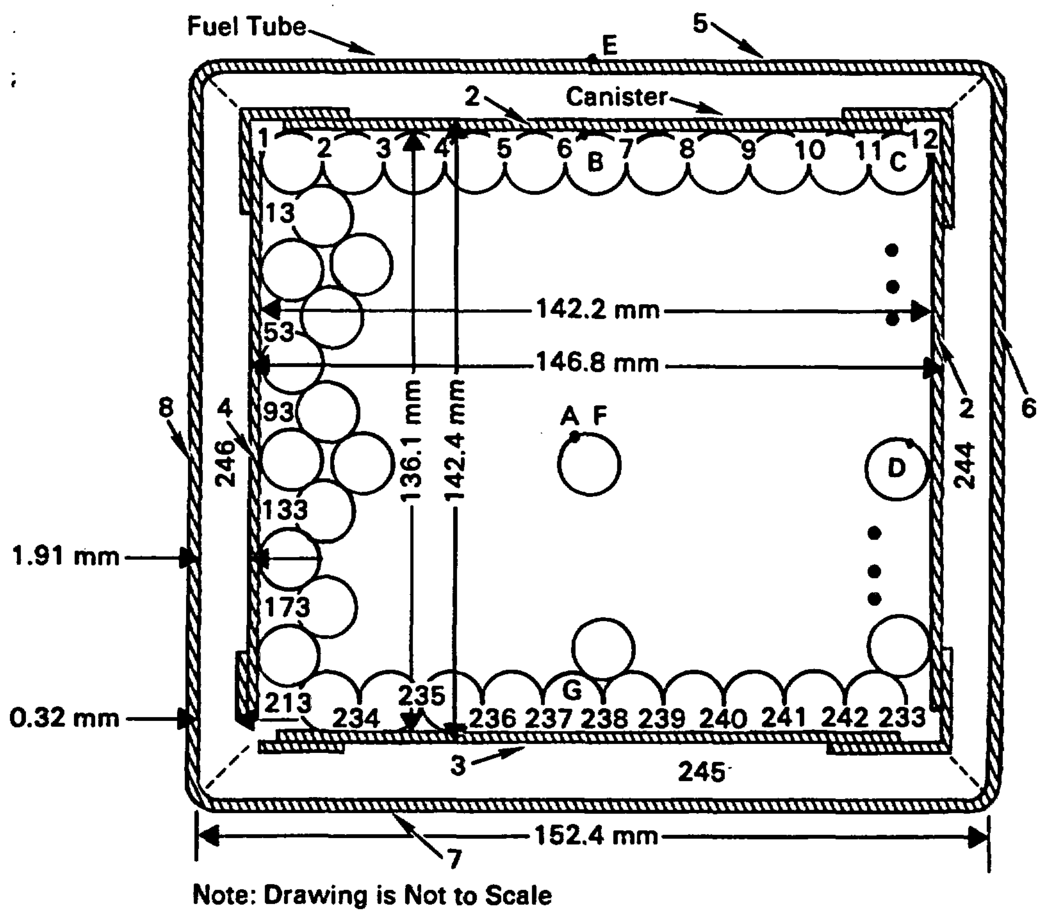
The computational model can conveniently be considered in two main parts: the geometry model, which describes the physical shape of the flow paths and solid materials in the system, and the constitutive heat transfer models, which describe how energy is transported through the system. A description of each of these models is presented below, along with a discussion of the modeling uncertainties.

4.3.2.1 Nodal Representation

It was assumed that test section geometries could be accurately represented with two-dimensional models. The test section was designed to minimize axial gradients and convective heat transfer, and thus was oriented horizontally, with sealed ends. All, or nearly all, heat transfer was to be in the radial direction. For these boundary conditions, the geometry was modeled in COBRA-SFS as a cross-section at the midplane, two nodes long. A detailed subchannel model was developed for the "slice" of the test section and is described below.

The subchannel layout for the consolidated assembly required 237 subchannels and 126 rods, as illustrated in Figure 4.21. The walls of the canister were modeled with a single node for each face of the canister. The annulus between the canister and the fuel tube was modeled with four subchannels, as shown. To be absolutely precise, the annular channels in the model of the test section should have taken into account the presence of the steel plates inserted in the sides of the annulus--as shown in Figure 4.19. However, because the calculated temperature gradient across the annulus was so small, the minor differences in the geometry were neglected. The fuel tube was modeled with four nodes, using a single node per side. The boundary temperature for a given test run was imposed by specifying, via input instructions, the temperature on the outer surface of the wall nodes of the fuel tube.

Radial and axial heat generation profiles were specified as uniform, and the rods in the consolidated geometry were modeled with stainless steel and mullite thermal properties. Both the canister and the fuel tube were modeled with stainless steel properties.



Note: Drawing is Not to Scale

FIGURE 4.21. COBRA-SFS Subchannel Model of the Zero Gap Consolidated Test Section

4.3.2.2 Modeling Assumptions, Parameters, and Correlations

Graybody view factors for radiation heat transfer are specified in COBRA-SFS as an array of exchange factors for every surface. These view factors are calculated from blackbody view factors determined using the crossed-string correlation method of Hottel (Cox 1977) and the specified emissivity of the surface. The blackbody and graybody factors are computed by first treating each rod surface as consisting of four separate quadrants, calculating the exchange factors for each quarter-rod surface, then appropriately summing the factors to obtain a value for the radiation exchange between any given rod or wall surface and all other surfaces in view. The radiation view factors are a function of the physical geometry of the assembly and the surface emissivities of the rods and walls.

The rods in the consolidated assembly were assumed to have surface emissivities of 0.8, and the wall surface emissivities were assumed to be 0.2. View factors calculated for the geometry assumed zero gaps between rods. Uniform surface emissivity of the rods was also assumed.

Radiation in the annulus between the outer surface of the canister and the inner surface of the fuel tube was modeled by specifying blackbody view factors among the eight participating surfaces. The blackbody view factors for the annulus were again calculated using Hottel's cross-string correlation method. These factors were specified as input to COBRA-SFS, along with the surface emissivity for the walls, and the code calculated the corresponding graybody view factors.

Technically, the view factor calculation should have been modified to account for the shadowing effect of the plates and shims positioned in the sides of the annulus to prevent convection. But initial calculations showed the temperature distribution across the annulus to be so uniform as to obviate any significant heat transfer by radiation in this part of the test section. For this reason, the effect of the shims on radiation exchange in the annulus was ignored.

Heat transfer between the solid surfaces (i.e., rods and wall nodes) and the fluid is calculated in COBRA-SFS as a heat flux driven by a temperature difference. It is formulated in terms of a heat transfer coefficient, which, in steady state, reduces to the familiar equation,

$$q'' = h\,(T_{wall} - T_{fluid}) \tag{4.1}$$

where q'' = heat flux, (Btu/hr-ft^2)
h = heat transfer coefficient, (Btu/hr-ft^2-°F)
T_{wall} = rod or wall surface temperature, (°F)
T_{fluid} = fluid temperature in the subchannel, (°F)

This formulation reflects the antecedents of COBRA-SFS as being concerned primarily with forced convection heat transfer. The heat transfer coefficient, h, is expressed in the code as some Nusselt number known (from empirical sources) as

$$Nu = \frac{hD_h}{k} \tag{4.2}$$

where Nu = Nusselt number

D_h = hydraulic diameter of the channel, (ft)

k = thermal conductivity of the fluid, (Btu/hr-ft-°F)

The Nusselt number is specified by input to the code, and can be expressed as a constant, or as some function of the Reynolds and Prandtl number of the fluid.

Assuming no axial flow, the heat transfer coefficient, h, can be replaced by the equivalent term for conduction, $h = k/\Delta x$ (Fourier's Law), where k is the thermal conductivity, and Δx is the distance between conducting surfaces. Equating the conductances between convection and conduction-only formulations, it is possible to determine a relationship to describe conduction heat transfer with a Nusselt number. That is, if $h = Nu(k/D)$, [(from Equation 4.2)], and $h = k/\Delta x$, then

$$Nu = \frac{D_h}{\Delta x} \tag{4.3}$$

This formula should yield an appropriate Nusselt number to model heat transfer from the rods or walls to the fluid. The trick, of course, is to determine the appropriate value for Δx.

If it is assumed that the main heat transfer path between the rods and the fluid is from the subchannel center to the rod surface, then the Nusselt number can be approximated as follows. For rods in a triangular array with pitch, P, and rod diameter, D_r:

$$\Delta x = 0.5\ (P/\cos 30°) - 0.5\ D_r \tag{4.4}$$

$$D_h = 4(0.4\ P^2 \sin 60° - 0.5\ (0.25\ \pi\ D_r^2))/\ (0.5\ \pi D_r) \tag{4.5}$$

For the case of consolidated rods in contact, $P = 12.7$ mm (0.50 in.), and $D_r = 12.7$ mm (0.5 in.), resulting in a fluid heat transfer correlation of the form $Nu = 1.3$. This value was used to describe the heat transfer from the rods to adjacent fluid for all rods within the enclosure. For the open annulus exterior to the fuel assembly, heat transfer from the walls to fluid was described by $Nu = 2.0$. No buoyancy effects were modeled within the test section, thus, the effects of thermal stratification and natural convection (axial and radial directions) were not accounted for.

An additional constitutive heat transfer parameter that must be specified in these simulations is the contact conductance. This parameter is not required for unconsolidated assembly thermal analyses, as all conduction heat transfer proceeds from the rods to the fluid and then to the walls. In a consolidated spent fuel assembly, however, there are several conduction paths. In a consolidated test section, the rods are in contact with the inner surface of the enclosing canister, and the rods touch one another in a close-packed array. Within the assembly, a rod is in physical contact with the six neighboring rods that surround it. It is obvious that not all the heat flows from the rods to the fluid in the channel. Some of the heat will flow directly from rod surface to rod surface, or rod surface to wall surface, at the point of contact.

The appropriate contact heat transfer coefficient, h_c, and contact area, A_c, for a given case are far from obvious, however. There are a number of physical models available for determining the contact heat transfer coefficient between two surfaces, but these are usually highly empirical and restricted to particular geometries or materials. In addition, they often depend on esoteric physical properties of the surfaces, such as roughness, statistical wavelength, and hardness. The contact area is similarly difficult to define precisely, particularly for curved surfaces in precarious contact. So, in practical terms, it is more efficient to simply select a value of thermal conductance, H_c, thus lumping the uncertainties in h_c and A_c into one parameter, and determining a suitable value by comparisons to appropriate experimental data.

For the geometries considered here, it is unreasonable to expect extremely good contact conductance. The simulated fuel rods were straightened to a tolerance of less than 0.083 mm/m (0.001 in./ft) before assembly, which would tend to promote uniformity of contact, but the rods were merely stacked in the triangular array without any particular effort to squeeze them into tight contact. A contact conductance of 1.02×10^{-4} W/cm^2-°C (0.5×10^{-4} Btu/s-ft^2-°F) was selected to model the heat transfer by direct rod-to-rod and rod-to-wall conduction. Previous experience (Cuta, Rector, and Creer 1984) has shown that this value yielded reasonable results when applied in consolidated geometries. In actual BWR consolidated fuel rods, contact conductances may be significantly different than this assumed value because crud is present on rod surfaces and actual rods are not necessarily straight within the 0.0833 mm/m (0.001 in./ft) tolerance of this model test.

4.3.2.3 Modeling Uncertainties

The computational model developed for this analysis was based on design information supplied by Eggers (1985). In developing the model, uncertainties were associated with the following heat transfer and fluid flow parameters:

- material emissivities
- contact conductances
- axial heat losses.

As in the simulations of other spent fuel heat transfer tests described previously, there can be considerable uncertainty in the emissivity values since they were not experimentally determined. Again, more uncertainty is associated with the wall surface emissivity due to its small value compared with the rods. In addition, the consolidated rods radiation is relatively ineffective due to rod shadowing, thus limiting the effect of the rod emissivity uncertainty. The values selected are best-estimate values deduced from the literature and limited parameter studies with COBRA-SFS.

Several types of contact occur within the consolidated assembly (i.e., rod-to-rod, rod-to-wall) and uncertainties are associated with each type.

Parameter studies of rod-to-rod contact performed (Cuta and Creer 1986) showed that, over a range of contact conductances from 0 to 1×10^{-3} Btu/sec-°F, the peak rod temperature was predicted to vary 29°C (52°F) for the vacuum test with zero rod gaps (400 W). This is equivalent to 14% of the predicted peak clad temperature. Thus contact conductance is an important parameter in the consolidated assembly simulations.

The geometry and boundary temperature was assumed uniform, allowing the test assembly to be modeled with two axial nodes. In actuality, however, the measured boundary temperature showed a significant skew at the end regions due to heat losses from the test section ends. The nonuniformity of the boundary also affects the measured rod temperatures and therefore can account for some of the discrepancy of predictions with data.

An additional source of uncertainty in this test is the unmodeled shim pieces used to inhibit convection within the assembly. By omitting the presence of the shims in the model, the radiation shielding and conduction effects of these pieces are ignored. This is not expected to influence the predictions significantly in that temperature gradient across the annulus is quite flat.

4.3.3 Comparisons of Predictions to Data

Results of COBRA-SFS predictions are presented in Figure 4.22 for the consolidated assembly with zero rod gap in air and helium (800 W). Excellent agreement is seen in both the peak clad temperature and the radial temperature distribution across the test section for the two media. Further evidence of the code's ability to successfully predict the temperature distribution in a consolidated fuel assembly is presented in Figure 4.23, which illustrates the relative temperature differences across the assembly.

Despite their more complex geometry, consolidated assemblies actually pose a simpler problem in heat transfer analysis for COBRA-SFS than do unconsolidated assemblies. The consolidated rods are essentially a lumped heat source, with a relatively flat radial temperature profile, and the predominant mode of heat transfer for this geometry is conduction. Radiation is relatively ineffective, due to rod shadowing, and free convection is prevented by the

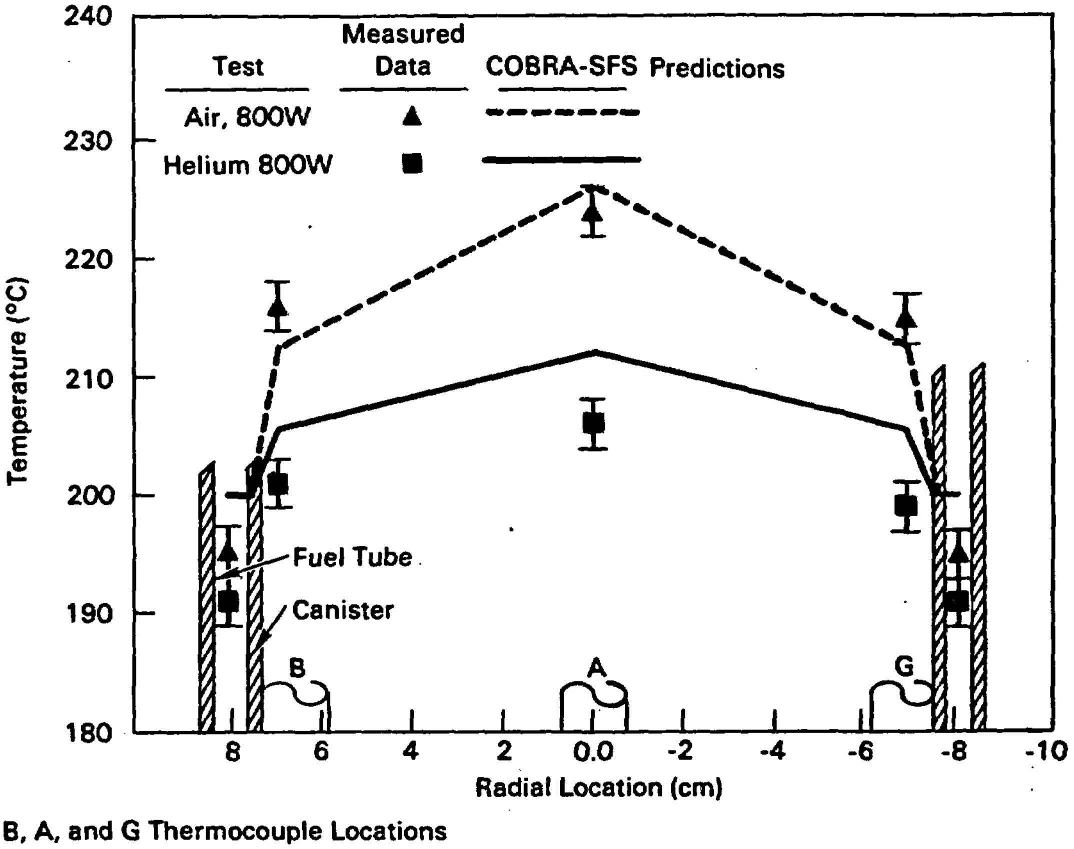


FIGURE 4.22. Comparisons of Calculated and Measured Radial Temperature Profiles in a Consolidated Assembly with Zero Rod Gaps

close packing of the rods, the horizontal orientation, and the sealed ends of the test section. Heat flows in the radial direction by conduction through the fluid (i.e., from rod-to-fluid channel-to-rod-to-fluid channel radially from the center of the assembly), and also, in the zero rod gap cases, by conduction from rod-to-rod at the areas of contact.

For COBRA-SFS to calculate temperatures in good agreement with the data, the code needs to correctly model the conduction heat transfer from the rods to the fluid, and the contact conductance rod-to-rod and rod-to-wall for the consolidated geometry. The rod-to-fluid conduction is governed by the Nusselt number, and rod-to-rod or rod-to-wall conduction is governed by the contact conductance. Both of these parameters, Nusselt number and contact conductance,

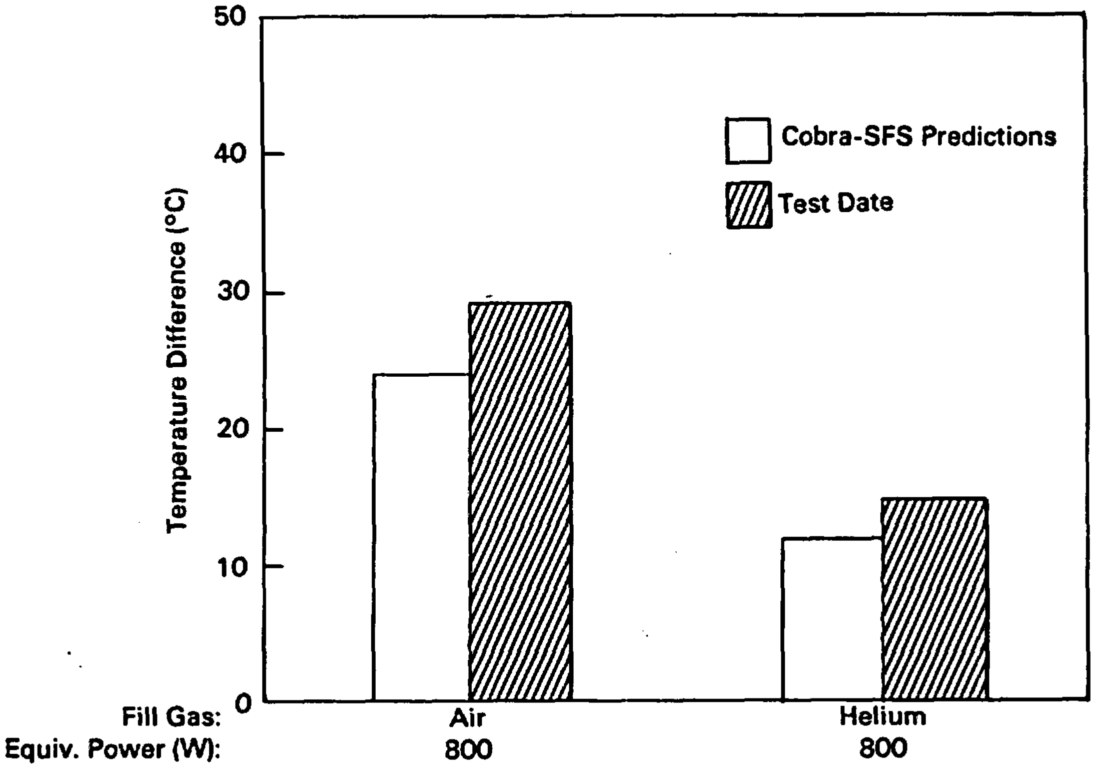


FIGURE 4.23. Comparisons of Predictions to Measured Temperature Differences (Thermocouple Positions A to E) in a Consolidated Assembly with Zero Rod Gaps

are specified by input. The values used in the calculations were selected based on reasonable assumptions regarding the test section geometry. The good agreement between the calculations and experimental results shown above indicates that appropriate values were selected for these parameters and that the code is capable of correctly calculating the heat transfer in a consolidated assembly.

5.0 MULTIASSEMBLY EVALUATION TESTS

To be a truly useful analytical tool, COBRA-SFS must also be validated against data from multiassembly storage systems. As with single assembly spent fuel thermal analyses, the combined roles of conduction, convection, and radiation heat transfer must be adequately represented. These models, however, must now perform over a wider and more varied range of parameters, geometries and complexities of the thermal systems.

To demonstrate the capability of COBRA-SFS to analyze the more difficult multiassembly storage systems, comparisons of code predictions with experimental test data from three multiassembly dry storage system tests are presented. Comparison of code predictions and data are provided for one run of the CASTOR-1C Spent Fuel Storage Cask Performance Test (16 BWR assemblies), 3 runs from the REA-2023 BWR Cask Performance Test (52 BWR assemblies), and 2 runs from the TN-24P Spent Fuel Storage Cask Performance Test (24 PWR assemblies). In total, the runs selected demonstrate the ability of COBRA-SFS to predict the thermal performance of complex multiassembly storage systems under a variety of loadings, fill media, and cask orientations. In the following sections, evaluations of COBRA-SFS predictions for the CASTOR-IC, REA-2032, and TN-24P multiassembly storage systems are presented.

5.1 CASTOR-1C SPENT FUEL STORAGE CASK PERFORMANCE TEST

To add to the current body of knowledge and to gain operational experience in dry spent fuel storage, a program for handling and monitoring spent fuel containers was initiated by the Federal Republic of Germany, using a cask of the CASTOR-1C type. This program was carried out at the Wurgassen Nuclear Power Plant by the German Association for the Reprocessing of Nuclear Fuels in conjunction with the Preussen Elketra utility.

In this series of tests, temperature distributions of the CASTOR-1C cask, loaded with 16 BWR spent fuel assemblies, were recorded continuously during a two-year period, thereby providing information on the cask thermal response as a function of decay heat level. For purposes of this study, only the maximum decay heat level prediction run will be compared to data since this case provides cask temperatures closest to allowable limits. The CASTOR-1C spent fuel storage cask and cask performance test conducted at the Wurgassen plant are briefly described in this section, along with results of comparisons of code predictions with data. Results of prelook and post-test results from previous COBRA-SFS simulations are presented in an application report by Rector et al. (1986a). Input, representative output, and convergence lists of the run presented herein are provided in Appendix D.

5.1.1 CASTOR-1C Cask and Test Description

The General fur Nuklear Services (GNS) CASTOR-1C cask (GNS 1985) is designed to safely store and remove the decay heat from 16 BWR spent fuel assemblies for extended time periods. An elevation view of the CASTOR-1C cask is shown in Figure 5.1. The cask consists of a thick-walled nodular cast-iron body, which is cast in one piece. The body physically protects the fuel assemblies and provides radiation shielding. The central cavity of the cask contains a stainless steel basket that separates and supports the spent fuel assemblies. The top of the cask is sealed using a multiple-lid system. The overall cask dimensions and design specifications are summarized in Table 5.1. Each major component of the cask is described in more detail below.

A transverse cross section of the CASTOR-1C cask is shown in Figure 5.2. The nodular cast-iron body has an overall length of 5510 mm (18 ft) and a maximum outside diameter of 1730 mm (5.7 ft). The side wall thickness (without fins) is approximately 440 mm (17.3 in.). Gamma and neutron radiation are shielded by the cast-iron wall of the cask. For improved neutron shielding through the side, two concentric rows of axial holes in the cask body wall are filled with polyethylene rods (moderator material). The rods are 60 mm (2.4 in.) in diameter and extend axially from the bottom of the cask to above the top elevation of the fuel assemblies.

The outside surface of the cask varies as a function of axial level. Near the top and bottom of the cask, the surface is a cylinder 1905 mm (6.25 ft) in diameter with four flat surfaces machined so the minimum flat-to-flat distance is 1730 mm (5.7 ft). In the axial region of the fuel assemblies, a

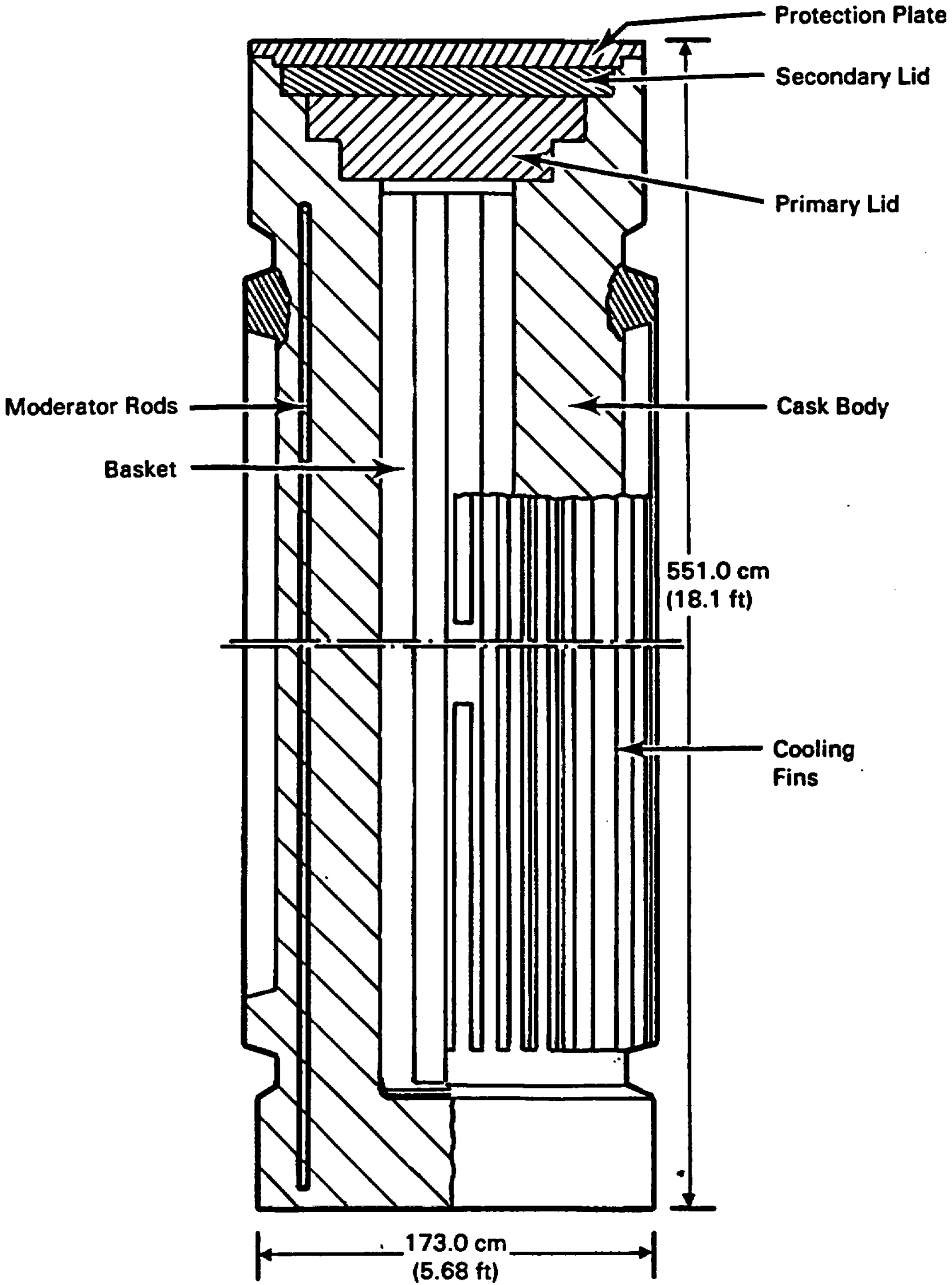


FIGURE 5.1. Elevation View of the CASTOR-1C Cask

TABLE 5.1. CASTOR-1C Cask Dimensions and Design Specifications

Cask overall length:	551 cm (18 ft)
Cross section:	173 cm (5.7 ft)
Cask cavity width:	66.6 cm (2.2 ft)
Cavity length:	456 cm (15 ft)
Side wall thickness without fins:	44 cm (17 ft)
Lid thicknesses:	
- primary lid	34 cm (13 in.)
- secondary lid (including moderator)	13 cm (5 in.)
- protection plate	8 cm (3 in.)
Bottom thickness:	44.7 cm (18 in.)
Moderator dimensions:	
- number of polyethylene moderator rods	80
- rod diameter	6 cm (2.4 in.)
- thickness, secondary lid	6 cm (2.4 in.)
- thickness, bottom	4.2 cm (1.7 in.)
Number of cooling fins:	48
Cask fuel assembly capacity:	16
Cask atmosphere:	helium
Cavity pressure:	0.8 bar (11.76 psia)
Weight:	
- empty cask	76.6 ton
- loaded cask	81.1 ton

set of 48 axial cooling fins is provided to enhance the removal of heat by natural convection. A cross section of the CASTOR-1C cask illustrating the cooling fin geometry is shown in Figure 5.3. The fins are 120 mm (4.7 in.) long, 50 mm (1.97 in.) wide at the base, and are spaced approximately 112 mm (4.4 in.) apart. The outside of the cask is protected by an epoxy resin coating in the fin area. The fins are also covered with a high-emissivity paint to aid in transferring heat from the cask surface. The remainder of the cask surface is covered with a corrosion-resistant nickel coating.

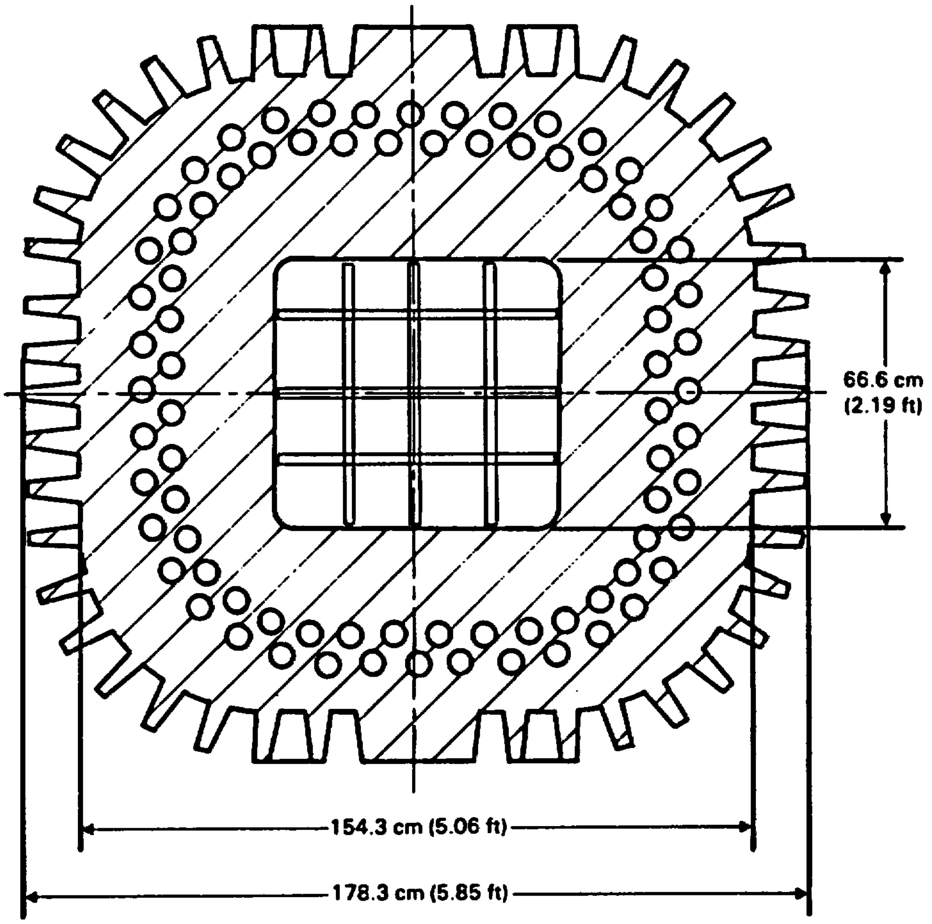


FIGURE 5.2. Transverse Cross Section of the CASTOR-1C Cask

The thickness of material from the bottom of the inner cavity to the exterior bottom of the cask is approximately 450 mm (17.7 in.). The major portion of this is cast iron. However, some of the cast iron is machined from the bottom of the cask and is replaced by concentric rings of polyethylene that serve as neutron shields. A semi-permanent steel cover plate is secured over the rings to hold them in place.

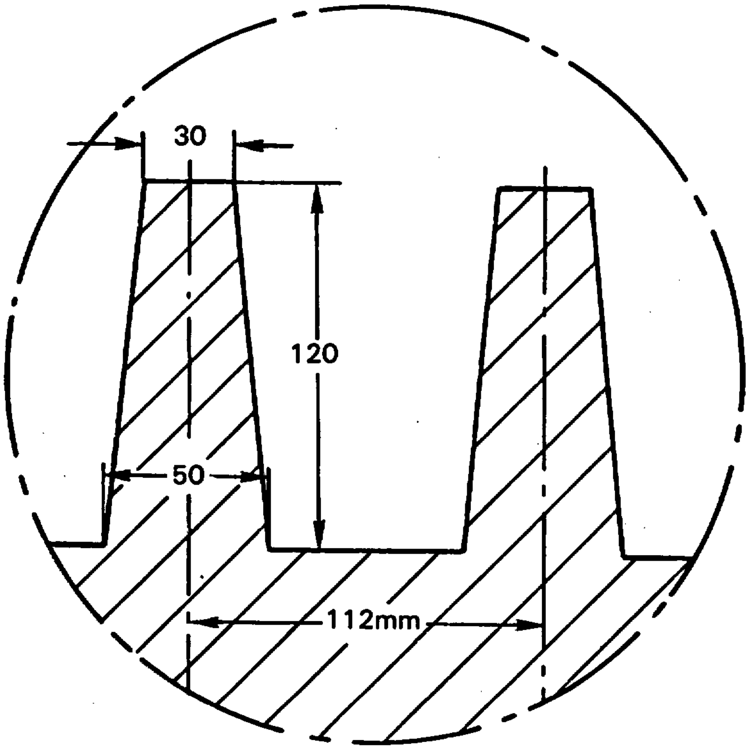


FIGURE 5.3. CASTOR-1C Cooling Fin Geometry

The cask inner cavity is square, 666 mm (26.2 in.) wide and 4560 mm (15 ft) long. The bottom of the cavity is sloped slightly to enhance draining of fluid. The inside of the cask, including the sealing surfaces, has a nickel coating for corrosion protection. A support plate is placed on the bottom of the cavity to provide a level support for the basket and fuel assemblies.

The basket is of welded construction and is made of borated stainless steel. The basket divides the cavity into 16 regions, each designed to contain a single BWR spent fuel assembly. A cross section of the fuel basket is visible in Figure 5.2. The stainless steel plates used to construct the basket are 10 mm (0.4 in.) thick, and the overall basket width is 640 mm (25 in.). This leaves a gap between the basket and cavity wall of approximately 13 mm (0.5 in.) on all sides. The basket is designed to allow the top and bottom portions of the cavity to be open. This allows gas flow between adjacent assembly tubes and natural circulation inside the cavity. The basket also serves as a path for conduction heat transfer from the center assemblies to the cask body.

The CASTOR-1C cask is sealed with a multiple-lid system consisting of a primary lid, a secondary lid, and a protection plate. The three lids are shown in Figure 5.1. The primary cover is constructed of stainless steel and has an outside diameter of 1200 mm (3.9 ft) and an overall thickness of about 340 mm (13.4 in.). The secondary cover is made primarily of stainless steel and has a 1415-mm (4.6 ft) diameter and a 130-mm (5.1-in.) thickness. Some of the stainless steel in the secondary cover is replaced with concentric polyethylene rings that act as neutron shields. The protective plate is made of carbon steel and serves as a general mechanical protection against outside forces as well as dust and humidity. Each lid is bolted directly to the cask body. During normal operation the cask is filled with helium with a cavity pressure of 0.8 atmospheres.

The sixteen spent fuel assemblies used in the Wurgassen CASTOR-1C cask test were GE 7x7 and 8x8 assembly types. The design characteristics of these two assembly types are listed in Table 5.2. Each fuel assembly contained fuel rods (and one center water rod in the 8x8 assembly only) spaced and supported in a square array by the lower and upper tie plates. A typical GE 8x8 fuel assembly is shown in Figure 5.4. Besides the standard fuel rods, two other rod types are used in the fuel assembly: tie rods and a nonfuel water rod. The eight tie rods in each assembly have lower end plugs that thread into the lower tie plate casting and upper end plugs that extend through the upper tie plate casting. These tie rods support the weight of the assembly only during fuel handling when the assembly hangs by the handle; during operation, the fuel rods are supported by the lower tie plate. The ORIGEN2 code (Croff 1980a, 1980b) was used to predict decay heat generation rates of the 16 Wurgassen BWR spent fuel assemblies used in the CASTOR-1C cask performance test. Decay heat rates for the assemblies were determined from end-of-cycle burnup values and from the reactor operating history (Rector et al. 1986a). The predicted assembly decay heat generation rates on three dates are shown in Table 5.3 for each of the 16 Wurgassen assemblies. The average predicted assembly decay heat rates were 837 W, 452 W, and 369 W, for the three dates, corresponding to cooling times of 434, 887, and 1100 days, respectively. At 434 days cooling time, the standard deviation of the predicted decay heat

TABLE 5.2. Characteristics of Typical General Electric BWR Fuel Assemblies

	7x7 Assembly	8x8 Assembly
Assembly length	4354 mm (171.40 in.)	4354 mm (171.40 in.)
Fuel rods		
Number	49	63
Length	3964 mm (156 in.)	3964 mm (156 in.)
Active length	3683 mm (145 in.)	3733 mm (147 in.)
Outside diameter	14.3 mm (0.563 in.)	12.5 mm (0.493 in.)
Wall thickness	0.89 mm (0.035 in.)	0.86 mm (0.034 in.)
Pitch	18.7 mm (0.738 in.)	16.3 mm (0.640 in.)
Material	Zr-2	Zr-2
Tie rods - fueled		
Number	8	8
Outside diameter	14.3 mm (0.563 in.)	12.5 mm (0.493 in.)
Wall thickness	0.89 mm (0.035 in.)	0.86 mm (0.034 in.)
Material	Zr-2	Zr-2
Spacer capture rods		
Number	1	1
Outside diameter	14.3 mm (0.563 in.)	12.5 mm (0.493 in.)
Material	Zr-2	Zr- 2
Spacers		
Number	7	7
Material	Zr	Zr-4
Springs	Inconel-X	Inconel-X
Tie plate material	304 SS	304 SS

rate is ±6.0%, which reduces to ±4.4% for the longest cooling period. The associated axial decay heat profile used for the simulations is presented in Figure 5.5 and was determined using reactor activity scans and ORIGEN2.

5.1.2 Computational Model Description

A three-dimensional, half-symmetry sector model of the CASTOR-1C cask was used for the COBRA-SFS analysis. A half-symmetry model was dictated by

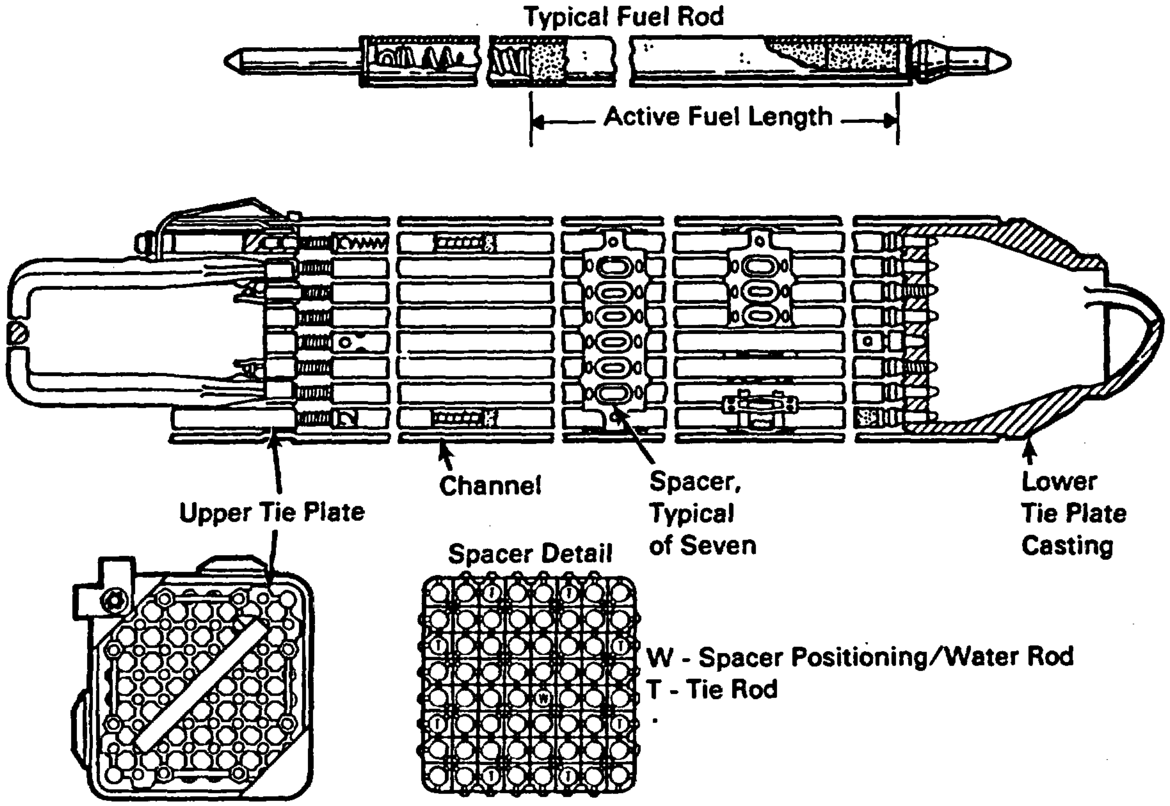


FIGURE 5.4. Typical General Electric 8x8 Fuel Assembly

the arrangement of 7x7 and 8x8 BWR fuel assemblies and by the cask loading pattern. The model, the boundary specifications, and properties used, are described in detail below.

5.1.2.1 Nodal Representation

A transverse cross section of the computational cell arrangement used to represent the cask body is presented in Figure 5.6. A total of 136 wall nodes at each axial level is used to model the heat transfer through the cask body. Of these, 40 are zero-thickness nodes that represent the temperatures on the outside and inside surfaces of the cask body. These surface nodes are necessary to accurately calculate the radiation heat transfer between cask surfaces.

TABLE 5.3. Predicted Wurgassen BWR Assembly Decay Heat Rates

Assembly ID(a)	Burnup, GWD/MTU	Cooling Time, Days		
		434	887	1100
		Predicted Decay Heat Rate, W		
		03/10/82	06/06/83	01/05/84
B476	27.6	846	456	373
B471	27.6	851	460	376
B472	27.8	852	461	377
B476	27.6	851	460	376
B486	27.6	846	460	373
B489	27.8	852	454	377
B490	27.5	846	460	373
B493	27.5	841	454	371
BZ701	27.2	717	452	329
BZ703	28.5	838	398	369
BZ704	28.3	877	467	379
BZ706	27.2	712	396	328
BZ707	28.3	877	467	379
BZ708	28.5	838	452	369
BZ709	28.3	877	467	379
BZ710	28.3	877	467	379
Total		13,398	7,231	5,907
Average	27.8	837	452	369
Std. Dev:	±0.45	±50	±22	±16
%SD of Avg:	±1.6	±6.0	±4.9	±4.4

(a) Identification numbers starting with B denote 7x7 rod assemblies; numbers starting with BZ denote 8x8 rod assemblies.

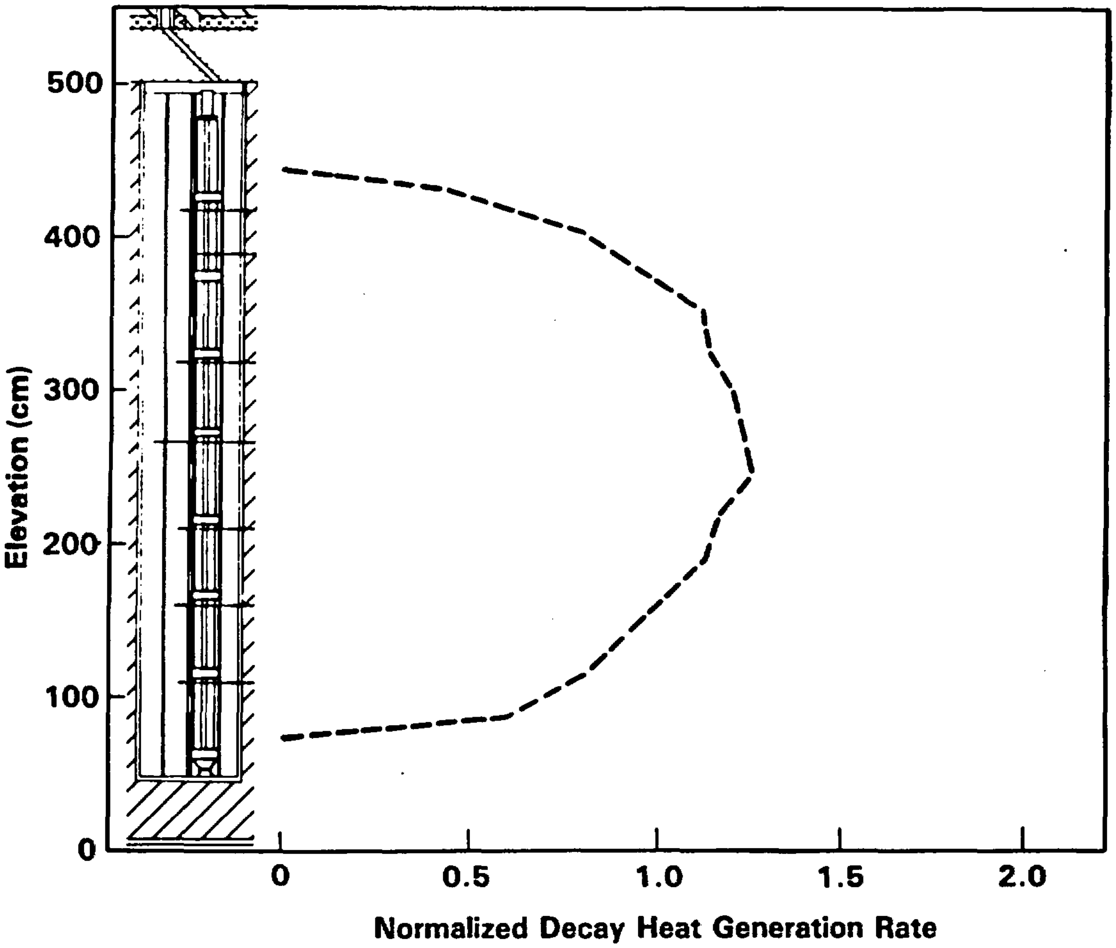


FIGURE 5.5. Axial Decay Heat Profile Used for CASTOR-1C Analysis

A transverse cross section of the computational cell arrangement used to represent the cask basket and fuel assemblies is presented in Figure 5.7. The stainless steel basket is represented by 34 wall nodes at each axial level. The BWR fuel assemblies are modeled using a detailed rod and subchannel nodalization. A typical 7x7 assembly is modeled using 49 rods and 60 fluid subchannels. A typical 8x8 assembly is modeled using 64 rods and 77 fluid subchannels. The resulting half-symmetry cask model consists of a total of 170 wall nodes, 452 rod, and 548 subchannel nodes at each axial level. The basket and fuel assembly region of the cask is modeled using 18 uniform axial nodes.

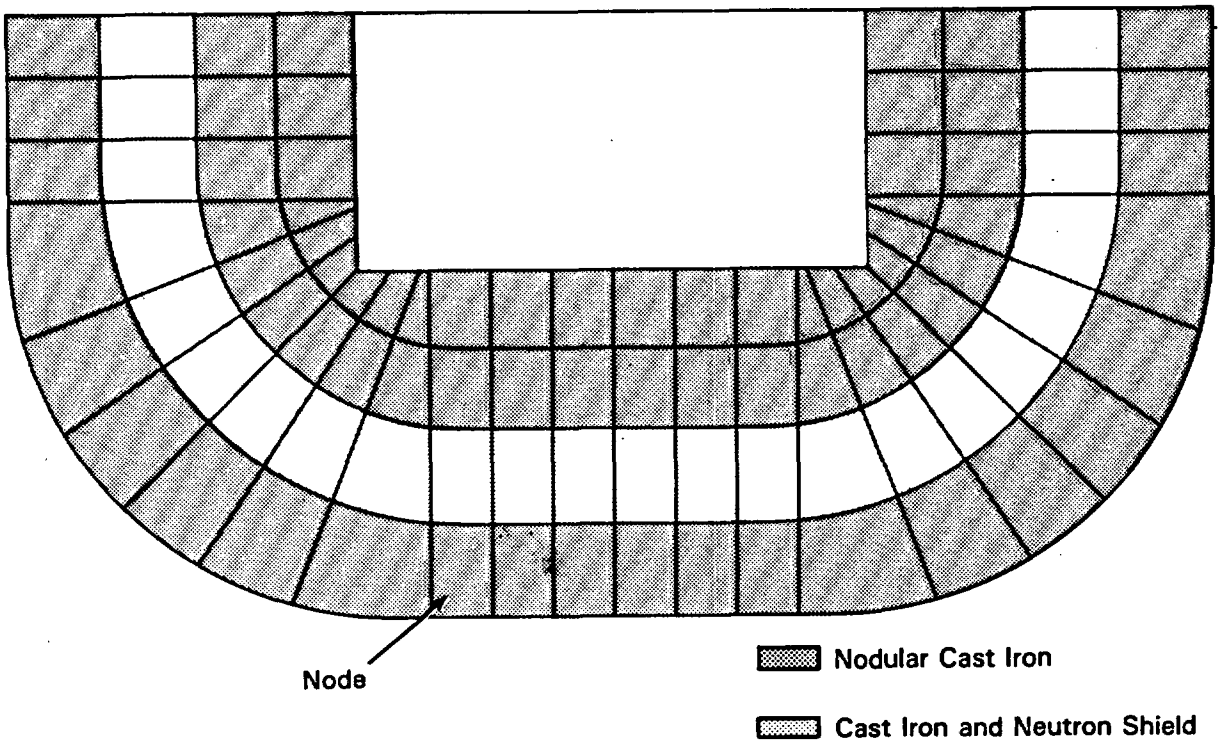


FIGURE 5.6. COBRA-SFS One-Half Symmetry CASTOR-1C Cask Body Model

Heat is removed from the fuel assemblies by all three modes of heat transfer: conduction, convection, and radiation. Within each assembly, heat is transmitted from the rods to the basket by conduction through the fluid. Fluid conduction between adjacent subchannels is modeled based on a transverse control volume of specified gap width and centroid-to-centroid length.

Conduction heat transfer through the basket and cask body is modeled by specifying the appropriate thermal resistance between adjacent wall nodes. The input thermal resistance values may reflect a composite of materials and parallel and/or series heat transfer paths. For example, wall nodes containing both polyethylene neutron absorber cylinders and cast iron are modeled using a composite conductivity. In developing these resistances, it was assumed that there was no additional thermal resistance at the welded junctions between

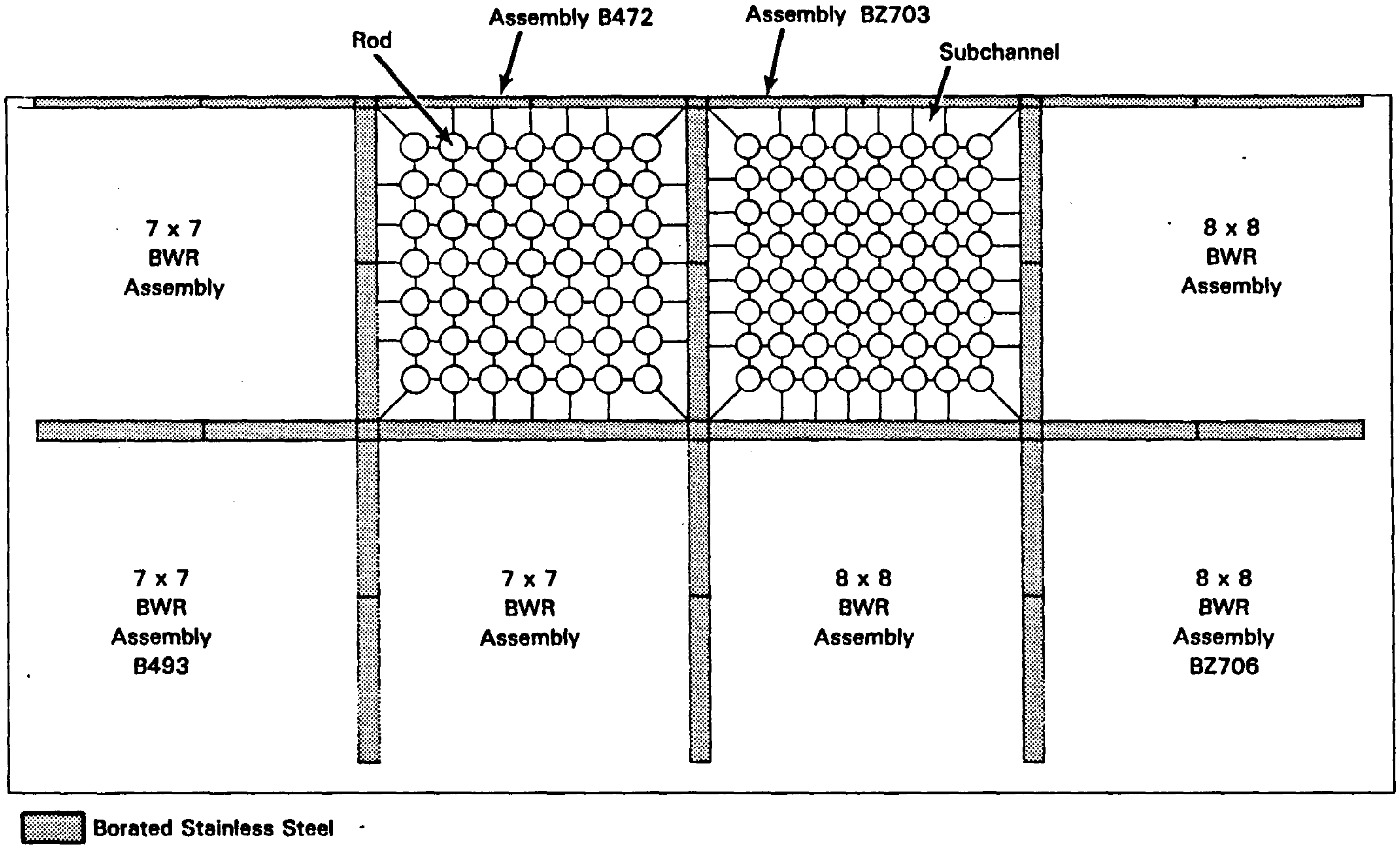


FIGURE 5.7. COBRA-SFS One-Half Symmetry CASTOR-1C Cask Cavity and Basket Model

the basket plates. Heat transfer from the basket to the cask inner wall was modeled using a thermal resistance derived by assuming a 13 mm helium-filled gap.

The overall contribution of convective heat transfer is dependent on the flow field established. For these simulations the flow field is obtained by adjusting the total pressure drop until: 1) the pressure drop across all channels is equal, and 2) the total net flow rate is zero. Thus, the flow resistance of the fuel assemblies and basket are important convection component parameters. The rod and wall friction for all subchannels except those adjacent to the cavity surface are modeled using a friction factor expression of $f = 100/Re$, which is for a square rod array with typical BWR pitch-to-diameter ratios (Sparrow and Loeffler 1959). The wall friction for subchannels adjacent to the cavity surface was modeled using the standard friction factor expression for fully developed laminar pipe flow; $f = 64/Re$ (Kays and Crawford 1980).

Heat transfer from the rods and walls to the coolant was prescribed through the use of a film coefficient of the form $Nu = 3.66$ (Kays and Crawford 1980). This formulation is an analytical solution of the energy equation for flow in a circular tube with a constant surface temperature and fully developed velocity profile. The film coefficient was evaluated as a function of temperature at each location.

Each BWR spent fuel assembly, surrounding basket fuel tube, and cavity wall is treated as a separate thermal radiation enclosure. Assumed emissivities are presented in Table 5.4. Rod-to-rod, rod-to-wall, and wall-to-wall radiative heat transfer within each radiation enclosure is prescribed using graybody exchange factors. The exchange factors for each BWR spent fuel assembly are derived using geometric view factors for one-quarter pin surface segments. When determining view factors, this subdivision of the fuel rod surface has previously been shown to be adequate in determining the proper radiative heat transfer from a rod bundle (Cox 1977, Lombardo et al. 1986).

TABLE 5.4. Assumed CASTOR-1C Cask Surface Emissivities

Surface Emissivities

Fuel Rods = 0.8
Fuel Basket = 0.4
Nickel Plated Surfaces = 0.25

5.1.2.2 Boundary Specifications and Material Properties

The computational noding model described earlier extends radially outward to the cask surface. Within this model the wall and fluid energy equations are solved simultaneously. Boundary conditions are provided to the model by specifying heat transfer coefficients which describe the heat transport from the cask surface to the ambient air. The two coefficients of interest are: 1) heat transfer from the cask barrel to the ambient, and 2) heat transfer from the cask ends to the ambient.

The outside surface of the cask varies as a function of axial level. In the axial region of the fuel assemblies, a set of 48 axial cooling fins are provided to assist in removing heat by natural convection. The amount of heat being removed by natural convection from a finned surface is calculated using the Nusselt number expression (Chaddock 1970):

$$Nu = 0.112\ (Ra \bullet b/L)^{0.534}\ [1-e^{-129/(Ra \bullet b/L)}]^{0.284} \qquad (5.1)$$

where Ra is the Rayleigh number, b is the distance between vertical fins and L is the total vertical length of the fin.

Near the top and bottom of the cask, the outer surface of the cask is essentially a smooth cylinder. The amount of heat removed by natural convection is calculated using the Nusselt number expression for vertical cylinders in air (Lindeburge 1981):

$$Nu = 0.13\ (GrPr)^{0.33} \qquad (5.2)$$

where Gr is the Grashof number, and Pr is the Prandtl number.

The top surface of the cask can be represented by a horizontal flat plate. The Nusselt number expression for this geometry in air (Lindeburge 1981) is

$$\mathrm{Nu} = 0.14\ (\mathrm{GrPr})^{0.33} \tag{5.3}$$

The bottom of the CASTOR-1C cask rested on a supporting surface. Since the surface temperature and contact resistance were unknown, it was conservatively assumed that the bottom surface of the cask as an adiabatic boundary.

To properly evaluate code predictions and the cask models, comparisons of relative temperature differences among the various cask components are required. One obvious result of the pretest predictions is the overprediction of the measured surface-to-ambient temperature difference. The results from the correlations presented above and similar correlations used in the REA 2023 cask analysis (Wiles et al. 1986) have been found to typically underpredict the heat transfer from these large cask bodies by 30 to 40%. Because the radiation component from these surfaces is fairly well defined (measured surface emissivities and constant radiation exchange factors), the differences between the pretest predictions of surface-to-ambient temperatures are attributed to deficiencies in the convective heat transfer component. This is not surprising since the correlations were developed based on ideal geometries and test conditions, and are being applied outside their intended range of applicability. Thus, to facilitate the cask component temperature difference comparisons, the convective correlations listed above were increased by approximately 40% to provide reasonably close agreement between the predicted and measured surface temperatures. The correlations presented here are typical of what is available in the literature and what might be employed in conservative applications of the code.

Heat is also removed from the fins by thermal radiation. The amount of heat removed is calculated using a composite graybody exchange factor. This factor is calculated using Hottel's method (Cox 1977) and is based on the surface emissivities and the blackbody view factors between the cask and fin surfaces and ambient air. The radiation heat transfer from the top and smooth side surfaces is also accounted for. The emissivity of the outer painted surface of the cask was measured by GNS to be 0.93, the emissivity of the outer nickel plated surfaces was measured to be 0.25 and, the ambient air was assumed to be a blackbody surface ($\epsilon = 1.0$). A list of the surface emissivities for the fuel and various cask components is presented in Table 5.4.

The material properties used to develop the CASTOR-1C model are presented in Table 5.5. Most of these properties were obtained from GNS. Constant thermal conductivities are specified for cast iron and neutron moderator. However, the thermal conductivity for the fuel basket is specified as a function of temperature. As stated earlier, the thermal conductivities are not used in the COBRA-SFS code directly but are used to determine the resistance coefficient between adjacent wall nodes. A preliminary CASTOR-1C simulation was performed using average values for thermal conductivities. Specific temperatures from this run were then used to evaluate the thermal conductivity at each location and subsequently for each thermal connection.

TABLE 5.5. CASTOR-1C Cask Material Properties

Thermal Conductivities

Nodular Cast Iron = 0.35 W/cm°K

Neutron Moderator = 0.15×10^{-2} W/cm°K

Fuel Basket = $(9.503 + 1.445\text{x}10^{-2}T - 4.989\text{x}10^{-2}T^2 + 3.33\text{x}10^{-9}T^3)\ 10^{-2}$ W/cm°K

where T is temperature in °C

5.1.2.3 Modeling Uncertainties

In the design information used to develop the CASTOR-1C cask model, a number of uncertainties exist that affect the ability to accurately predict the cask thermal performance. The following parameters introduce uncertainty into the analysis:

- The basket-to-cask wall gap is assumed to be a nominal 13 mm (0.51 in.). No effort has been made to account for thermal expansion or eccentric positioning of the basket within the cavity.
- The fuel assemblies are assumed to be vertical and positioned in the center of each basket fuel tube. In reality, the fuel assemblies will probably lean against the side of the fuel tube for support. The resulting eccentricity will affect the heat transfer from the assembly to the basket and the resulting temperature distribution.
- Natural convection heat transfer from the outside surface of the cask is difficult to predict accurately. The correlation selected is based on vertical rectangular fins extending from a flat surface in a static environment. The actual geometry and test conditions do not match these ideal assumptions.
- The bottom surface of the cask is assumed to be adiabatic. In reality, the heat transfer to the supporting surface will depend on the contact resistance between the surfaces.

5.1.3 Comparisons of Predictions to Data

For purposes of this study, only the highest decay heat level data are presented. To perform the predictions, cask internal pressure, loading pattern, assembly decay generation rates and profiles, and ambient temperatures were supplied. Comparisons of the peak clad axial temperature profiles are presented in Figure 5.8 along with the predicted and measured surface temperatures. Excellent agreement between predictions and test data can be seen, with the predicted temperature drop (peak cladding-to-ambient) falling within 1% of the test data. Excellent agreement is also seen in the axial temperature profiles. Equally good agreement was also obtained for assembly BZ704, but is not shown because of the symmetry of results.

To complete the evaluation of the code predictions and the cask model, comparisons of temperature differences between cask components at 266 cm (104 in.) above the cask bottom are displayed in Figure 5.9. Through the basket and cask body, exceptionally good agreement between predictions and data

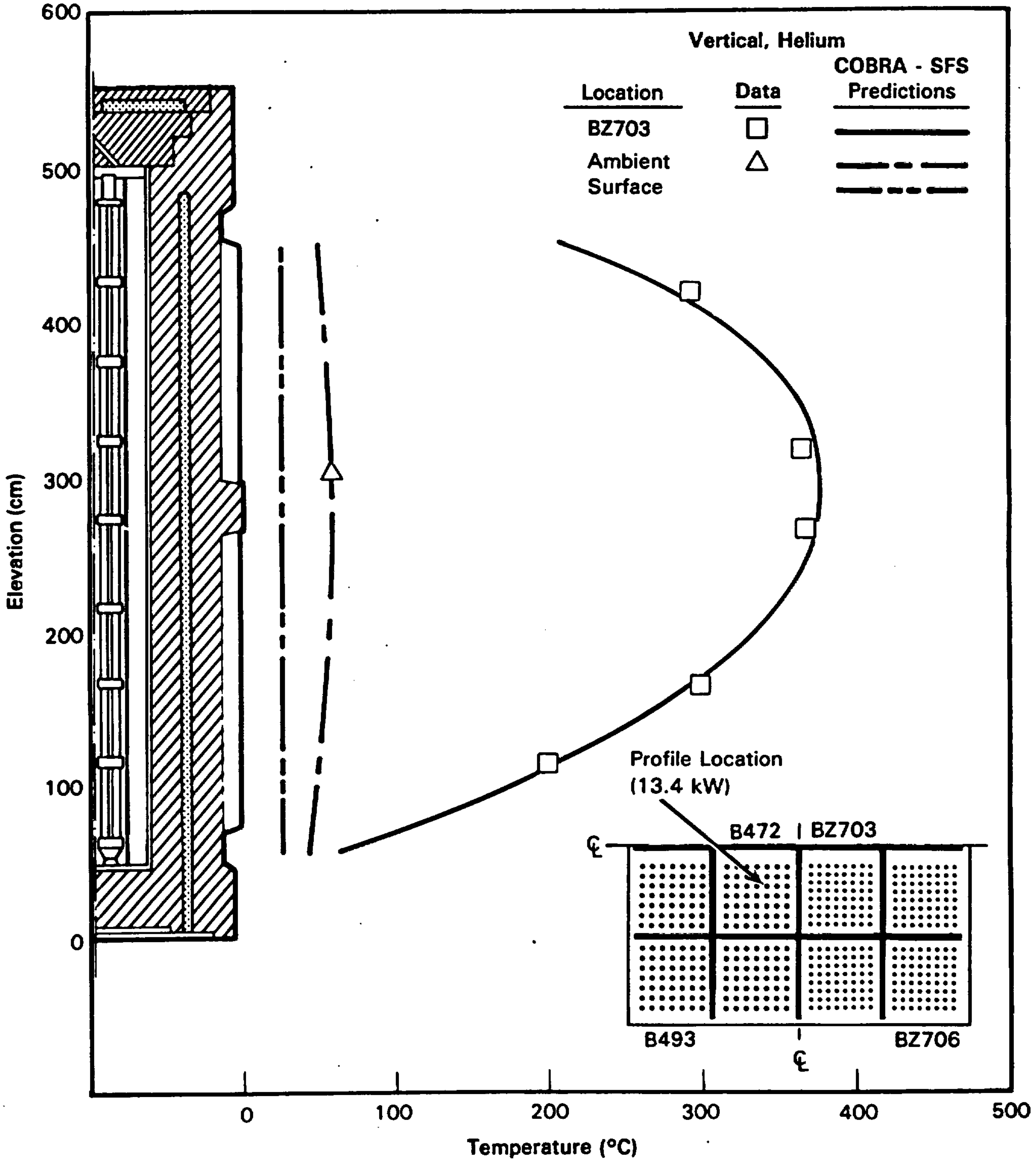


FIGURE 5.8. Comparisons of COBRA-SFS Axial Temperature Profile Predictions with Vertical, Helium CASTOR-1C Test Data

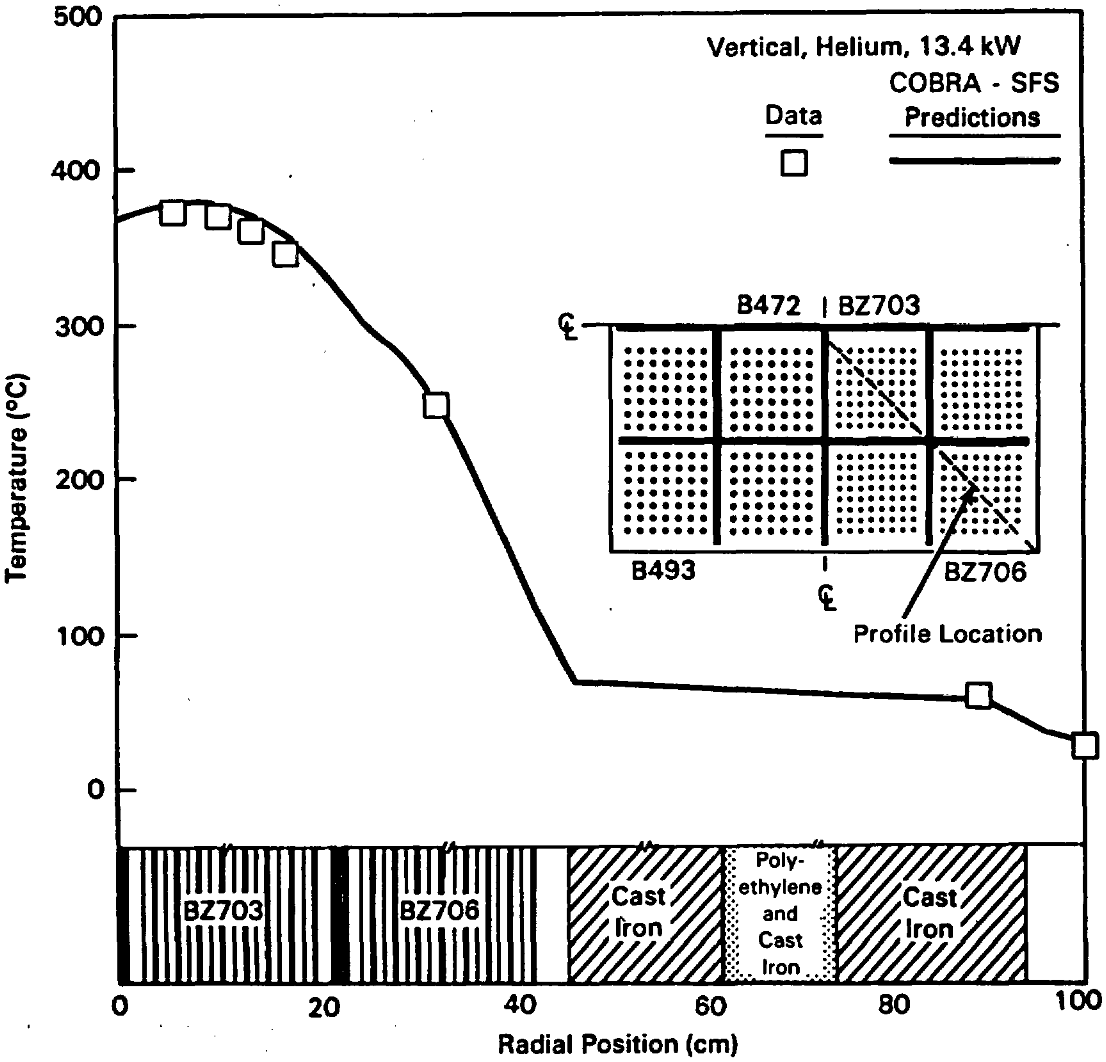


FIGURE 5.9. Comparisons of COBRA-SFS Radial Temperature Profile Predictions with Vertical, Helium CASTOR-1C Test Data (266-cm Elevation)

is shown. The ability to correctly predict the peak temperature and axial and radial profiles confirms that the important physical phenomena occurring within the cask are properly modeled with COBRA-SFS and that the code is capable of analyzing the added complexities of multiassembly storage systems.

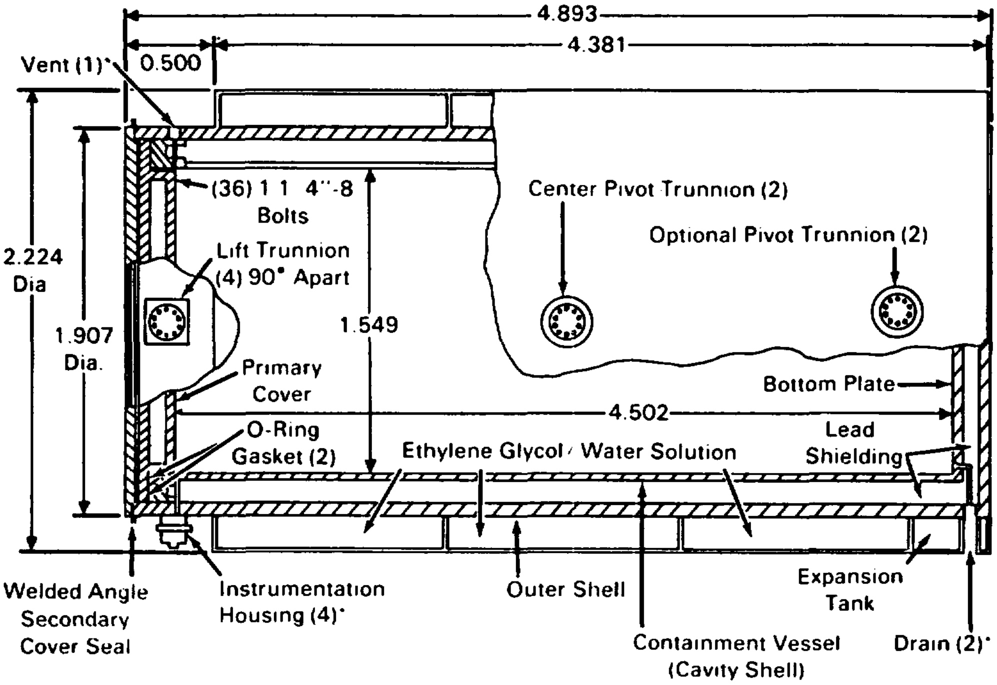
5.2 REA-2023 BWR SPENT FUEL STORAGE CASK PERFORMANCE TEST

In this test series the thermal performance of the REA-2023 BWR Spent Fuel Storage Cask was examined for two loadings (part and full load), two orientations (vertical and horizontal), and three backfill environments (nitrogen, helium, and vacuum). Experimental temperature data were recorded at several axial and radial positions within the cask for the 14-run test matrix. COBRA-SFS prelook and post-test predictions and comparisons with data for the entire 14-run matrix have been performed and documented in an earlier applications report (Wiles et al. 1986) and will not be repeated here. To demonstrate the ability of COBRA-SFS to predict the temperature distributions of a multiassembly cask, three runs of the 14-run test matrix are presented below. The runs selected examine the predicted and measured performance of a fully-loaded cask with all three fill media in a vertical orientation.

In the following sections, a description of the REA 2023 BWR cask and performance test is presented, along with details of the COBRA-SFS computational model, assumptions, and correlations employed. Comparisons of code predictions with test data for the three test cases are then presented and the results discussed. Listings of the input, representative output, and convergence lists for the cases simulated and reported here are presented in Appendix E. Additional details of the REA cask performance test and analyses can be found in detailed reports by McKinnon et al. (1986b) and Wiles et al. (1986).

5.2.1 REA 2023 Cask and Test Description

The REA 2023 BWR spent fuel storage cask is shown in Figure 5.10 and is discussed in detail in REA's topical report submittal to the U.S. Nuclear Regulatory Commission (REA 1983). The cask is of the double containment design with silicone elastomer O-rings to seal the inner cavity and a seal-welded final closure as a secondary cover. The cask has a smooth, painted, outer shell, an ethylene glycol/water neutron shield, and a lead gamma shield. The spent fuel basket is constructed of stainless steel clad Boral for criticality control, copper plates to conduct heat to the cask inner wall, and stainless steel for structural strength. The cask is approximately 2.25 m (8 ft) in



Dimensions are in Meters

*Rotated From True Position

FIGURE 5.10. REA 2023 BWR Spent Fuel Storage Cask

diameter, and 5 m (16 ft) long, and can accommodate 52 unconsolidated BWR spent fuel assemblies.

The inner cask containment shell is 1.91-cm (0.75-in.) thick stainless steel. The cask inner bottom plate, outer bottom plate, and outer shell are 5-cm (2-in.) thick stainless steel. Lead gamma shielding, 10.8 cm (4.25 in.) thick in the sidewall, 8.26 cm (3.25 in.) thick in the bottom, and 7.62 cm (3.0 in.) thick in the primary lid, is provided.

The neutron shield outer shell is a 0.64-cm (0.25-in.) thick stainless steel plate approximately 399 cm (157 in.) long. The shield itself is a 15.24 cm (6 in.) annulus containing a 50/50 ethylene glycol/water solution. Within the neutron shield are trunnion supports, to which the trunnions may be externally bolted. Connected to the lower end of the neutron shield is the expansion tank, which communicates with the neutron shield by a siphon pipe.

The inner or primary lid, which is recessed into the cask cavity, has a bottom plate 2.54 cm (1.0 in.) thick, a top plate 5.08 cm (2.0 in.) thick, and a 7.62 cm (3.0 in.) layer of lead between the plates. The lid is bolted to the cask body with high-strength bolts; sealing is accomplished by two silicone elastomer O-rings. An outer or secondary lid made of 5.08-cm (2.0-in.) thick stainless steel was clamped to the cask body for these tests.

The basket is fabricated in four sections that are located in the cask inner cavity as shown in Figures 5.11 and 5.12. Contact is made with the inner wall of the cask, thus minimizing thermal resistance. Each basket section has thirteen 15.2-cm (6-in.) square Brooks and Perkins fuel tubes, each of which contains one BWR spent fuel assembly. Each tube consists of concentric inner and outer square "shrouds", which integrally encapsulate Boral neutron absorber plates. The Boral neutron absorber plates, which extend above and below the active length of the fuel, are 0.185 cm (0.073 in.) thick, and contain a ^{10}Bo content of 0.02 g/cm^2 to provide adequate neutron attenuation.

The outer shell of each basket section and two internal ribs are constructed of 0.64-cm (0.25-in.) thick copper plates for conduction of heat out to the inner wall of the cask (Figure 5.12). Other structural members of the basket are fabricated from stainless steel. The basket rests on the bottom of the cask, and has cutouts to permit drainage of water and circulation of gas.

All 52 BWR spent fuel assemblies used in the cask performance test were from Nebraska Public Power District's Cooper Nuclear Station. The fuel assemblies were of the General Electric 7x7 design as shown in Figure 5.13, with design characteristics given in Table 5.6. Besides standard fuel rods, each assembly has eight fuel rods that are used as tie rods that thread into the lower tie plate casting. The upper ends of the fuel/tie rods extend through and are fastened to the upper tie plate with stainless steel nuts and locking

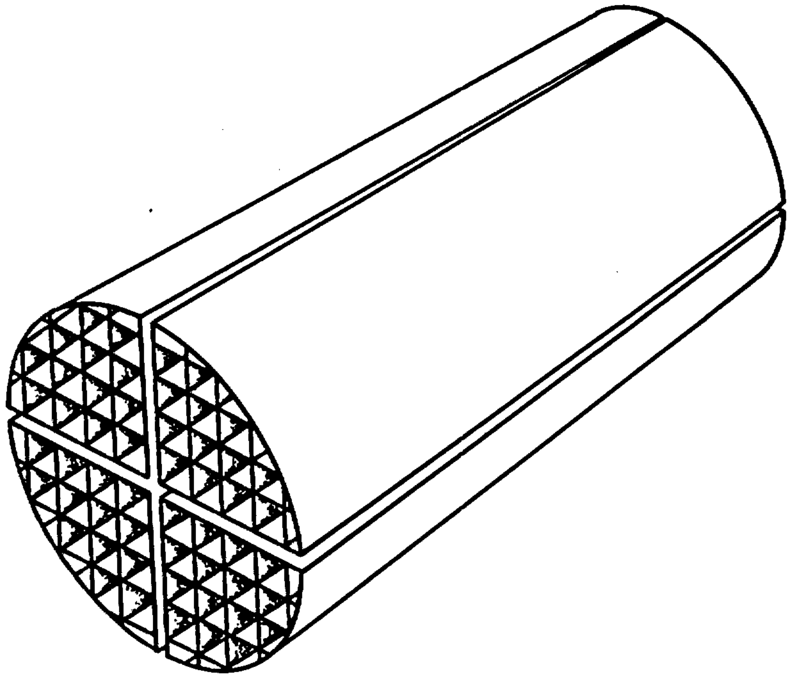


FIGURE 5.11. REA 2023 Cask Basket for 52 BWR Fuel Assemblies

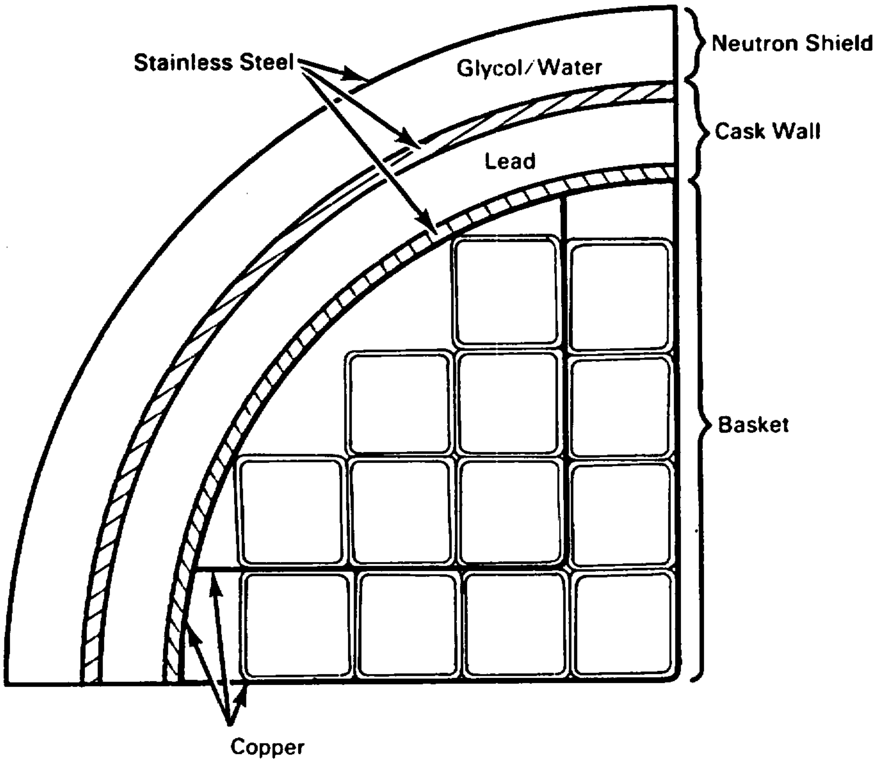


FIGURE 5.12. Quarter Section Plan View of REA 2023 BWR Cask

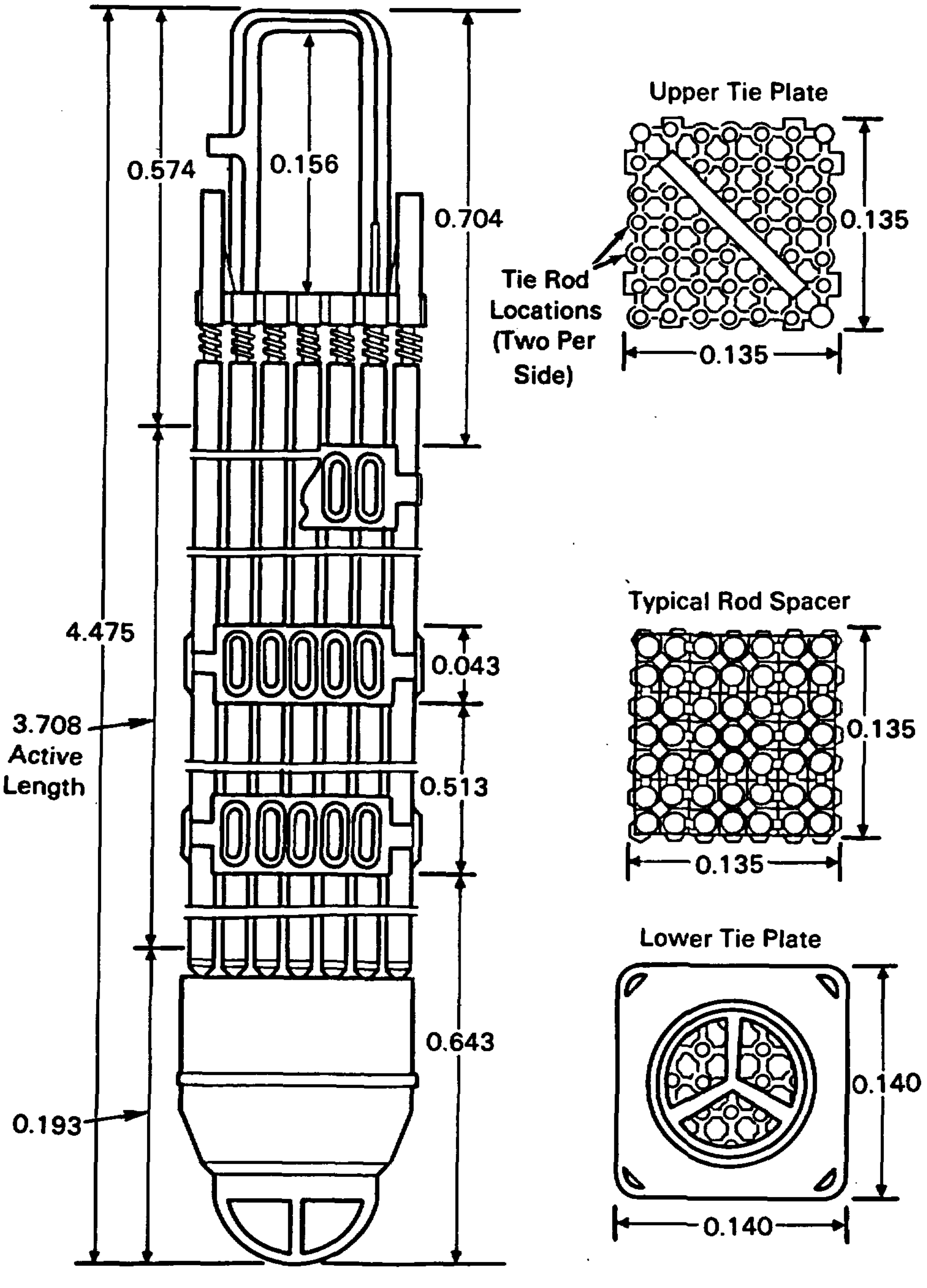


FIGURE 5.13 Cooper BWR Spent Fuel Assembly

TABLE 5.6. Cooper BWR Spent Fuel Assembly Design Parameters

Fuel rod array	7x7	
Overall length	4.47 m	175.83 in.
Nominal active fuel length	3.66 m	144 in.
Fuel rod pitch	1.87 cm	0.738 in.
Space between fuel rods	0.445 cm	0.175 in
Outside rod diameter	1.43 cm	0.563 in.
Cladding thickness	0.081 cm	0.032 in.
Cladding material	Zircaloy-2	
Pellet outside diameter	1.24 cm	0.487 in.
Fuel pellet material	UO_2	
Pellet immersion density	10.42 g/cc	0.38 $lb/in.^3$
Fission gas plenum length	40.6 cm	16 in.
Helium fill gas pressure	1.0 atm.	14.7 psia
Zircaloy-2 weight/assembly	48 kg	106 lb
304 stainless steel weight/assembly	8.6 kg	19 lb

tabs. These fuel/tie rods support the weight of an assembly only during fuel handling operations when the assembly hangs by the bail.

Spent fuel assembly decay heat characterization consisted of calorimetry and axial radiation scans. Calorimetry was performed on all 52 spent fuel assemblies prior to their use in the cask during the performance test. Gamma/neutron scans at nine preselected axial elevations were performed on each fuel assembly. A plot of the axial decay heat distribution is presented in Figure 5.14. The load patterns for partial and full load testing are shown in Figure 5.15. The load and assembly decay heat generation patterns were selected to maintain quarter symmetry for the convenience of computer code simulations. Cask performance testing consisted of 14 primary test runs conducted in the sequence shown in Table 5.7. Cask temperatures were recorded hourly until steady state was attained during each test run.

5.2.2 COBRA-SFS Computational Model

A three-dimensional, one-eighth section model of the REA cask was developed for the COBRA-SFS analysis. Descriptions of the model, material properties, and correlations are provided, along with a discussion of the modeling uncertainties.

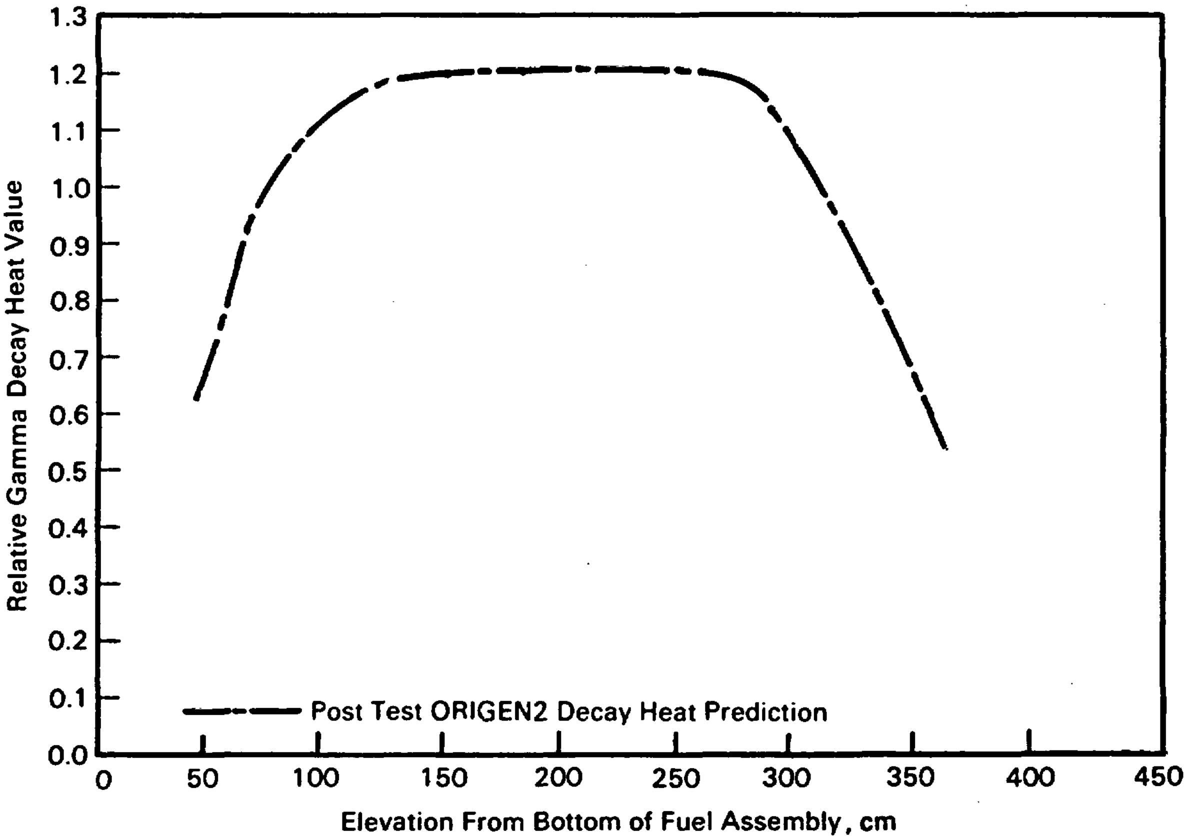


FIGURE 5.14. Axial Decay Heat Profile for Cooper BWR Assemblies

5.2.2.1 Nodal Representation

A three-dimensional model of the REA cask was developed for this analysis. By assuming symmetry of the cask geometry and fuel loading, the cask was simulated with a one-eighth section model; a transverse cross section of the computational cell arrangement is presented in Figure 5.16. The subchannel noding used in modeling the spent fuel assemblies is illustrated in Figure 5.16 along with the wall noding employed for the cask structural members. A total of 24 uniform nodes were used in the axial direction, as shown schematically in Figure 5.17. Approximately 300 fluid subchannels were used to describe the flow paths at each axial level for the fully loaded cask. For the partially loaded cask, flow areas of empty fuel tubes were modeled as single subchannels. Flow areas created by basket spacers were also treated as single subchannels.

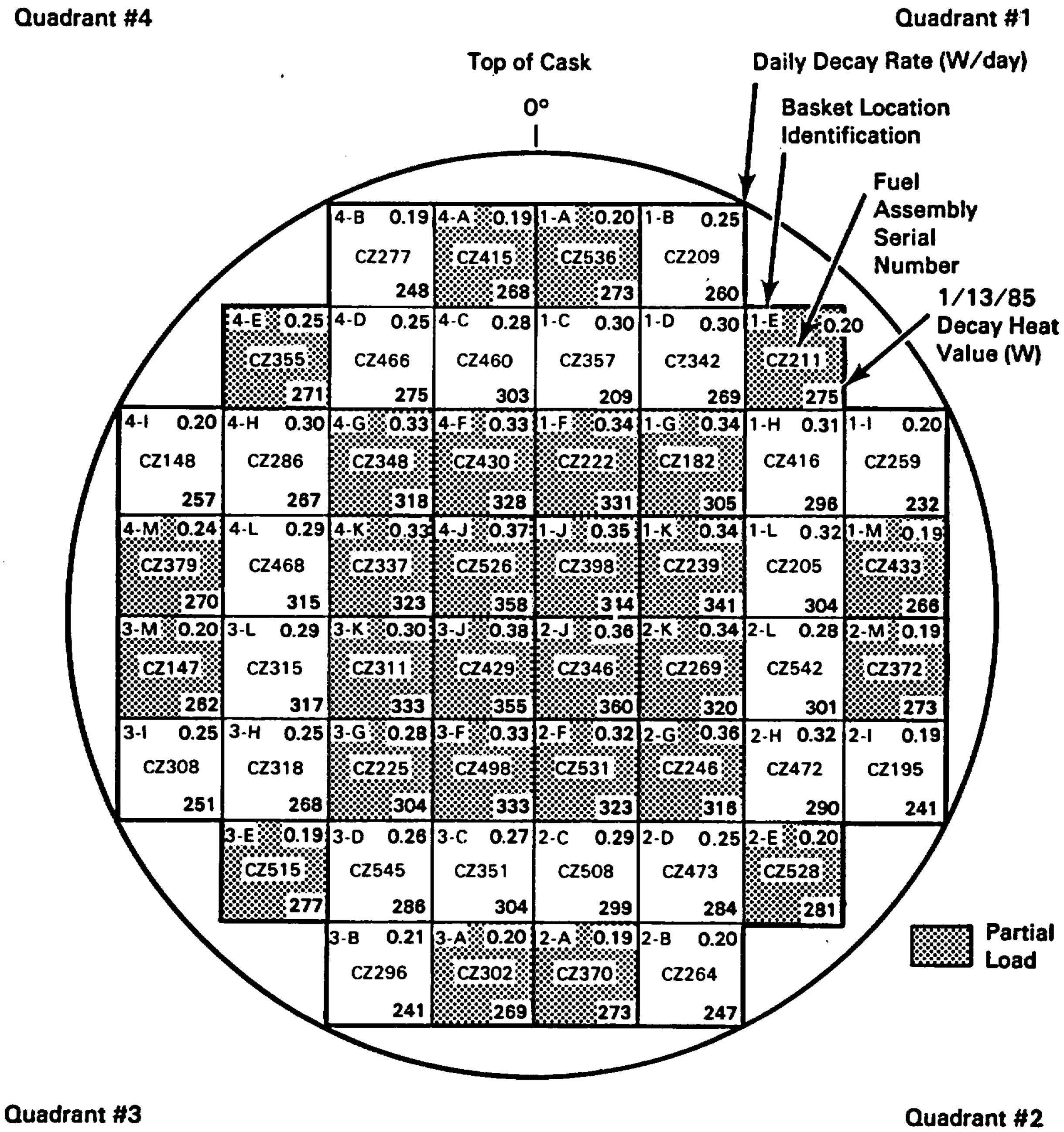


FIGURE 5.15. REA 2023 BWR Cask Partial and Full Load Patterns

To describe the cask and basket structural members at each axial level, 106 slab nodes were used. Radiation and/or conduction heat transfer between wall nodes was included within a plane by specifying the appropriate thermal conductance terms. Wall axial conduction along with fluid-to-fluid conduction

TABLE 5.7. REA 2023 BWR Cask Performance Test Matrix

Run Number	Number of Assemblies	Backfill	Cask Orientation
1	28	Vacuum	Vertical
2	28	Nitrogen	Vertical
3	28	Nitrogen	Horizontal
4[(a)]	28	Helium	Horizontal
5[(a)]	28	Helium	Vertical
6[(a)]	52	Vacuum	Vertical
7[(b)]	52	Nitrogen	Vertical
8[(b)]	52	Nitrogen	Vertical
9	52	Nitrogen	Horizontal
10[(a)]	52	Helium	Horizontal
11[(a)]	52	Helium	Vertical
12	52	Helium	Vertical-Insulated
13	52	Helium	Vertical-Insulated
14	52	Vacuum	Vertical-Insulated

(a) Two runs at different environmental conditions were obtained.
(b) Repeat of Run 7 after cask had been rotated to shift fuel assemblies.

between adjacent fluid subchannels was also accounted for. The fuel tube walls and adjacent heat conduction strips were split into two circumferential nodes. For the complex geometry of the basket-cask interface, finer noding was employed to allow more complete modeling of conduction and radiant heat exchange within this region. Coarser noding was employed within the relatively simple geometry of the cask body.

Each rod in each fuel assembly was individually modeled; a total of 329 rods were used in the fully loaded cask model. Each fuel rod consisted of five radial nodes: four for the fuel and a single node for the cladding. Circumferential noding was not used in the rods. The heat generation rates were based on spent fuel calorimetry data (McKinnon et al. 1986b). The values used reflected the elapsed time from the calorimeter measurements to the steady-state test time (the decay rate of change values was obtained from ORIGEN-2 predictions). The loading patterns, assembly heat rates, and daily decay rates for the partially and fully loaded cask are presented in Figure 5.15. The fuel assembly numbering scheme also is shown in Figure 5.15.

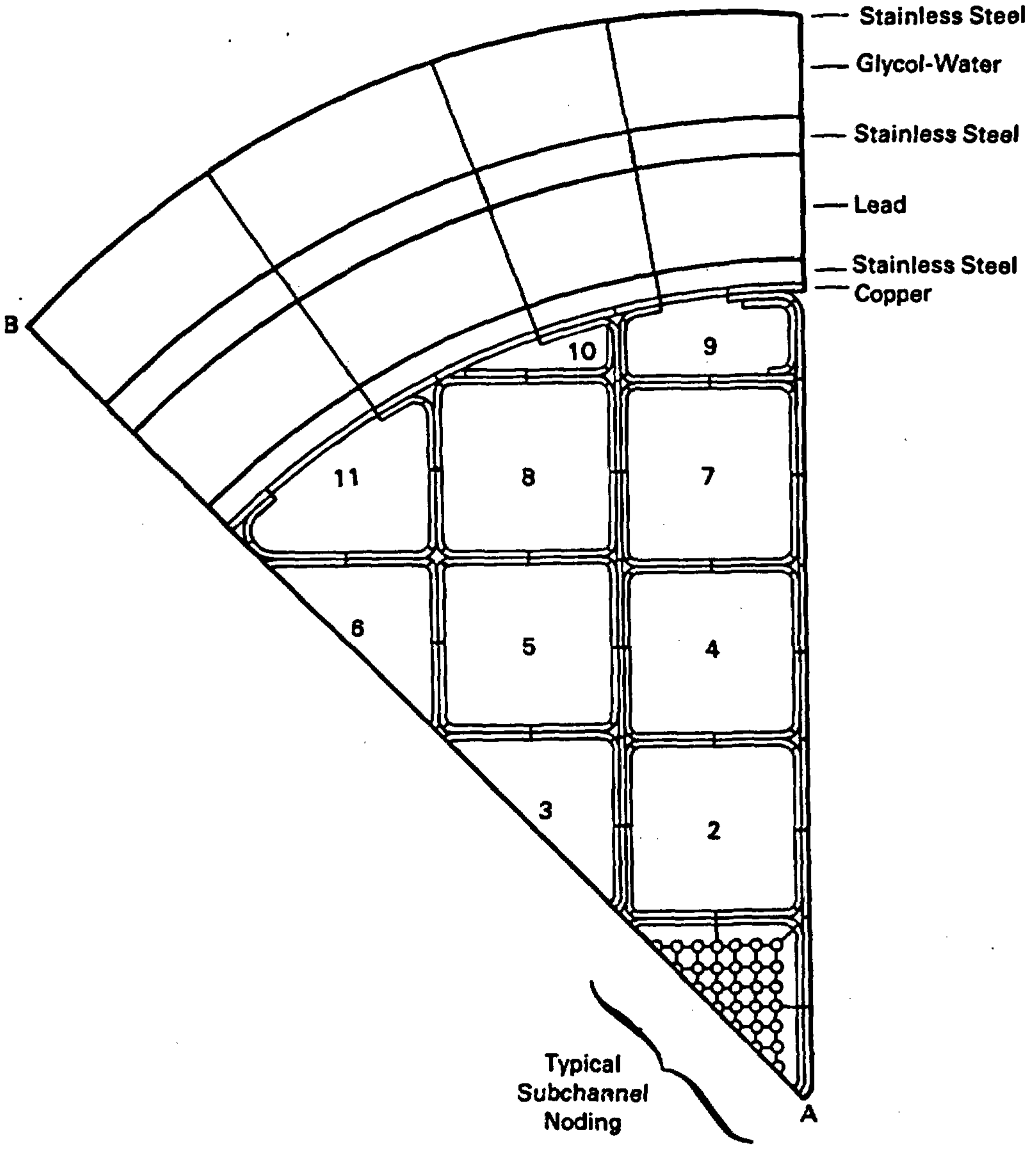


FIGURE 5.16. COBRA-SFS One-Eighth Section Model of the REA 2023 BWR Cask

Decay heat values used in the one-eighth sector model represent the average loading for cask quadrant 2, and ranged from 0.28 kW to 0.38 kW per assembly. The axial decay heat profile displayed in Figure 5.14 was applied to all assemblies. A uniform radial power distribution within a fuel assembly was assumed.

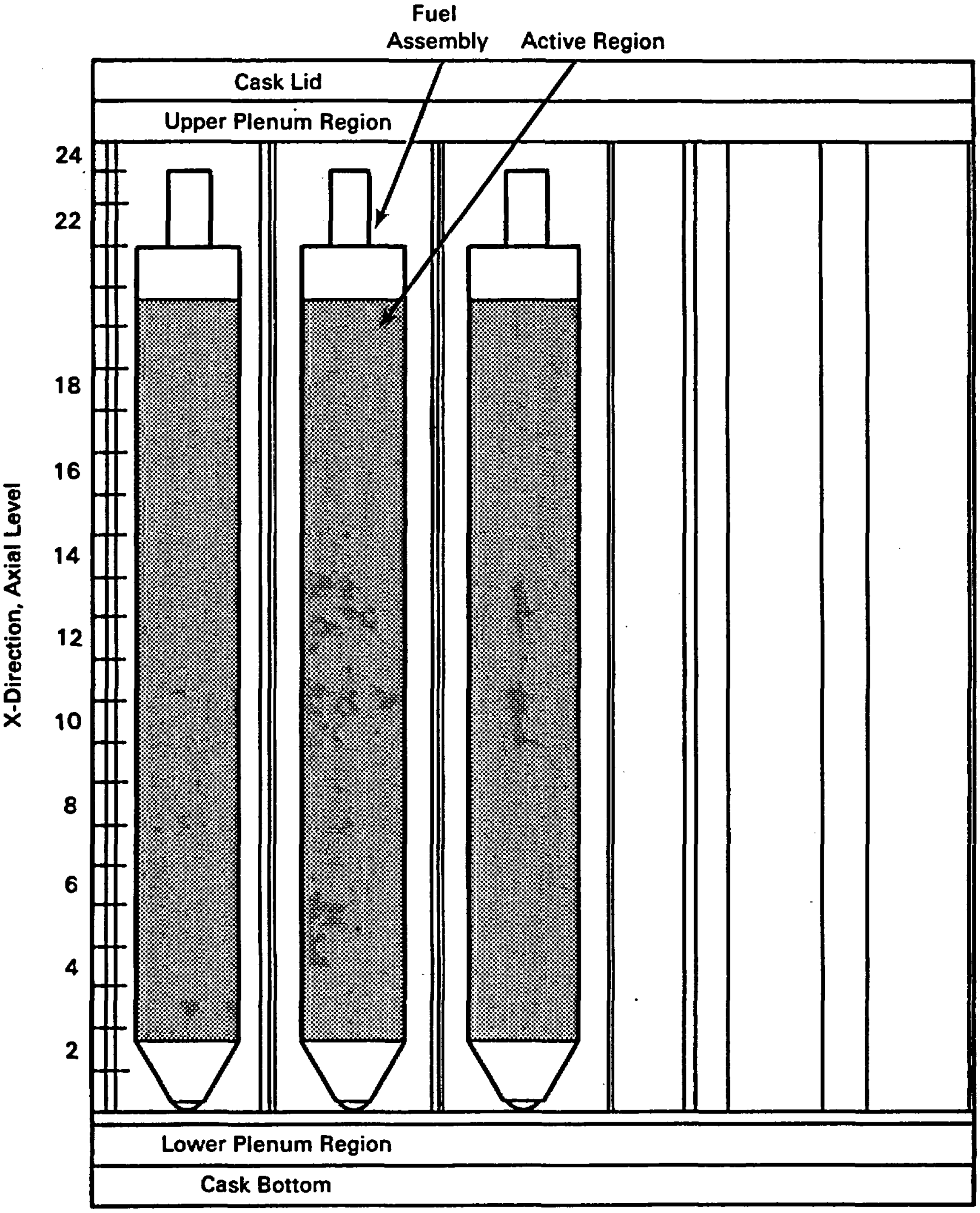


FIGURE 5.17. COBRA-SFS Axial Noding Scheme of the REA 2023 BWR Cask

The radiant heat exchange between rods and fuel tube walls was computed from prescribed, gray body exchange factors based on one-quarter rod surface segments. All gaseous fill media were considered nonparticipating.

The computational model described above extends into the cask body, terminating at the inner boundary of the ethylene glycol/water chamber. Within this region, the mass, momentum, and energy conservation equations are solved to predict velocity and temperature distributions. Heat transfer from the glycol inner boundary to the ambient air is calculated using a boundary heat transfer model that solves a one-dimensional energy equation. Heat transfer within the boundary region includes radiation and natural or forced convection heat transfer. Four radial nodes were employed: a single node each for the inner neutron shield liner, the outer neutron shield liner, the ethylene glycol/mixture, and the ambient air. Solar insolation was neglected in the calculations.

An optional plenum model was used to describe the heat transfer from the recirculating fluid-to-ambient in the regions immediately above and below the fuel tubes and assemblies. As with the boundary region model, only one-dimensional energy equations are solved. The upper lid was modeled with 10 nodes; five nodes apiece for the axial and radial directions. For the bottom of the cask, only five nodes were used, because the bottom surface of the cask was assumed to be adiabatic. The overall heat transfer from the lid and bottom was modeled by specifying the thermal resistance between plenum nodes. Conduction heat transfer from the basket and cask body to the lid and to the cask bottom is also simulated via the plenum model.

5.2.2.2 Material Properties and Correlations

The material properties used in the model, with the exception of emittances, were well defined. Fluid properties were input as functions of temperature and were continuously updated during the simulations; property values for the solids and for the ethylene glycol/water mixture (Curme and Johnston 1952) remained constant and were evaluated using a preliminary predicted cask temperature distribution. Wall heat transfer in the radial and circumferential directions was modeled by specifying appropriate thermal resistances. The input value of resistance for a composite of materials is a combination of parallel and/or series paths. The resistances were obtained as functions of temperature, but remained constant during the simulation. As-measured emissivity values were provided for the fuel tube and the high-emissivity paint used to coat the outer surface of the neutron shield (Taylor 1983, 1984). A wide range of emittances is possible for the other cask components; these emittances are dependent on fabrication technique, temperature, and oxidation buildup. A tabulation of the emittances used in the analysis is presented in Table 5.8; emittances not experimentally determined are assumed values.

As with simulations of other cask performance tests described previously, heat transfer from the rods and walls to the gas coolant was prescribed using a film coefficient of the form Nu = 3.66 (Kays and Crawford 1980). This value is a solution of the energy equation for a constant surface temperature and fully developed velocity and temperature profiles in a circular tube. The film coefficient was evaluated as a function of temperature at each location.

TABLE 5.8. REA 2023 BWR Cask Test Material Emittance Values

Component	Emittance
Fuel rods	0.8
Fuel tubes (stainless steel)	0.2 (measured)
Other stainless steel surfaces	0.2
Copper	0.5
Lead	0.6
High emissivity paint	0.78 (measured)
Cask surface (stainless steel)	0.3

The overall contribution of convective heat transfer is dependent on the flow field established. For these simulations the flow field is obtained by adjusting the total pressure drop until 1) the pressure drop across all subchannels is equal and 2) the total net flow rate is approximately zero. Thus, the flow resistance of the cask becomes an important convection parameter. The overall cask flow resistance is assumed to be a combination of:

- rod and wall surface drag
- spacer losses
- fuel tube inlet and exit losses
- fuel assembly inlet and outlet losses.

Rod and wall friction were modeled using an analytical solution for fully developed laminar flow along cylinders arranged in a square array, $f = 100/Re$ (Sparrow and Loeffler 1959). Spacer and fuel assembly inlet and outlet losses were included by specification of a pressure loss coefficient of 1.0. The major source of uncertainty, however, was the fuel tube inlet and outlet flow resistances. Loss coefficients for the fuel tube inlet and outlet were obtained from a handbook of hydraulic resistance (Idel'Chik 1966); uniform values of $K = 9$ and $K = 3$ were assigned for the fuel tube inlets and outlets, respectively.

Heat transfer from the subchannel model to the boundary requires specification of the heat transfer across the glycol/water annulus, and from the cask surface to the ambient. Heat transfer from natural convection in the partitioned glycol/water annulus was modeled as a function of the temperature difference across the annulus using

$$Nu = 0.22A^{-1/4} \frac{Pr}{0.2 + Pr} Pr\ Gr^{\ 0.28} \tag{5.4}$$

where Pr is the Prandtl number, Gr the Grashof number, and A the annulus aspect ratio, defined as the ratio of the annulur height to width (Catton 1978). Because of uncertainties associated with application of this correlation to the neutron shield, Equation 5.4 was assumed to apply with the cask oriented either horizontally or vertically.

Heat transfer from the cask surface to the ambient included both radiation and convection components. Forced convection heat transfer from the vertical cask surface to the ambient was likened to a cylinder in crossflow; because the direction of crossflow was not constant throughout the test, an average film coefficient was required. An empirical relationship developed by McAdams (1954) of the form

$$Nu = B\ (Re)^N \tag{5.5}$$

where B = 0.0239 and N = 0.805 was chosen for the REA cask, since it provides an estimate of the average convection heat transfer coefficient around a cylindrical cask body (Welty, Wicks, and Wilson 1969). For horizontal surfaces exposed to crossflow, specifically the cask lid, Reynolds' analogy was applied giving a correlation of the form:

$$Nu = 0.036\ PrRe^{0.8} \tag{5.6}$$

The forced convection coefficients listed above were calculated using wind data at the time of steady state for each run. The effects of cask orientation on the outer surface convection were ignored because Equations (5.5) and (5.6) give similar results regardless of orientation. The bottom of the cask was assumed adiabatic because the plywood sheet on which the cask rested resulted in a high thermal resistance.

Again it should be said that these standard correlations for convection heat transfer were inadequate in predicting the actual cask surface heat transfer. Therefore, simulations reported here and in the detailed cask analysis report (Wiles et al. 1986), used detailed cask analyses convection coefficients that were appropriately increased ~40% to provide close agreement in the predicted and measured cask surface temperatures. The correlations presented above were shown to provide insight into the uncertainties of modeling cask surface convective heat transfer with available standard correlations.

Radiation heat transfer to the ambient was included in addition to the natural/forced convection component described above. The radiation component was based on radiative heat exchange between gray bodies and was determined as a function of heat transfer area and cask emissivity. Two cask surface emissivities were used: 0.78, an as-measured value of the high-emissivity paint used to cover the surface of the neutron shield (Taylor 1984), and 0.3, the assumed emissivity for the unpainted stainless steel cask surfaces (Taylor 1983). The ambient was assumed to be a black body ($\epsilon = 1.0$).

5.2.2.3 Modeling Uncertainties

The computational model for this analysis was developed from design drawings supplied by REA, predicted and measured assembly heat generation rates, and predicted and measured axial heat generation profiles. In developing the model, uncertainties associated with five important heat transfer and fluid flow parameters were encountered:

- contact resistances
- material emissivities
- surface-to-ambient thermal resistance
- ambient conditions
- flow resistances.

Contact heat transfer was assumed to be a function of material type, gap size, surface finish, contact pressure, and the effective contact area. Areas not in contact transferred heat through a gap via radiation and conduction through the fluid. In cases where partial contact is assumed, the relatively low thermal resistance of the contact path dominates the parallel thermal resistance term, making the uncertainty in gap size relatively insignificant. Thus, uncertainties in the contact heat transfer are primarily a function of the materials in contact and the effective contact area.

The cask basket components subject to large uncertainties in contact heat transfer are 1) fuel tubes, 2) basket spacers, 3) conduction strips, and 4) fuel assemblies. Fuel tube contact heat transfer (fuel tube-to-fuel tube, fuel tube-to-basket spacer, and fuel tube-to-conduction strip) is possible only from the fuel tube bead surface area. Because the bead surface is a small fraction of the total fuel tube surface area, no contact between the fuel tubes was assumed.

Contact heat transfer for the basket spacers (spacer-to-spacer and spacer-to-basket) is ensured by use of special proprietary fasteners. Measurement of the contact conductance for a similar fastened joint was experimentally determined and reported in an REA proprietary document. Because it is unlikely that the conductances in the cask will be as high as those measured on a benchtop model, the conductance used in this analysis was arbitrarily taken to be 80% of the as-measured value. Contact heat transfer for the conduction strips (strip-to-basket and strip-to-basket spacer) also is ensured with fasteners. Again, the conductance used was assumed to be 80% of the as-measured value.

For this analysis, it was assumed that fuel assemblies are centered within the fuel tubes so that no contact exists between fuel rods and fuel tubes. This assumption will result in conservatively high cladding temperatures, especially when the cask is horizontally oriented.

Other regions where contact heat transfer is subject to large uncertainties are 1) basket-cask interface and 2) lead-stainless steel interface. Basket-cask contact heat transfer uncertainty is due to the fabrication techniques employed; contact is not ensured because of the differing basket and cask radii of curvature. In determining the contact conductance, an average of the measurements of the as-built gaps was used. No contact was assumed along the basket-cask interface.

The uncertainty in the geometry of the lead within the stainless steel annulus of the cask body again results from the fabrication technique. Molten lead is poured and allowed to solidify in place; during cooling, contraction of the lead from the outer stainless steel shell is expected. Thus, no contact was assumed; an estimated value of the lead-stainless steel gap was provided by the lead pourer, E. L. Manufacturing, Peebles, Ohio.

As-measured emissivity values were provided for the fuel tubes and for the high emissivity paint used to coat the outer surface of the neutron shield (Taylor 1983 and 1984). A wide range of emissivity values was found in the literature for other cask structures (e.g., strips, spacers, fuel). The values were found to be dependent upon fabrication technique, oxidation buildup, and temperature. Thus, a large degree of uncertainty exists in the emissivity values. However, the uncertainty in the fuel rod emissivity has been shown to have little effect on the radial temperature distribution in an enclosed assembly (Wiles et al. 1986).

Heat transfer from the outer cask surface includes radiation and forced convection components. The cask geometry, however, suggests that large Grashof numbers will result from the large vertical height of the cylinder, and that free convection will continue to play an important role in the overall heat transfer; i.e., both free and forced convection should be considered simultaneously. Additionally, studies have shown significant increases in surface heat transfer with increased turbulence intensities. Thus, the lack of turbulence data and a means to correlate the data, plus the difficulty in defining a method for correlating the combined convection effects, results in a large uncertainty in the cask surface heat transfer coefficient. Definition of the cask surface heat transfer is complicated also by the ambient weather conditions, i.e., insolation, rain, and snow. No attempts were made to model the effect of these natural phenomena on the cask thermal response.

The major uncertainty in flow resistance comes from the contribution of the fuel tube inlet and outlet flow losses. This uncertainty is due in part to the slight bowing of the as-built cask bottom, which results in inlet flow area variations from fuel tube to fuel tube.

5.2.3 Comparisons of Predictions to Data

Axial temperature profiles for the three different fill media (vertical orientation) are displayed in Figures 5.18 through 5.20. In each figure, predicted and measured temperature profiles are given as a function of elevation from the cask bottom for the centerline of assemblies 2J and 1A (see Figure 5.14), the cask surface, and the ambient. The figures are presented in order of increasing system temperature, i.e., helium, nitrogen, and a vacuum.

To facilitate data comparisons within the cask body and basket, the predictions again include a modified cask surface convection coefficient that has been increased to provide relatively close agreement between predicted and measured cask surface temperatures. Note that data points above 4.5 m and below 0.5 m represent gas temperatures, whereas corresponding predictions represent assembly temperatures and, thus, are expected to read higher than data. The results for the helium and nitrogen cases are shown to underpredict the peak cladding temperatures by some 16°C, in part due to the underpredicted

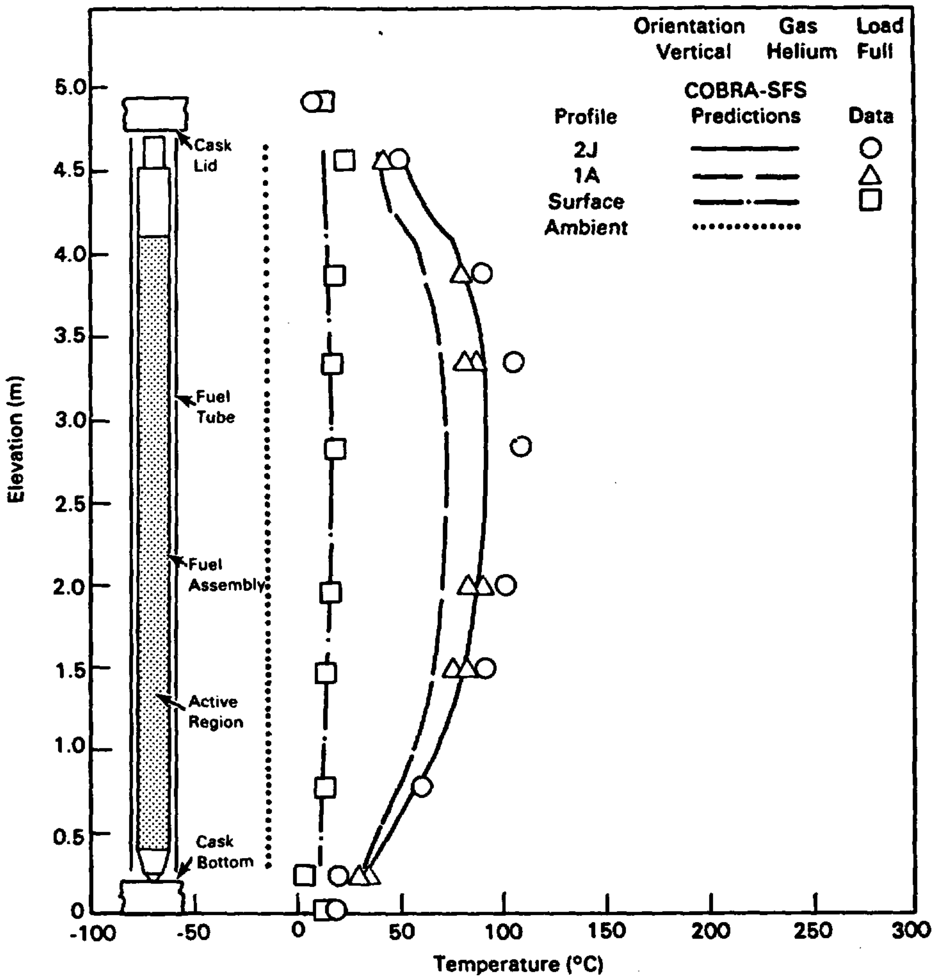


FIGURE 5.18. COBRA-SFS Predictions of Axial Temperature Profiles Compared to Full Load, Vertical, Helium, REA 2023 Test Data

basket temperatures (as indicated by the edge fuel assembly temperature, location 1A). The results for the vacuum case, on the other hand, overpredict the data by 16°C, this time due to overpredicted basket temperatures (fuel assembly location 1A). The disagreement between the predictions and data in these cases is attributed to uncertainties in the cask geometry and contact resistances. A more uniform basket-to-cask thermal resistance value (assumed media dependent) would improve the predictions for all media.

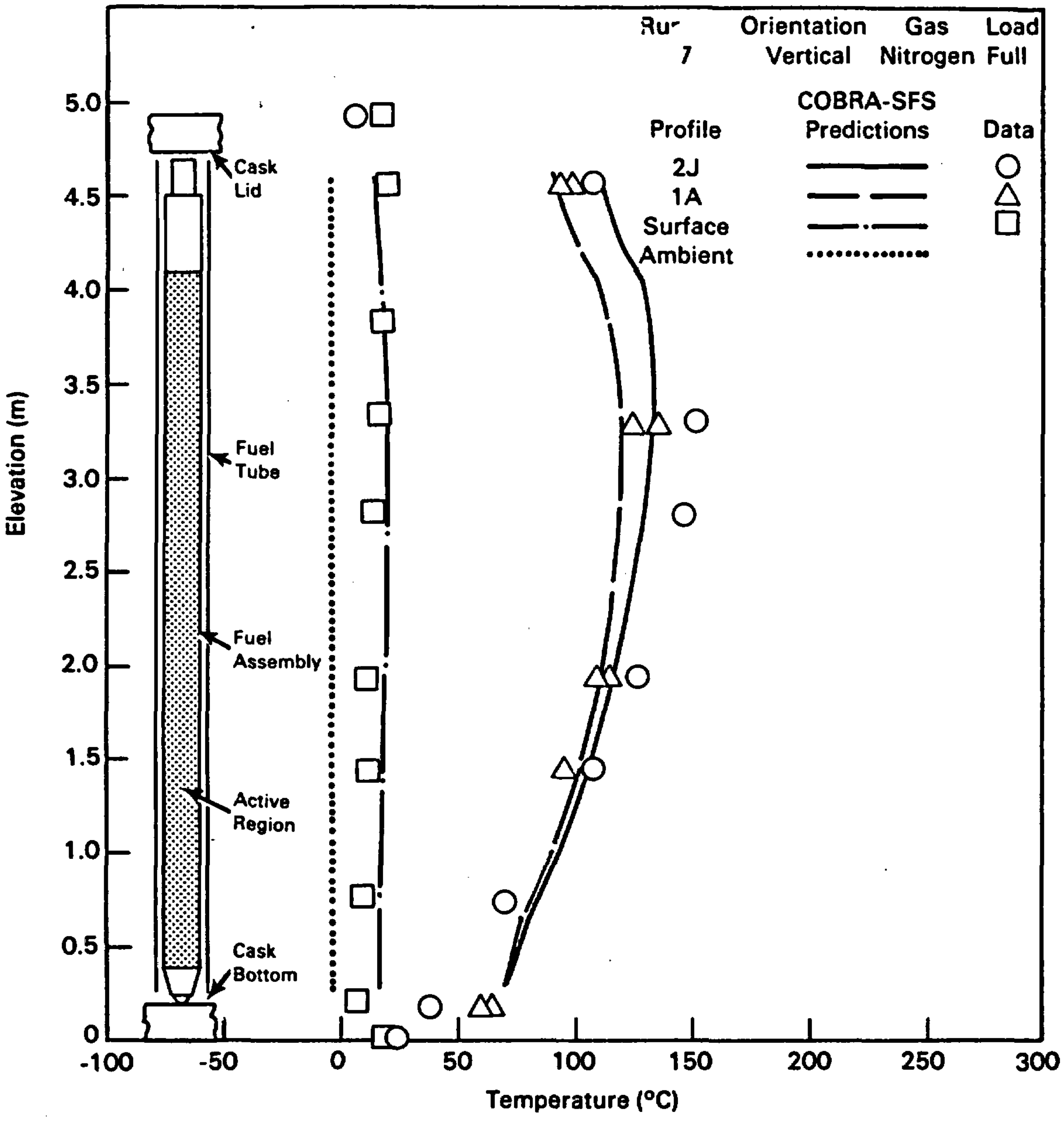


FIGURE 5.19. COBRA-SFS Predictions of Axial Temperature Profiles Compared to Full Load, Vertical, Nitrogen, REA 2023 Test Data

In general, there is good agreement between the predicted and measured axial temperature profiles. Improvement in the axial profiles in the nitrogen case may be obtained with refinements in the cask flow resistances, or the plenum region heat loss models.

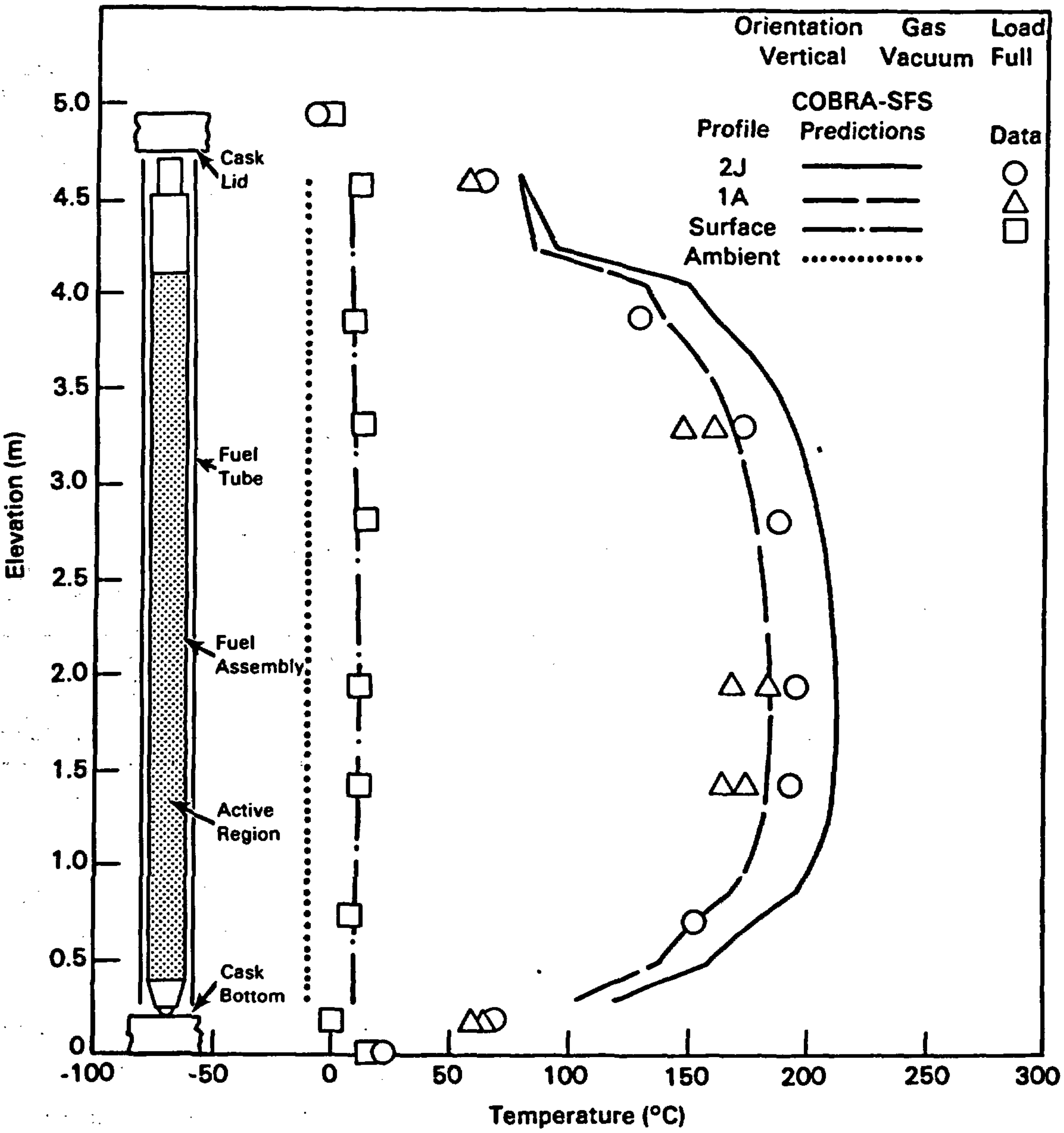


FIGURE 5.20. COBRA-SFS Predictions of Axial Temperature Profiles Compared to Full Load, Vertical, Vacuum, REA 2023 Test Data

Comparisons of the predicted and measured radial temperature profiles along the diagonal of quadrant 2 (Figure 5.14) from the center of the cask to the ambient are presented in Figure 5.21 for all three fill media, at an

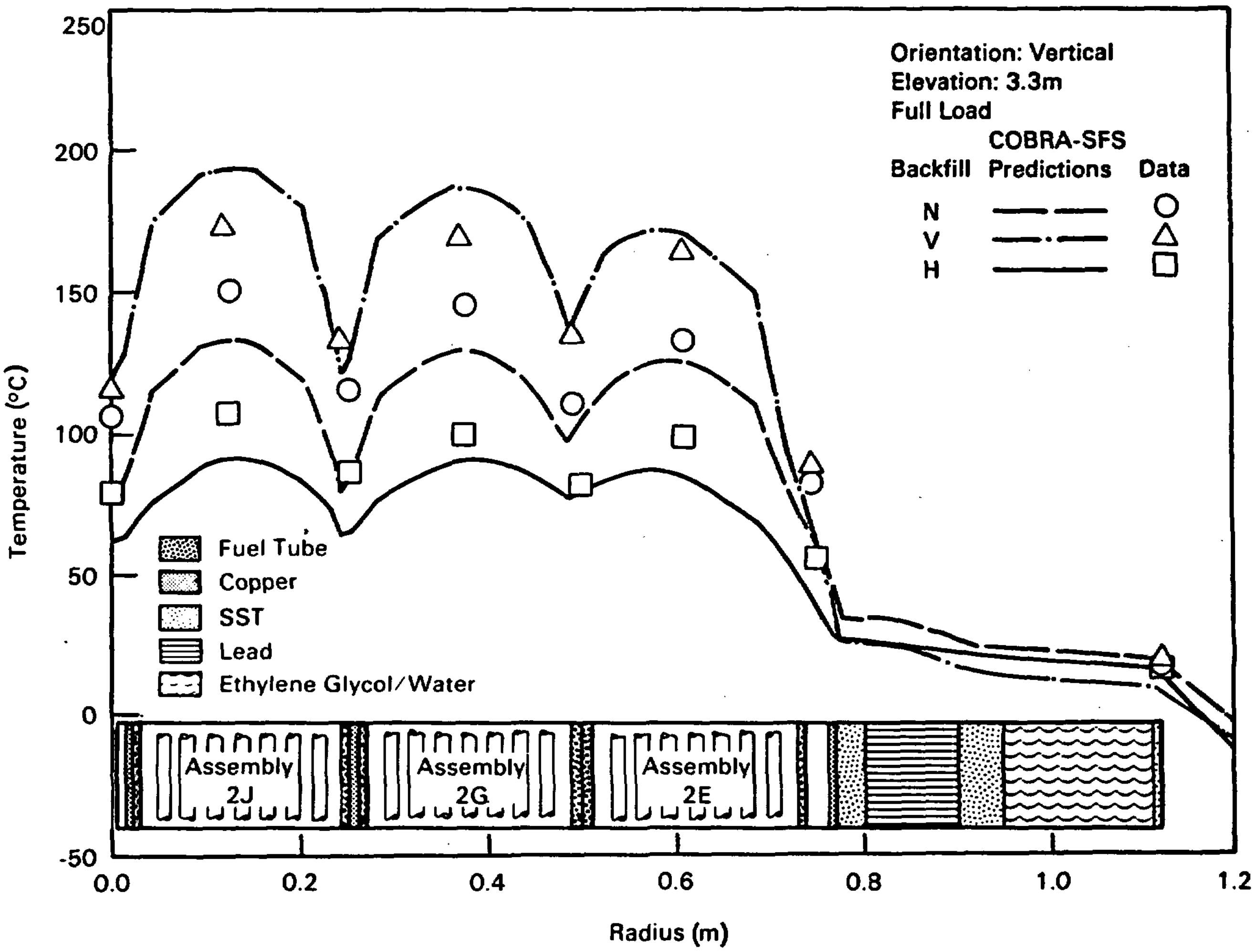


FIGURE 5.21. COBRA-SFS Predictions of Radial Temperature Profiles Compared to Full Load, Vertical, Helium, Nitrogen, and Vacuum, REA 2023 Test Data at 3.33 m Elevation

elevation of 3.33 m above the cask bottom. Data comparisons for the basket are complicated by uncertainties of the locations of the thermocouples within the interstitial regions of the basket junctions. These uncertainties greatly affect data comparisons where radial temperature gradients are severe, i.e., basket node 2E (Figure 5.14). For lack of alternative information, thermocouples were assumed to measure interstitial gas temperatures, thereby representing average temperatures of exposed junction surfaces. The predicted results, on the other hand, are given for the copper strips along the diagonal of the basket junctions, which, because of their high thermal conductivity and connection to the low temperature of the gas exterior, are at substantially lower temperatures than the surrounding junction walls. As a result, code predictions fall consistently below the data at the basket locations, as expected.

The radial profiles shown in Figure 5.21 indicate trends similar to axial profile results--underpredicted helium and nitrogen results, and overpredicted vacuum results. Correcting the agreement between predictions and data at the basket/cask interface (radial location r/R = 0.75) would be expected to improve the predictions for locations within the basket, and more importantly, peak clad temperature. The trend toward increasing assembly temperatures with decreasing radial position in the cask was correctly predicted by COBRA-SFS.

5.3 TN-24P CASK PERFORMANCE TEST

In this test series, the thermal performance of a fully loaded (21 kW total) TN-24P cask was investigated with three backfills (helium, nitrogen, and vacuum) in vertical and horizontal orientations. Experimental temperature data were recorded at several axial and radial positions within the cask for a 6-run test matrix. COBRA-SFS prelook and post-test simulations of the entire test series have been documented previously (McKinnon et al. 1986a) and will not be repeated here. To demonstrate the ability of COBRA-SFS to predict the effect of orientation in a multiassembly cask, results of vertical and horizontal cases with a helium backfill are presented and compared against the test data.

In the following sections, a description of the TN-24P cask and cask performance test is presented, along with a description of the COBRA-SFS computational model, assumptions, and correlations employed. Uncertainties in the model are then discussed, followed by predictions of the two selected cases. Listings of the input, representative output, and convergence lists for the reported cases are presented in Appendix F.

5.3.1 TN-24P Cask and Test Description

The cask body is a one piece cylindrical structure composed of forged steel. The overall external dimensions of the cask body are 5068 mm (16.6 ft) long and 2281 mm (7.5 ft) in diameter as shown in Figure 5.22. All surfaces except sealing surfaces are coated with a deposit of zinc-aluminum alloy. Sealing surfaces are clad with stainless steel. Internal surfaces have an aluminum titanium oxide overcoat; exterior surfaces are covered with white silicone paint.

The cask body consists of a 270-mm-thick (10.6-in.) cylindrical shell welded to a 280-mm (11-in.) bottom plate. A neutron shield containing L-shaped copper plates is welded to the cylindrical shell. The copper plates are welded to the inner surface of the neutron shield and provide enhanced heat conduction through the resin compound of the neutron shield. The cask can accommodate six bolted trunnions for handling and tie-down, four near the top and two near the bottom. Finally, the cask body has an instrumentation orifice sealed by a metallic gasket.

The diameter of the inner cavity is 1455 mm (57.3 in.), and the overall inner cavity length is 4150 mm (163.4 in.). Precision-machined surfaces are provided at the open end of the cask cavity for positive gasket sealing, and bolt holes are included at these locations to secure the cask lid and protective cover.

The basket comprises an array of 24 fuel tubes and channels that provide structural support and positive positioning of the fuel assemblies. The basket, shown in Figure 5.23, is composed of stacked interlocking plates constructed of borated aluminum. The plates are 10 mm (0.4 in.) thick, 160 mm (6.3 in.) wide, and vary in length depending on their position in the basket. Each layer of the basket is bolted to four uprights that are used to support and tie the basket together in the axial direction. The uprights provide a 45-mm (1.8-in.) gap between the bottom of the basket and the bottom of the cask. This gap, plus the 29-mm (1.1-in.) gap between the top of the basket and the cask lid, provides convection paths for the gas in the cask. The basket overall height is 4121 mm (162.2 in.). The position of the basket within the cask is maintained by bars welded to the interior surface of cask. The bars act as guides for the interlocking plates.

Two aluminum tubes are welded to the aluminum basket in two locations that are unoccupied by fuel. The tube locations match penetrations in the

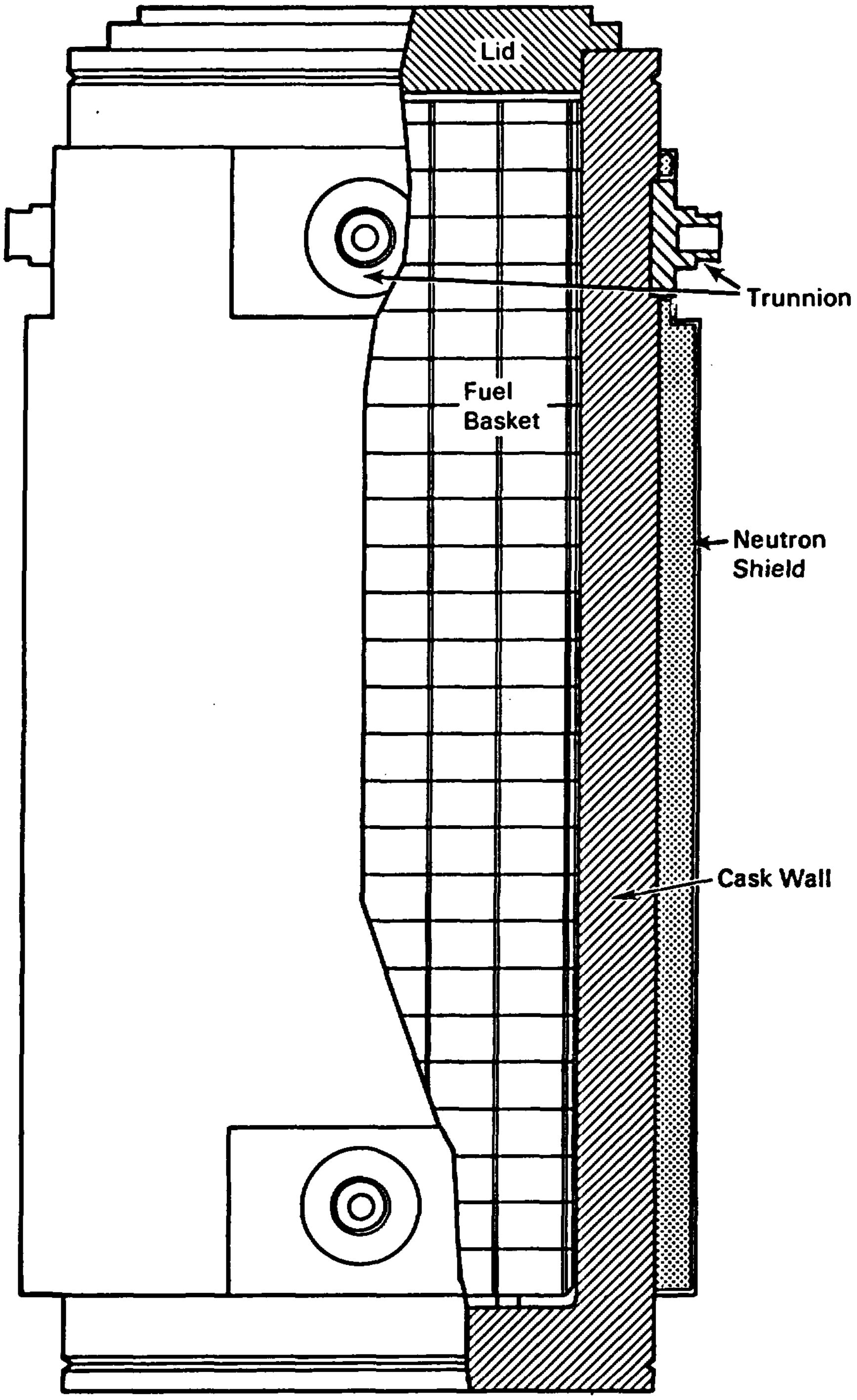


FIGURE 5.22. TN-24P PWR Spent Fuel Storage Cask

lid used to insert thermocouple lances and provide temperature readings representative of the basket. A carbon steel lid, 1720 mm (67.7 in.) in

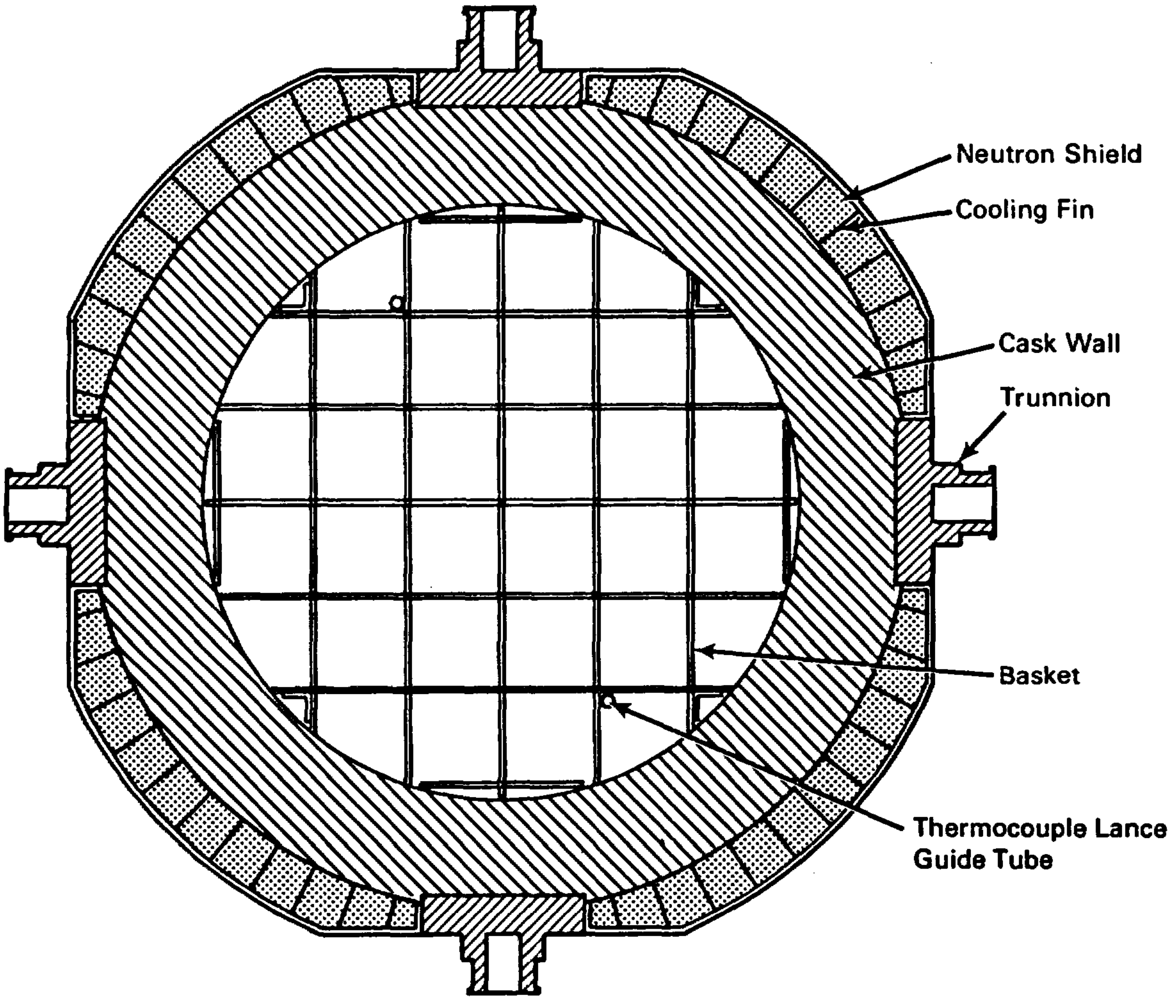


FIGURE 5.23. TN-24P Cask Cross Section

diameter and 285 mm (11.2 in.) thick, is the cask primary seal. Bolted to the top of the primary lid is the neutron shield disc, which contains granular polypropylene enclosed in a carbon-steel jacket. A protective carbon-steel, ellipsoidal-shaped cover fits over the lid and neutron shield disc and acts as a secondary seal.

Fourteen type K thermocouples were permanently attached to the inner wall and basket of the cask, as indicated in Figure 5.24. An additional 54 thermocouples were inserted in the fuel assemblies and basket using thermocouple lances. Each lance had six thermocouples installed at various axial positions

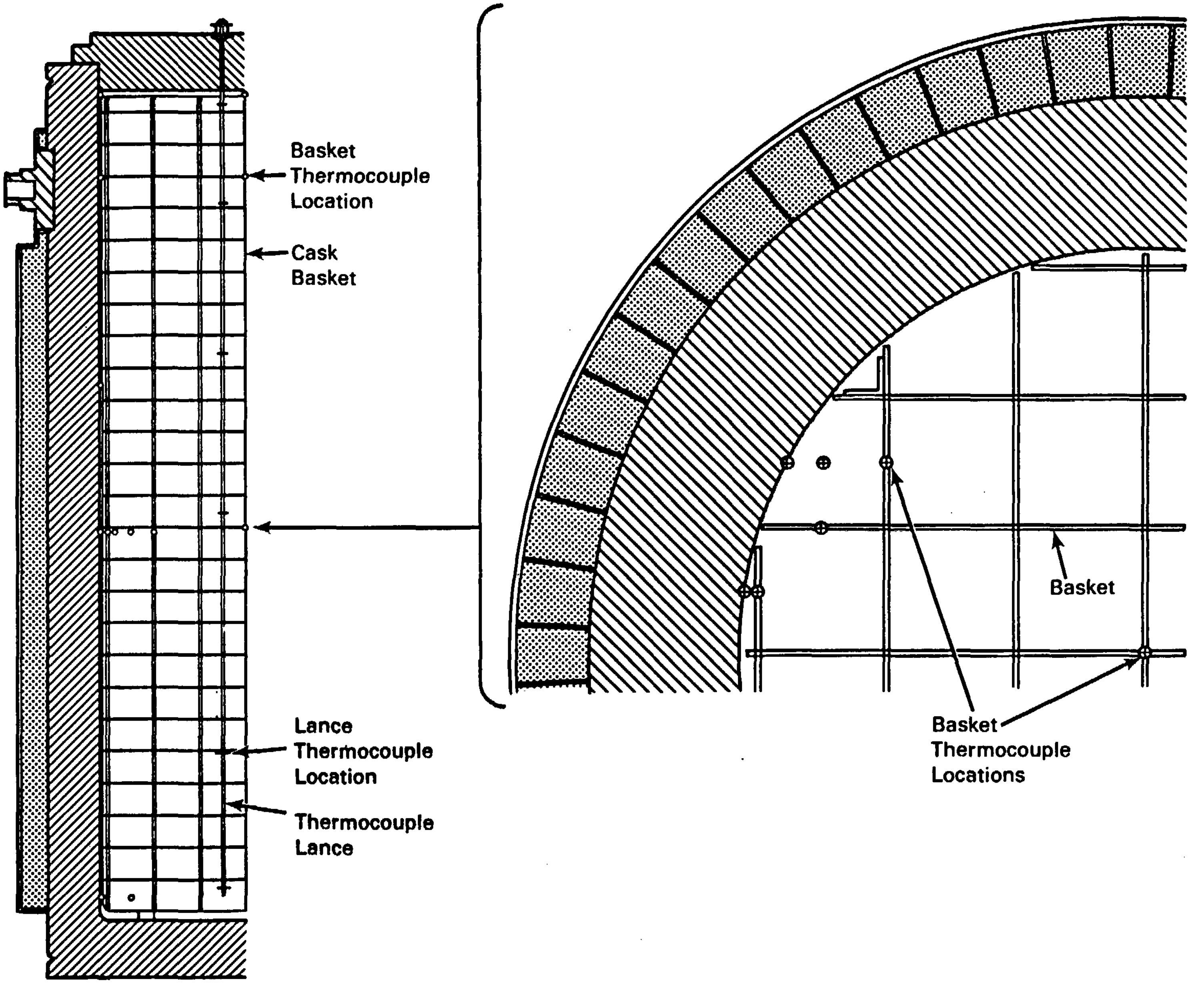


FIGURE 5.24. TN-24P Basket Thermocouple Locations

in a 8-mm-diameter (0.315-in.) tube. Lances were inserted through instrumentation penetrations in the primary test lid and into selected guide tubes of seven fuel assemblies and into two simulated guide tubes attached to the basket. The locations of the lances within the basket and their positions within the fuel assemblies are shown in Figure 5.24.

The selected axial and cross-sectional locations of the lance thermocouples facilitated redundancy, evaluations of temperature symmetry, and determinations of axial and radial temperature profiles in both vertical and horizontal orientations. In addition to these internal temperature measurements, the cask cavity pressure was also recorded.

The exterior surface of the cask was instrumented with 35 iron/constantan Type J thermocouples. Only during horizontal testing were thermocouples placed on the bottom of the cask. The thermocouple patterns on each surface were selected to provide appropriate axial, radial, and circumferential temperature profiles. In addition, a small, self-contained weather station measured the wind speed and direction, atmospheric pressure, air temperature, precipitation, relative humidity, and solar insolation.

Temperature uncertainties for the internal thermocouple lance temperature measurements are ±4°C, and external temperature measurements are ±4.5°C based on the combined uncertainties of the thermocouples, extension wires, and data acquisition system.

The PWR fuel assemblies used in the TN-24P cask performance test were discharged from Virginia Powers Surry Nuclear Power Station. The fuel assemblies were of the Westinghouse 15x15 design and contained 204 fuel rods, 20 control rod guide tubes, and one instrument tube per assembly. Seven grid spacers and upper and lower nozzles maintain the square array of the assembly. The ends of the control rod guide tube are bolted to the upper and lower nozzles to provide structural support. Axial and cross-sectional views of the 15x15 PWR fuel assembly are presented in Figures 5.25 and 5.26, respectively.

The ORIGEN2 computer code was used to predict the decay heat generation rates of the Surry spent fuel assemblies. The results of these calculations for the 24 assemblies used during performance testing are presented in Table 5.9

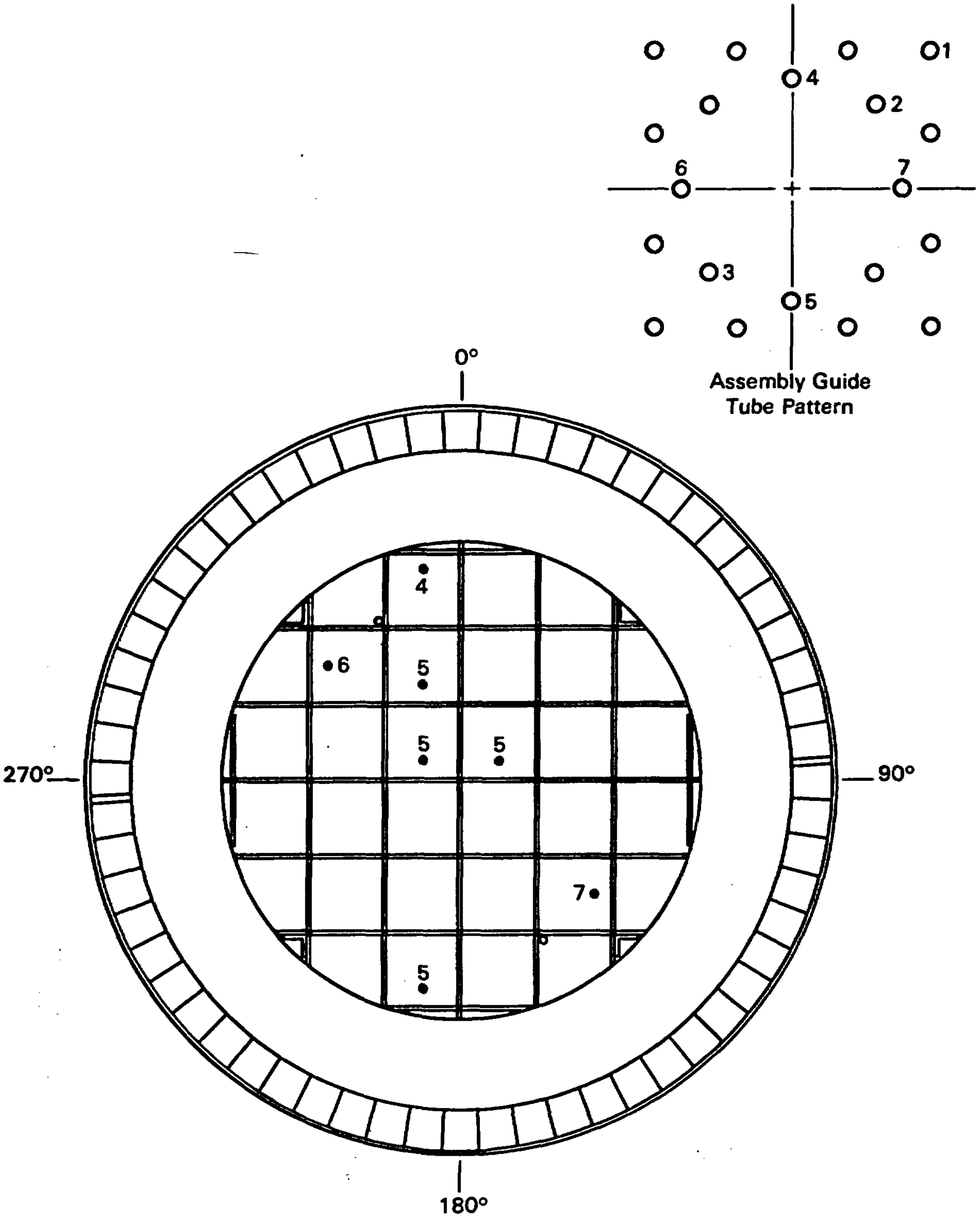


FIGURE 5.25. TN-24P Thermocouple Lance Locations

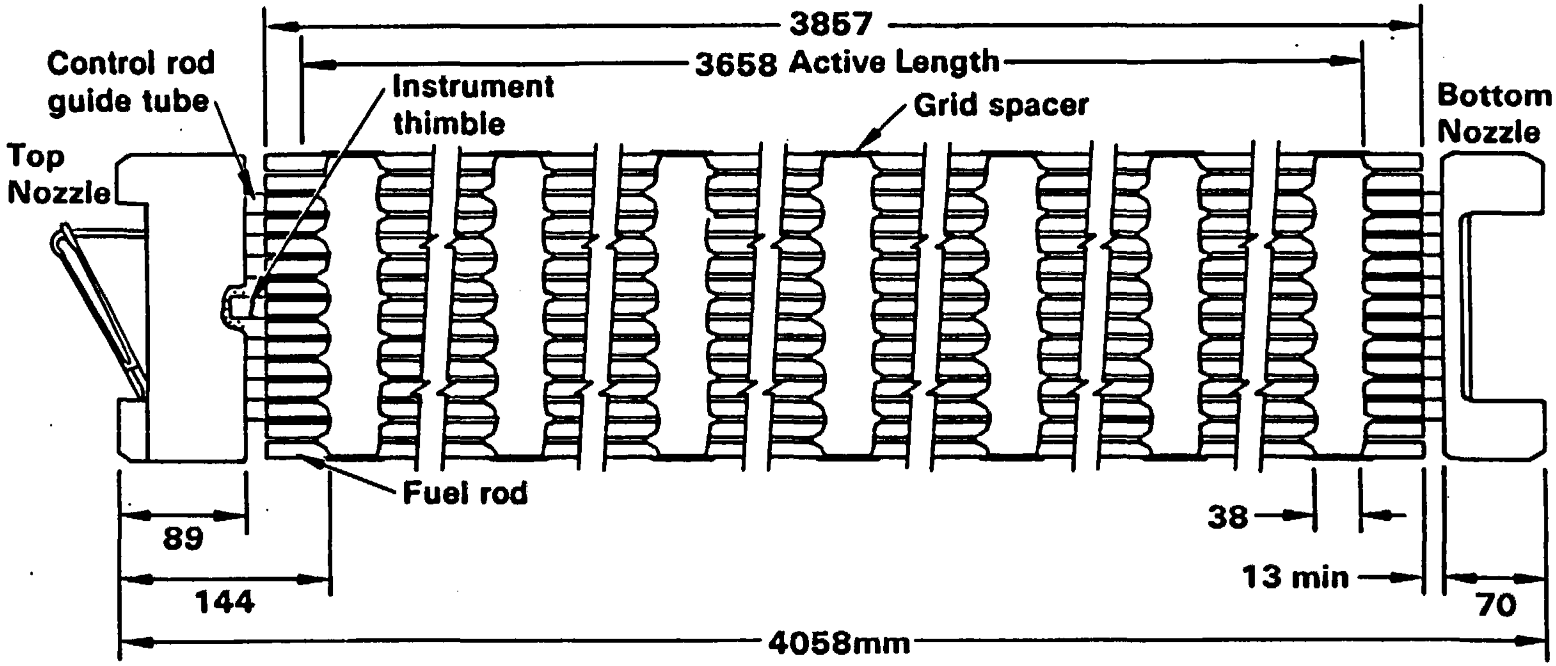


FIGURE 5.26. Surry 15x15 PWR Spent Fuel Assembly

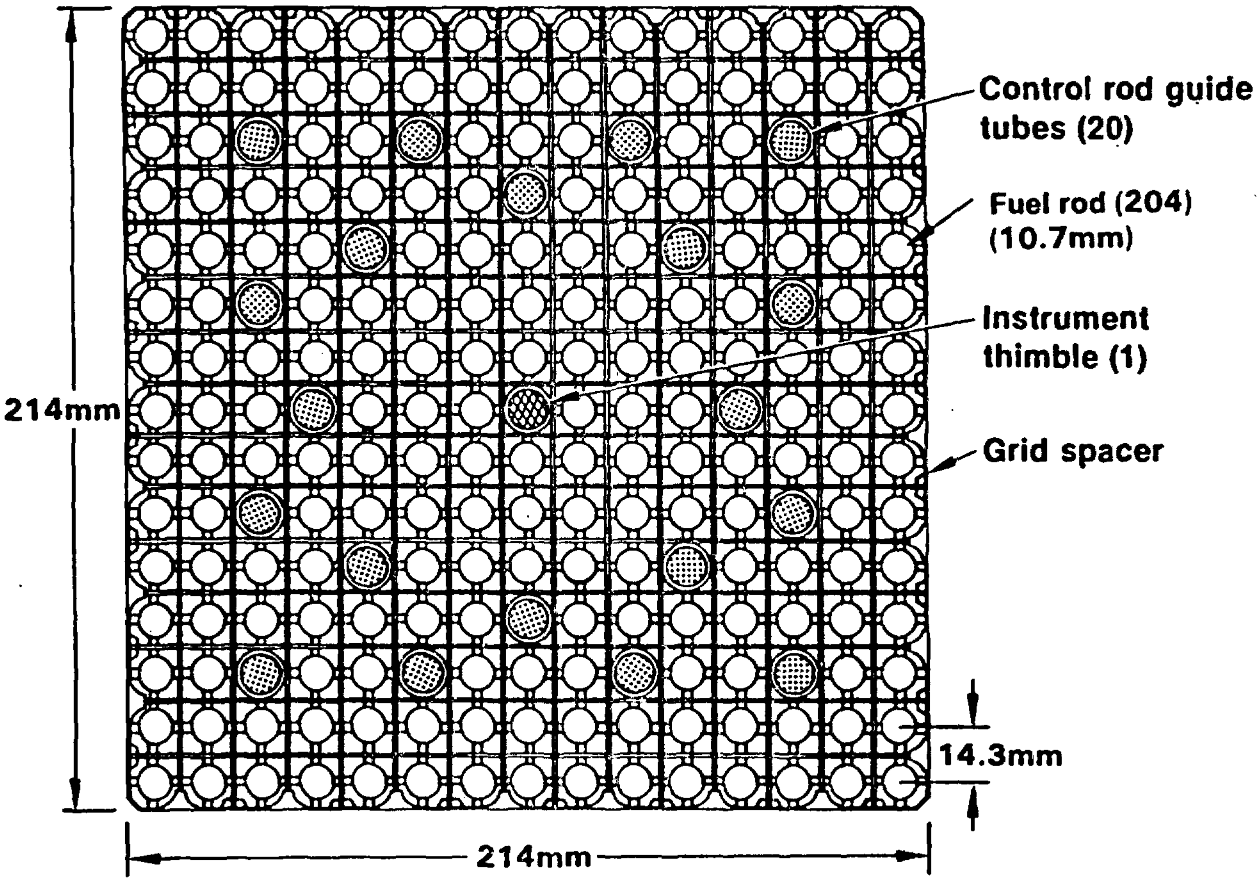


FIGURE 5.27. Surry 15x15 PWR Spent Fuel Assembly Cross Section

TABLE 5.9. Surry PWR Spent Fuel Characteristics

Assembly	Burnup (GWd/MTU)	Cooling Time (months)	Initial Enrichment (wt%)	Decay Heat Prediction (W) Start 1/14/86	Decay Heat Prediction (W) End 2/06/86
W02, W10, W16, W19 W23, W45, W49	29.8	50.3	3.2	845.5	832.3
W01, W17, W21, W38 W44, W46, W52	30.0	50.3	3.2	852.0	839.0
W06, W13, W27, W34	30.5	50.3	3.2	859.0	846.0
V03, V10, V16, V26	30.5	50.3	3.0	870.0	856.5
V18, V22	31.5	50.3	3.0	919.2	905.0

(details of the ORIGEN2 calculations are presented in the test report by McKinnon et al. (1986a)). Decay heat generation rates of all assemblies were predicted to total 20.6 kW; rates for the individual assemblies ranged from 830 to 919 watts. The load pattern for the cask is shown in Figure 5.28. Assembly placements were selected to create a quarter symmetry of heat generation within the basket and to produce a relatively flat temperature profile across the fuel assemblies.

Measured axial decay heat profiles or gamma scans for the Surry spent fuel assemblies were not available as input data to the ORIGEN2 computer code to predict axial decay heat profiles. Axial gamma radiation scans previously obtained on Turkey Point reactor spent fuel assemblies were therefore used to develop a typical assembly axial burnup distribution (Davis 1980). The Turkey Point and Surry PWR reactors and spent fuel assemblies are of the same designs so axial decay heat profiles were assumed to be very similar. The measured gamma activity from Turkey Point assemblies and predicted Surry assembly decay heat axial profiles are shown in Figure 5.29. Both profiles are typical of those for spent fuel assemblies from PWR reactors. The dips in the profiles are a result of grid spacers at those locations.

The TN-24P cask performance test consisted of the six runs indicated in Table 5.10. The test runs involved a fully loaded cask (21 spent fuel assemblies), three backfill media (vacuum, nitrogen, and helium), and two cask orientations (vertical and horizontal).

5.3.2 Computational Model Description

The TN-24P cask was analyzed using two different three-dimensional models. A one-eighth section model was used to investigate the cask thermal performance in a vertical orientation, while a one-half section model was used to analyze the cask when in a horizontal orientation. The smaller, computationally less expensive model was designed for cases in which the cask internals are centered within the cask, an assumption that applied only in the vertical orientation. For the horizontal orientation, previous experience (Wiles et al. 1986) has shown the importance of modeling the basket shift within the cask body and the effect of eccentrically located fuel assemblies within the basket fuel tubes. For this reason, the one-half symmetry model was also developed.

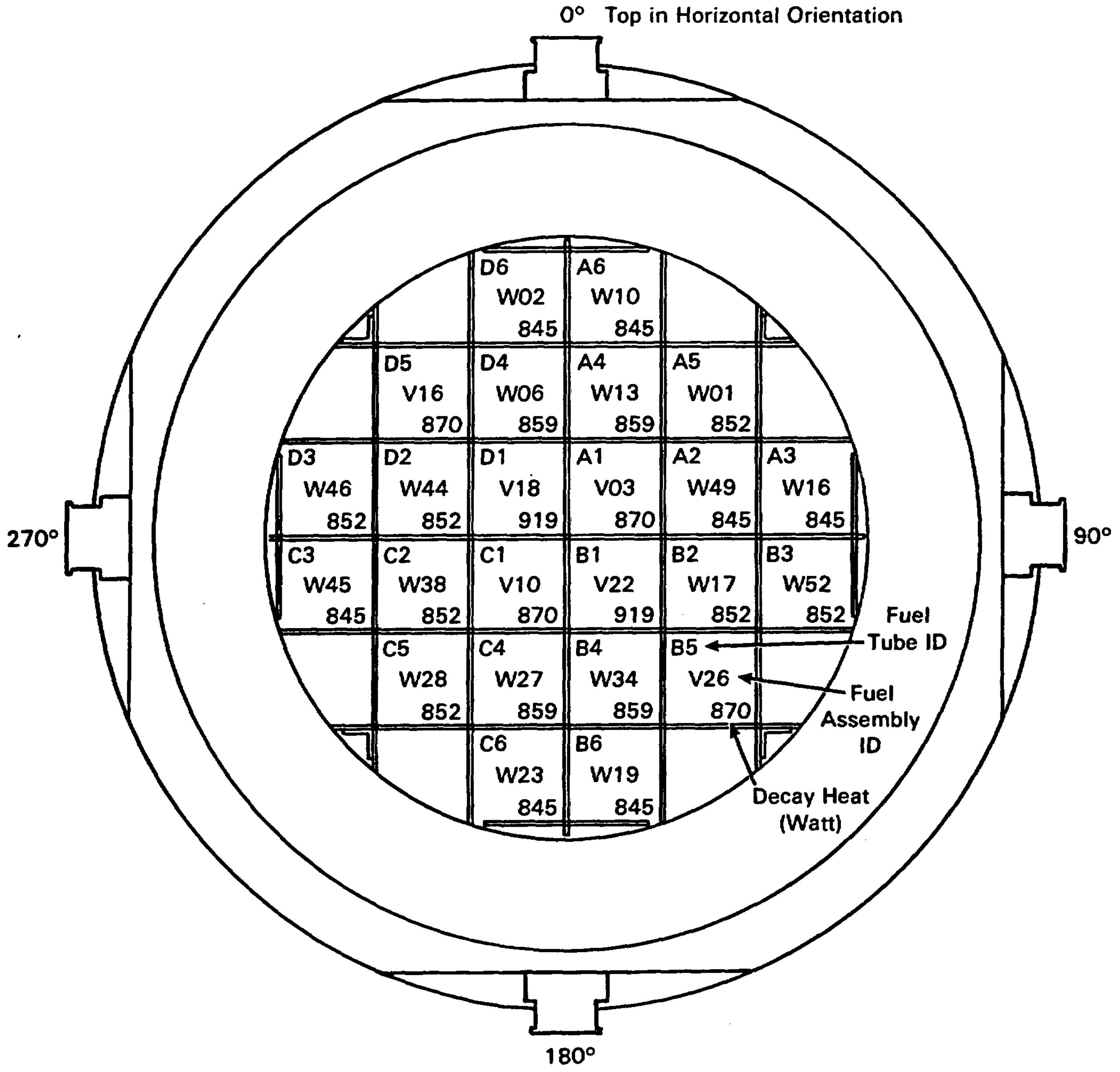


FIGURE 5.28. Spent Fuel Loading Pattern - TN-24P Cask Performance Test

Descriptions of the noding arrangement for the one-eighth sector model are presented below, followed by the one-half symmetry model. Details of the boundary specifications and properties used are then given along with a discussion of the modeling uncertainties.

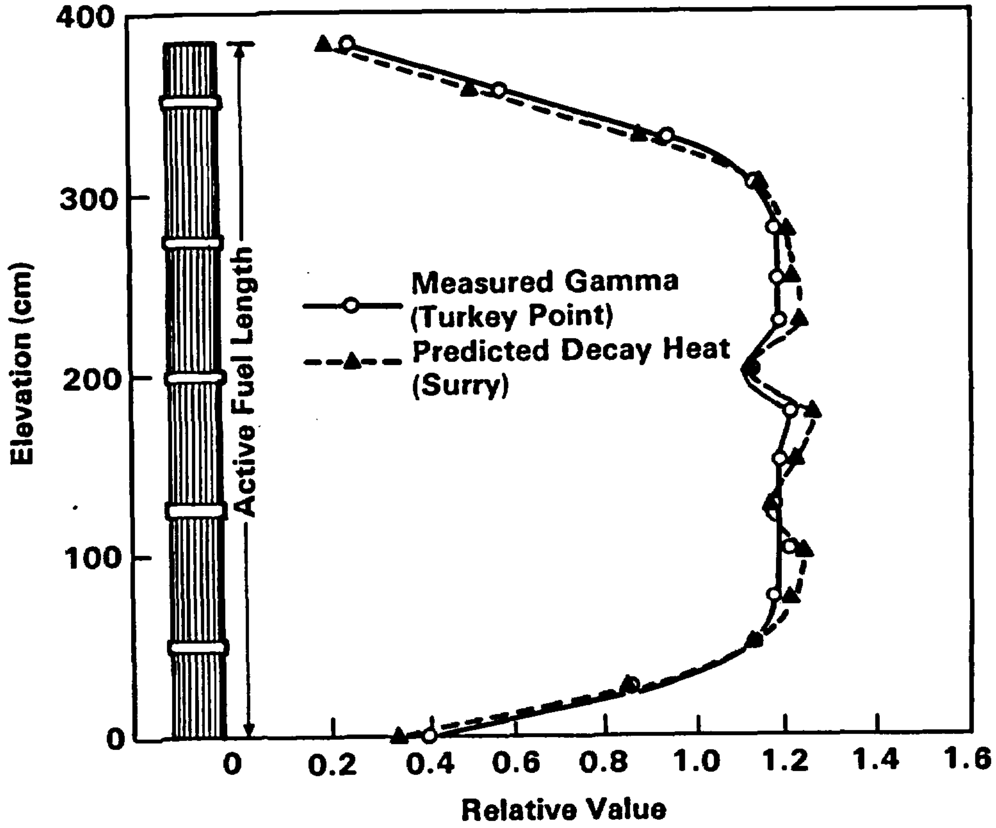


FIGURE 5.29. Predicted Axial Decay Heat Profile for Surry PWR Assemblies

TABLE 5.10. TN-24P Cask Performance Test Matrix

Number[(a)]	Cask Orientation	Backfill Medium
1	vertical	helium
2	vertical	nitrogen
3	vertical	vacuum
4	horizontal	helium
5	horizontal	nitrogen
6	horizontal	vacuum

(a) All runs were performed with a fully loaded cask (21 assemblies).

5.3.2.1 Nodal Representations

Both the COBRA-SFS one-eighth and one-half section models consisted of 18 uniform axial levels as depicted in Figure 5.30. For the one-eighth section model, each axial level comprised 51 wall nodes, 386 subchannels, and 450 rod nodes. A planar cross section of the one-eighth sector model illustrating the wall noding employed is shown in Figure 5.31.

The wall nodes included 27 basket nodes, 12 cask body nodes, 4 neutron shield nodes, and 8 cask shell nodes. The four outermost shell nodes are zero-thickness nodes that represent the cask surface temperature for the purpose of accurately calculating the contribution of radiation and convection heat transfer to the environment.

One of the lines of symmetry used to define the one-eighth section model runs through two of the basket fuel tubes. Fuel assemblies in these locations were modeled using individual fuel rods for a total of 120 rods. This representation, along with the layout of the 136 fluid subchannels used to describe the flow for the one-half fuel assembly, is shown in Figure 5.32. In the noding of full assemblies, the flexibility of the COBRA-SFS subchannel approach was used to selectively lump the rods and lump the channels to decrease the size of the computational model, as displayed in Figure 5.33. The 225 individual rods were represented by 105 lumped rods and the flow area within the assemblies was modeled by 57 lumped channels. To determine the rod lumping scheme, a simulation of an unlumped assembly was performed to determine the rod temperature distribution. From this simulation, a lumping pattern was then developed. Previous work (Rector, Cuta, and Lombardo, 1986) demonstrated the validity of combining rods with similar surface temperatures to form a single rod surface node. To facilitate data comparisons with thermocouple measurements, thermocouple lance locations were individually modeled as shown in Figure 5.33.

An expanded model was necessary to account for asymmetries in heat transfer paths that occurred when the cask was rotated into a horizontal orientation. The asymmetries resulted from two effects: 1) the unconstrained basket shifting downward to contact the lower inner cask surface, and 2) the fuel assemblies shifting within the basket fuel tubes. The one-half section model that accounts

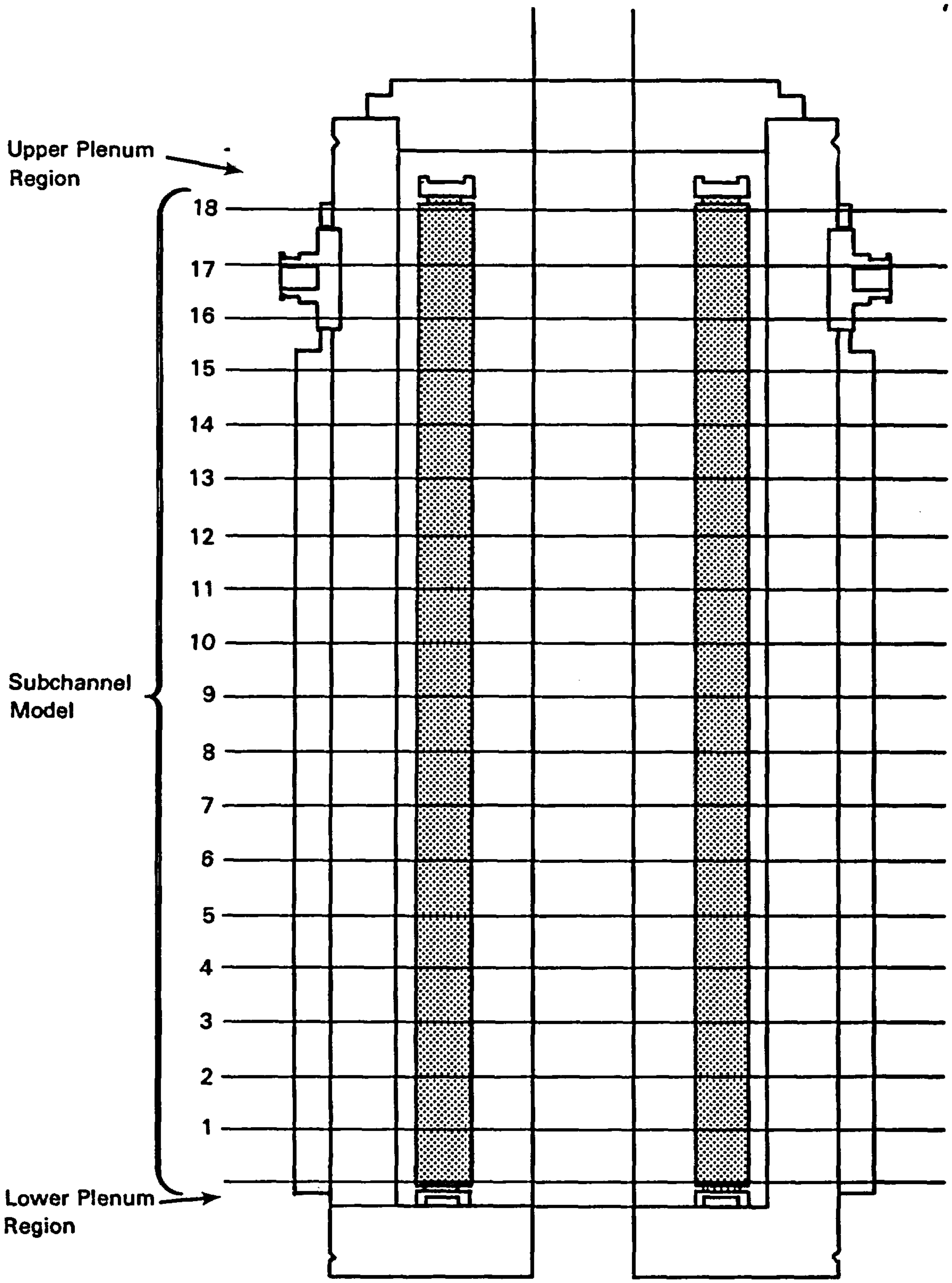


FIGURE 5.30. COBRA-SFS Axial Noding Scheme for the One-Eighth and One-Half Section Models of the TN-24P PWR Cask

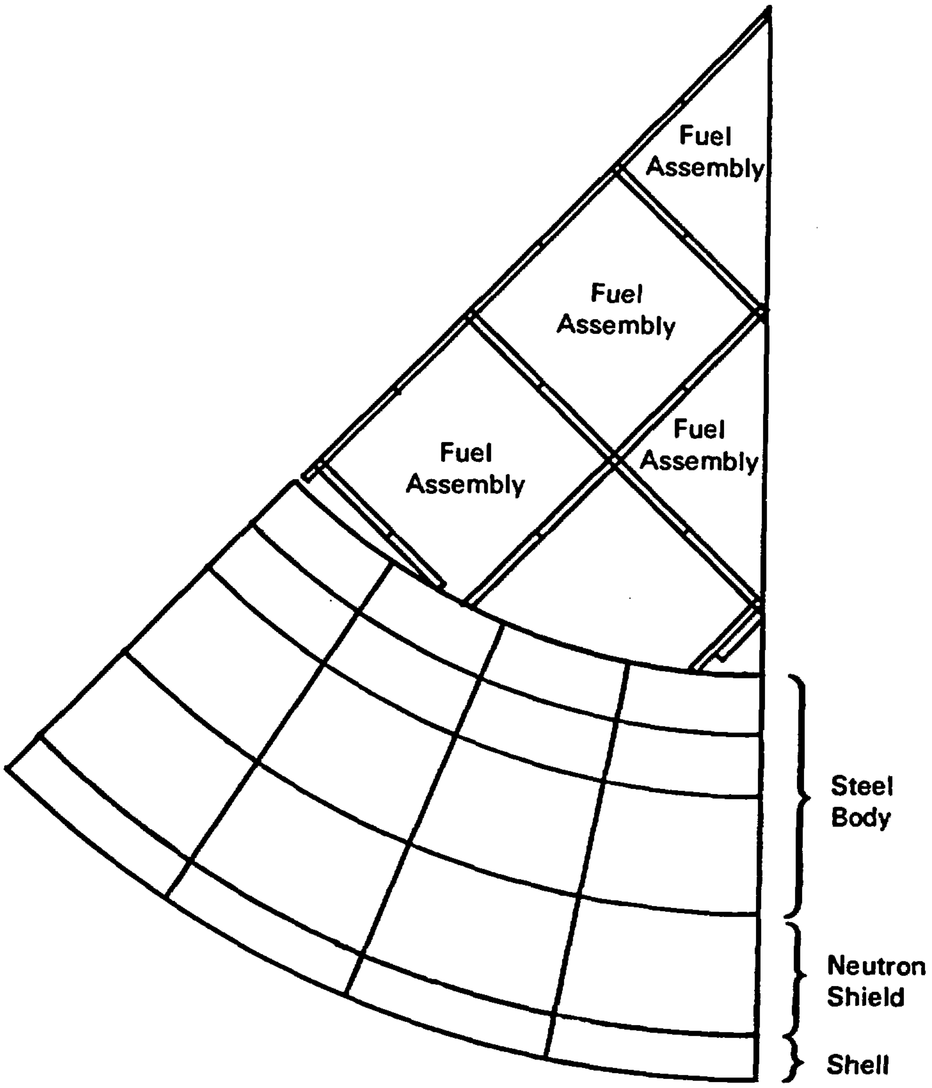


FIGURE 5.31. COBRA-SFS One-Eighth Section Model of the TN-24P PWR Cask Model for the TN-24P Cask Performance Test

for these effects is presented in Figure 5.34. In this model, 191 wall nodes were used at each axial level; 95 of which were basket nodes, 48 were cask body nodes, 16 were neutron shield nodes, and 32 were cask shell wall nodes. All of the fuel assemblies in the one-half section model were represented by the same lumping logic as used in the one-eighth section full fuel assembly representation.

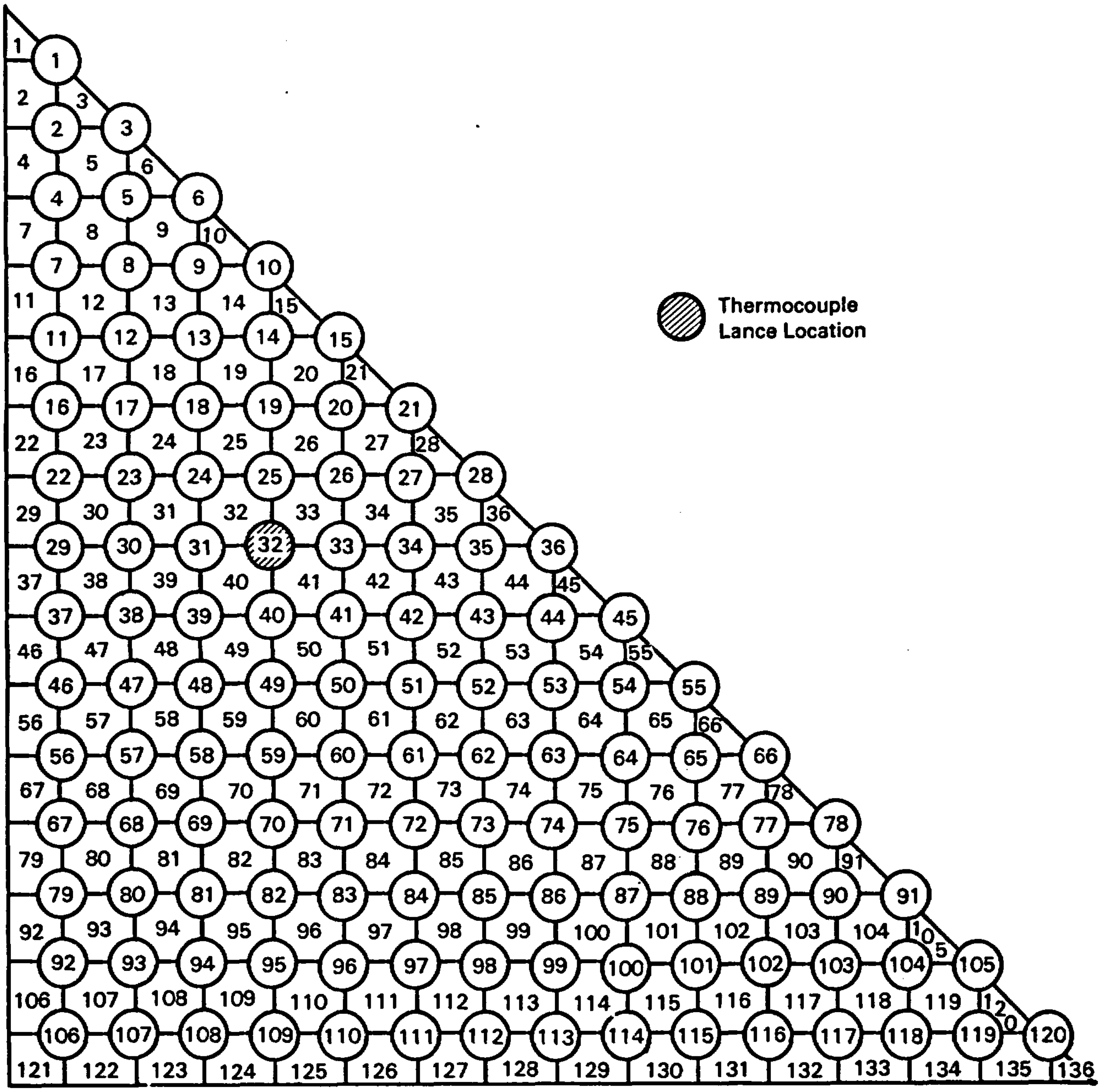


FIGURE 5.32. Half Assembly Subchannel and Rod Noding Scheme for the One-Eighth Section Model of the TN-24P PWR

Conduction heat transfer in the walls was modeled in the radial, circumferential, and axial directions via an input specification of thermal resistances between neighboring nodes. Each thermal resistance can reflect any combination of parallel and/or series resistance paths. An example of such a composite resistance in the TN-24P analyses is the polyethylene resin

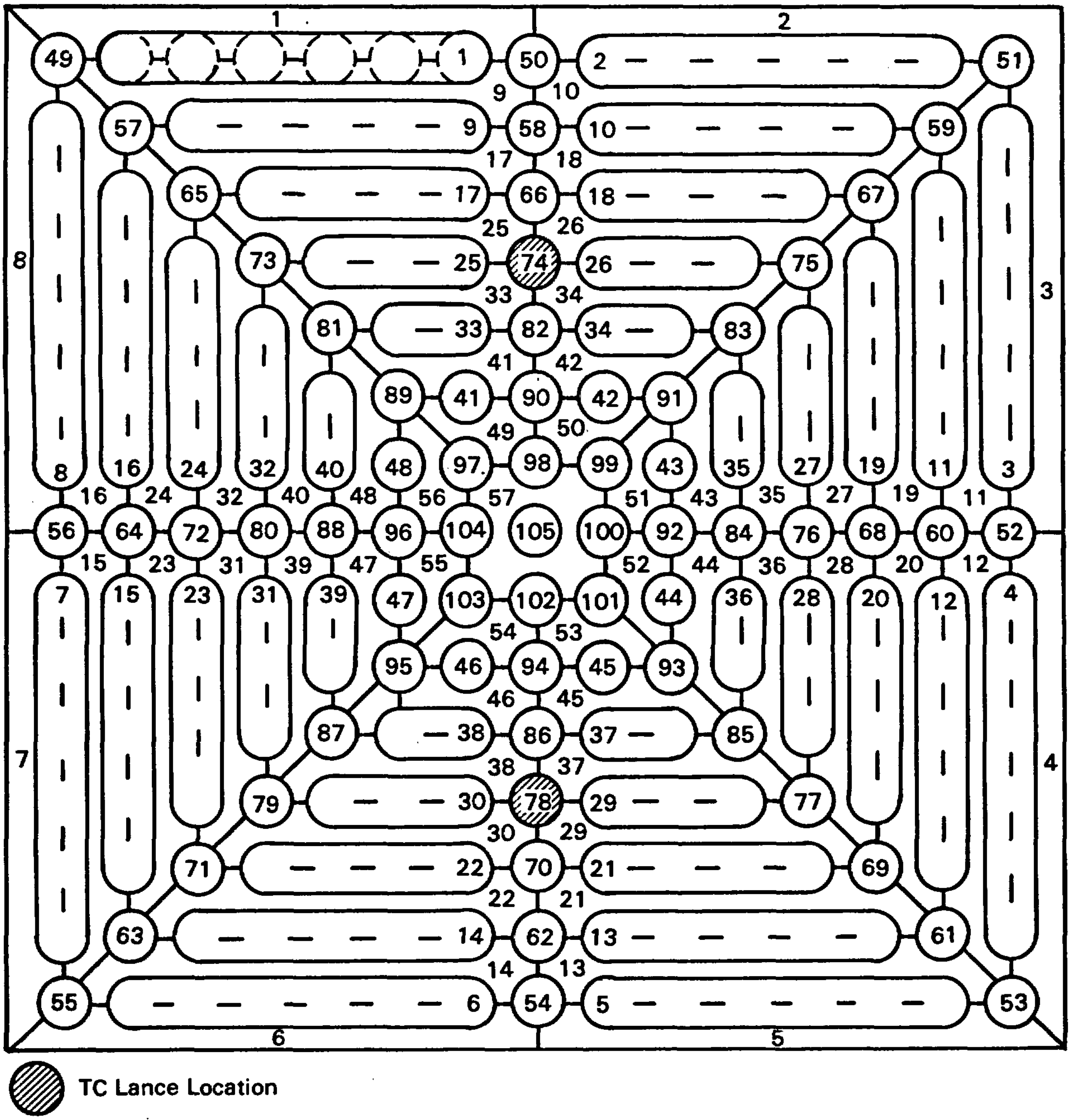


FIGURE 5.33. Lumped Rod and Channel Assembly Noding Scheme for the TN-24P PWR Cask

and copper fins, which formed the side neutron shield. In this region, a resistance was calculated that represented the two parallel paths through the shield.

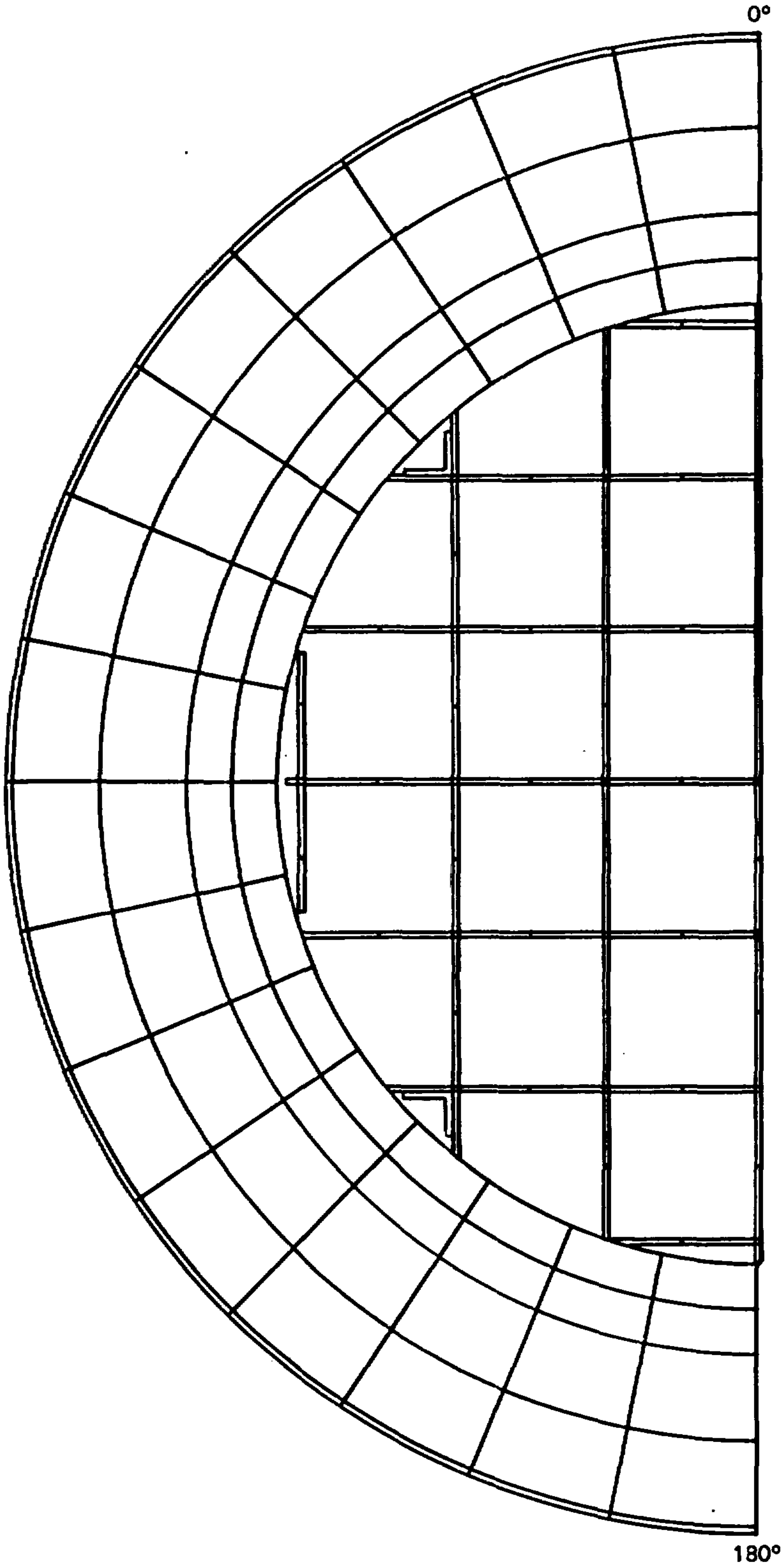


FIGURE 5.34. COBRA-SFS One-Half Section Model of the TN-24P PWR Cask

Axial and radial conduction in the aluminum basket was also accounted for. The dominating resistance in the radial conduction path resulted from the gap between the aluminum basket and the inner cask wall. This resistance was calculated through an iterative procedure in which 1) the average basket temperature was predicted, 2) the expansion of the basket was calculated, and 3) the gap resistance was predicted. Iteration on this term was necessary as the average basket temperature was directly related to the gap resistance.

Radiation heat transfer was treated on an assembly-by-assembly basis. In each enclosure containing a PWR fuel assembly, rod-to-rod, rod-to-wall, and wall-to-wall radiative heat transfers were modeled by specification of graybody exchange factors. The exchange factors for the fuel rods and walls were developed using one-quarter pin surface segments to define the radiation view factors. Radiation exchange in the empty enclosures, which consisted of either basket walls or basket walls and inner cask walls, was determined using wall-to-wall view factors. The COBRA-SFS code used these factors along with appropriate emissivities to calculate the graybody exchange factors.

5.3.2.2 Modeling Parameters, Correlations, and Material Properties

Resistances to flow included surface friction from the rods and walls, and irreversible losses from the grid spacers and assembly inlet and outlet nozzles. Surface friction for all channels was approximated using a friction factor of the form $f = 100/Re$, which was derived for a square rod array with pitch to diameter ratios typical of PWRs. Loss coefficients for the spacers and inlet and exit nozzles had specified values of 1, and 1.5, respectively.

Convective heat transfer from the rod and wall surfaces to the fluid was described using a film coefficient having the form $Nu = 3.66$ (Kays and Crawford 1980). This correlation is the analytical solution of the energy equation for a constant temperature and fully developed temperature and velocity profiles in a circular tube. Fluid-to-fluid conduction between adjacent subchannels was also accounted for.

Heat transfer from the cask surface to the ambient included convection, conduction, and radiation heat transfer. As described earlier for the CASTOR-1C and REA 2023 cask simulations, use of standard correlations to define the convective heat transfer from the casks results in an underpredicted heat transfer coefficient and, therefore, overpredicted cask surface temperatures. To facilitate the data comparisons presented here, the convective correlations were increased to provide similar predicted and measured cask surface temperatures. For details on the convective correlations employed in the analysis, refer to McKinnon et al. 1986a.

In the vertical orientation cases, the cask was placed on a rail car. The cask bottom boundary condition assumed no natural convection, only conductance through the rail car. Heat transfer from the rail car to the ambient air was specified by a heat transfer coefficient of the form, Nu = 1.0, or $h = k/D$, where D was half of the distance between the rail car and the ground and k was the conductivity of nitrogen.

The radiation heat transfer from the top and side outer surfaces to the surrounding environment was a function of surface emissivity and the ambient conditions. The ambient air was assumed to be a black body.

An optional plenum model was used to describe the heat transfer from the recirculating fluid to ambient in the regions immediately above and below the fuel tubes. In the plenum region model, only one-dimensional energy equations are solved. The upper lid was modeled with six nodes; three nodes apiece for the axial and radial directions. For the bottom of the cask, seven nodes were used in the axial direction, four in the radial. The overall heat transfer from the lid and bottom was modeled by specifying the thermal resistance between plenum nodes. Conduction heat transfer between the cask body and lid and the cask body and the bottom is also simulated by the plenum model.

The axial decay heat profile displayed in Figure 5.29 was applied to all of the assemblies. The one-eighth section model incorporated the decay heat rates from quadrant D shown in Figure 5.28. Assembly decay heat rates for the one-half section model were representative of quadrants C and D. A uniform radial decay heat distribution within each fuel assembly was assumed.

The material properties used for the TN-24P model are presented in Table 5.11. All surface emissivities and the greater portion of the solid thermal conductivities were provided by Transnuclear, Inc. The thermal properties of the solids were assumed constant, and properties of fill gases were specified as a function of temperature.

TABLE 5.11. Material Properties for the TN-24P Cask Analysis

Thermal Conductivities (Btu/ft-hr-°F)		Surface Emissivities	
Steel cask body	24.0	Fuel rods	0.8
Polyethylene resin	0.1	Fuel basket	0.8
Aluminum basket	119.0	Plated cask surfaces	0.9
Copper fins	218.0	Painted cask surfaces	0.9
steel shell	24.0	Copper fin surface	0.5
Polypropylene	0.1		

5.3.2.3 Modeling Uncertainties

The computational model contained a number of uncertainties in cask design and testing information that limited its ability to accurately predict the thermal performance of the TN-24P cask. These uncertainties include the following:

- basket-to-cask-wall gap width
- fuel assembly positioning
- cask boundary heat transfer (convection and conduction)
- decay heat generation rates and axial profiles
- plenum region flow and thermal resistance.

A brief discussion of these uncertainties is presented below.

The aluminum basket was designed to allow thermal expansion in the radial direction; no mechanical connections existed between the inside cask body surface and the basket. To approximate the thermal resistance attributed to the basket-cask gap, an average basket temperature was predicted, a radial expansion calculated, and a new value for the gap determined. This iterative procedure assumed that the basket was originally centered within the cask (for the vertical orientation) and that the basket expanded uniformly.

In the vertical orientation, each fuel assembly was assumed to be centered within the basket fuel tube such that the basket-to-outer rod distance was uniform on all four sides of the fuel assembly, at all axial locations. It is more likely that the assembly is positioned off-center, with varying axial distances to the basket walls.

Natural convection heat transfer from the outside cask surface to the ambient air is difficult to predict accurately. Modifications were made to standard convection correlations to reflect experience gained from previous cask simulations; however, changes to these correlations may be cask-dependent.

The connection between the cask bottom and ambient air was modeled as the sum of two resistances: 1) heat transfer through a simplified model of the rail car, and 2) conduction through stagnant ambient air. This was a simplified approach, with the rail car essentially acting as a fin.

The axial decay heat profile used in the COBRA-SFS analyses was not experimentally determined. Deviations from the true profile may result in substantial differences in predicted and measured temperatures (Rector et al. 1986a).

To account for heat transfer from the lower and upper plenums to the ambient air (through the cask lower and upper lids, respectively), values of the bulk-to-film thermal resistance must be specified. The value of this resistance is expected to be a function of the flow field established within the cask; however, because the flow field in the plenum regions is not calculated, this value is difficult to predict accurately. Furthermore, the gas entering the plenum regions is assumed to be instantaneously mixed and is assumed to be uniform across the cask cross section. In reality, the temperature of the plenum is expected to vary as a function of radial position. The loss coefficients as the fluid flows across the top and bottom of the basket are also difficult to define and were omitted from this analysis. Exclusion of these loss coefficients should result in slightly greater predicted recirculating flows.

5.3.3 Comparisons of Predictions to Data

Axial temperature profiles for the vertical and horizontal helium-filled runs at several positions within the cask are presented in Figures 5.35 and 5.36 respectively. Predicted and measured data are shown as a function of elevation from the cask bottom for four fuel assembly locations (assembly locations D1, D4, D5, and D6 of Figure 5.28), a peripheral basket location (Figure 5.25), the cask surface, and the ambient air. In a comparison of peak temperatures, COBRA-SFS showed excellent agreement with the data, slightly overpredicting the measured peak temperature in both cases by 10°C. Interior cask temperatures were also overpredicted, in part as a result of an overpredicted cask inner wall surface temperature.

In both orientations, good agreement in the shape of the axial profiles was achieved. One interesting trend predicted by COBRA-SFS is the slight shift in the axial profiles for the different cask orientations. This shift is displayed in Figure 5.37, which shows the predicted and measured axial guide tube temperature profiles for the two orientations, along with the ambient temperature. As the cask is rotated from vertical to horizontal, the overall profile is flattened, showing a slight decrease in temperature in the upper elevations, and a slight increase in the lower elevations. It is expected that the modeled shift in basket orientation (to contact the cask wall), the elimination of buoyancy effects, and the removal of the rail car as a heat sink in the horizontal orientation simulations account for the shift in the profiles. It is interesting to note that, with a helium backfill, lower peak temperatures were obtained with the cask in the horizontal orientation, a trend correctly predicted by COBRA-SFS. Again, the success of the COBRA-SFS predictions in the horizontal and vertical orientations displayed above demonstrates the ability of the code to predict the thermal performance of spent fuel storage systems under a wide variety of conditions.

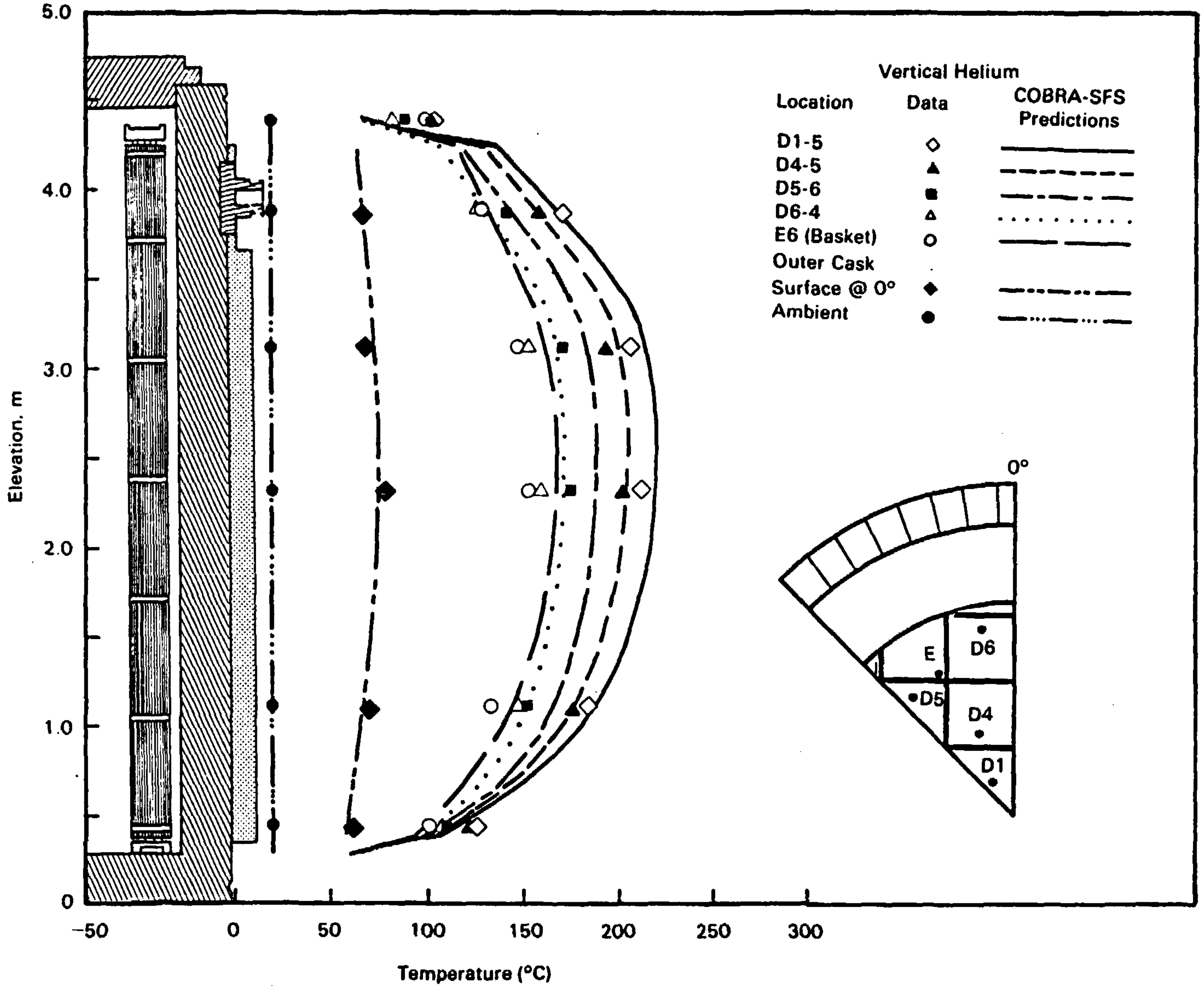


FIGURE 5.35. Comparisons of COBRA-SFS Axial Temperature Profile Predictions with Vertical, Helium TN-24P Test Data

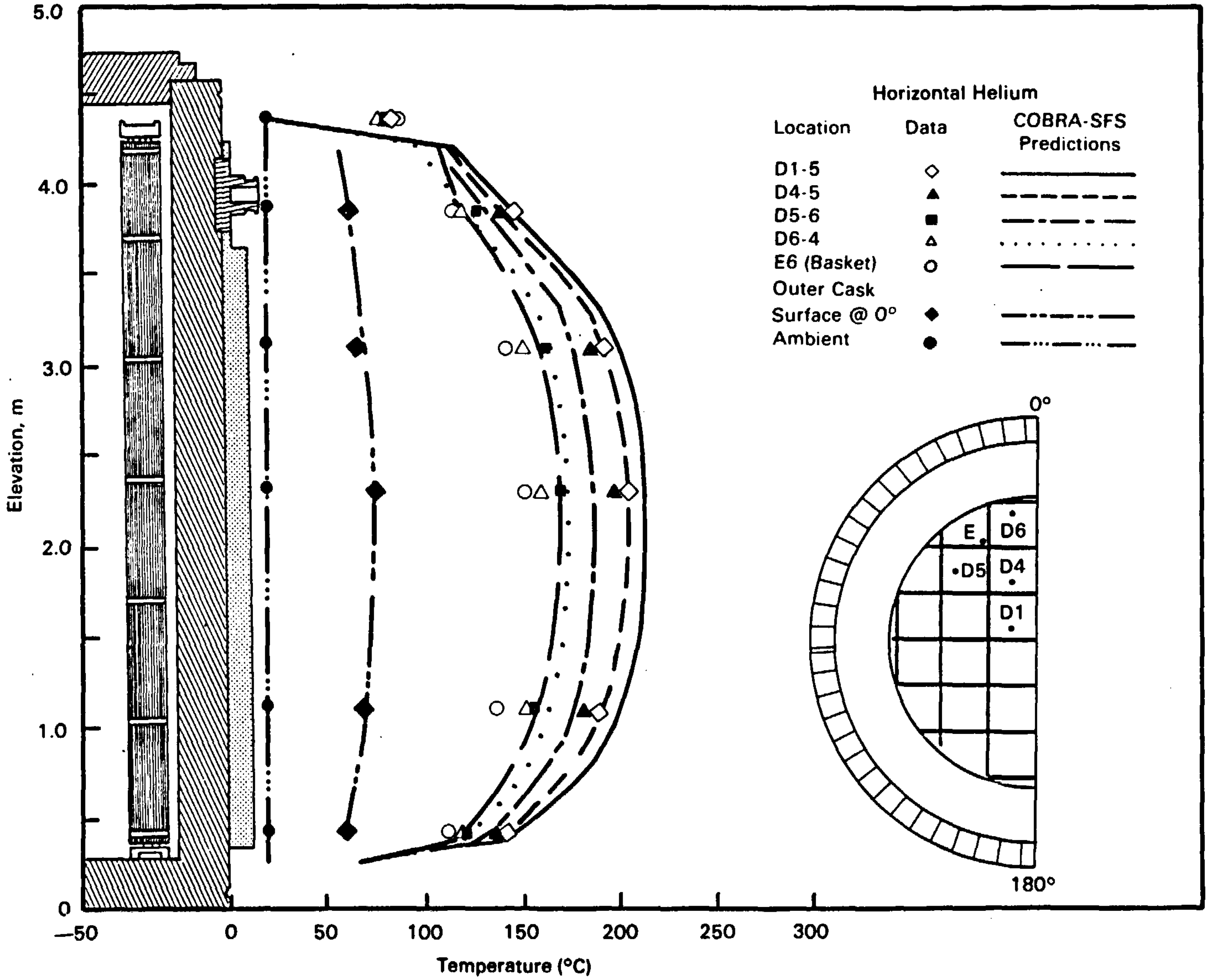


FIGURE 5.36. Comparisons of COBRA-SFS Axial Temperature Profile Predictions with Horizontal, Helium TN-24P Test Data

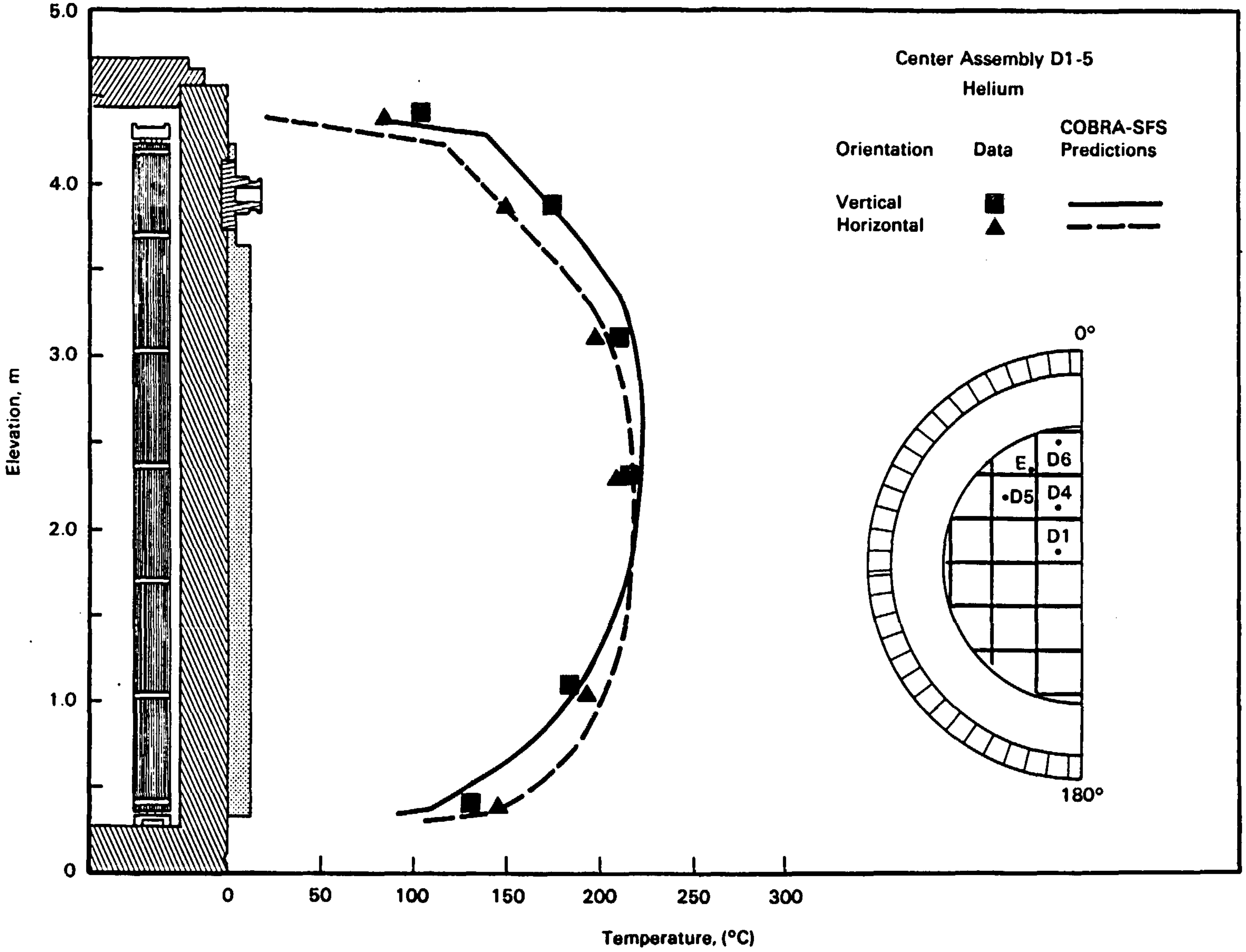


FIGURE 5.37. Comparisons of COBRA-SFS Peak Axial Temperature Profile Predictions with Vertical and Horizontal, Helium, TN-24P Test Data

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APPENDIX A

PWR SINGLE ASSEMBLY SPENT FUEL TEST SIMULATIONS INPUT, OUTPUT, AND CONVERGENCE LISTS

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PWR SINGLE ASSEMBLY SPENT FUEL TEST SIMULATIONS INPUT, OUTPUT, AND CONVERGENCE LISTS

Test Case	Page Number Input	 Convergence List	 Output
Vertical, helium	A.2	A.3	A.4
Vertical, nitrogen	A.8	A.10	A.10
Vertical, vacuum	A.14	A.16	A.16

```
+5000
   1      inhel emad input, validation analyses
prop     7    1
       1.        0.      100.0     .0780      1.24     83.33     .0410
       2.      200.      348.0     .0970      1.24    119.76     .0533
       3.      400.      596.0     .1150      1.24    156.25     .0641
       5.      600.      844.0     .1290      1.24    192.31     .0727
      10.      800.     1092.0     .1380      1.24    229.36     .0823
      15.     1000.     1340.0     .1380      1.24    265.25     .0907
      20.     1500.     1588.0     .1380      1.24    357.14     .1138
   1ss304                          9.8
chan     1   34
     153.0       00.0
   1    1   29    0    1
   1    1    0    0    1
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  12.15351.423.9943   13 .079 .563   17 .079 .563
  13.15351.423.9943   14 .141 .563   18 .079 .563
  14.17711.3261.326   15 .141 .563   19 .141 .563
  15.0768.7116.4972   20 .079 .563
  16.17711.3261.326   17 .141 .563   22 .141 .563
  17.15351.423.9943   18 .079 .563   23 .141 .563
  18.15351.423.9943   19 .141 .563   24 .141 .563
  19.17711.3261.326   20 .141 .563   25 .141 .563
  20.15351.423.9943   21 .079 .563   26 .141 .563
  21.0768.7116.4972   27 .141 .563
  22.17711.3261.326   23 .141 .563   29 .141 1.68
  23.17711.3261.326   24 .141 .563   29 .141 1.59
  24.17711.3261.326   25 .141 .563   29 .141 1.55
  25.17711.3261.326   26 .141 .563   29 .141 1.47
  26.17711.3261.326   27 .141 .563   29 .141 1.36
  27.17711.3261.326   28 .141 .563   29 .141 1.24
  28.0886.6629.6629   29 .141 1.07
2  299.47010.015.203

rods     1    1    2            1
   1    1   36    0
 2 36 .422  0.0    1 .125
 1 35 .422  1.0    1  .25    2  .25
 1 34 .422  1.0    1 .125    2  .25    3 .125
 1 33 .422  1.0    2  .25    4  .25
 1 32 .422  1.0    2  .25    3  .25    4  .25    5  .25
 1 31 .422  1.0    3 .125    5  .25    6 .125
 1 30 .422  1.0    4  .25    7  .25
 1 29 .422  1.0    4  .25    5  .25    7  .25    8  .25
 1 28 .422  1.0    5  .25    6  .25    8  .25    9  .25
 2 27 .422  0.0    6 .125    9  .25   10 .125
 2 26 .422  0.0    7  .25   11  .25
 1 25 .422  1.0    7  .25    8  .25   11  .25   12  .25
 1 24 .422  1.0    8  .25    9  .25   12  .25   13  .25
```

```
1 23 .422  1.0    9  .25   10  .25   13  .25   14  .25
1 22 .422  1.0   10 .125   14  .25   15 .125
1 21 .422  1.0   11  .25   16  .25
1 20 .422  1.0   11  .25   12  .25   16  .25   17  .25
2 19 .422  0.0   12  .25   13  .25   17  .25   18  .25
1 18 .422  1.0   13  .25   14  .25   18  .25   19  .25
1 17 .422  1.0   14  .25   15  .25   19  .25   20  .25
2 16 .422  0.0   15 .125   20  .25   21 .125
1 15 .422  1.0   16  .25   22  .25
1 14 .422  1.0   16  .25   17  .25   22  .25   23  .25
1 13 .422  1.0   17  .25   18  .25   23  .25   24  .25
1 12 .422  1.0   18  .25   19  .25   24  .25   25  .25
1 11 .422  1.0   19  .25   20  .25   25  .25   26  .25
1 10 .422  1.0   20  .25   21  .25   26  .25   27  .25
1  9 .422  1.0   21 .125   27  .25   28 .125
1  8 .422  1.0   22  .25   29  .25
1  7 .422  1.0   22  .25   23  .25   29  .50
1  6 .422  1.0   23  .25   24  .25   29  .50
1  5 .422  1.0   24  .25   25  .25   29  .50
1  4 .422  1.0   25  .25   26  .25   29  .50
1  3 .422  1.0   26  .25   27  .25   29  .50
1  2 .422  1.0   27  .25   28  .25   29  .50
1  1 .422  1.0   28 .125   29 .375
  2.8.0717 685..36699.540.0779 409..0243  10. .422    0
  2.8.0717 685..36699.540.0779 409..0243  10. .422    0
slab     0    1    1
    1    1  0.0
    1     13.05      5.203
    1    1    1   29    1

radg     1    1    0
    1    1    1    1
heat     2    0    1
               3.66                    3.66
              1000.                   1000.
  1.0
drag     2    0
 100. -1.0                   100. -1.0
 64.  -1.0                    64. -1.0
bdry     1    1    1    0
    1     0.01                           1.0
    1    7    .0209.4.0962263.8.3157315.5.5412319.5.7647382.0.9922241.7
            1.0239.6
    1     15.498     1  0.0
    1  1.0    1  1.0    1
calc     0
   .0                                           .1
       15
oper     1          3                                               1
      14.7       230.     .00005     .00230       230.       .005       0.0
   12
   0.    0..0588  .80.1176 1.05.2353 1.13.3529 1.13.4709 1.13
.5882 1.13.7059 1.13.8235 1.00.9411 .319.9412   0.   1.0   0.
outp     1
endd


 data from iterative solution using the recirculation module
 time =    0.0000    dt = ******    implicit dt = 0.0000    explicit dt = 8.6760    mode =  0
```

```
iteration  sweep           peak clad              total flow    pressure                   error
   no.      no.   ----------------------------     (lbm/s)     drop(psi)    -----------------------------------
                  temp(f)  fluid  rod  ass.                                   total     flow    fluid     rod
                                                                              energy            energy   energy

    1        1     371.4    31    35    1       -0.324e-07   0.0004803    24.3623  11.4458   0.0053   0.0022
             2     371.6    30    35    1                                  0.9881  11.4458   0.0477   0.0019

    2        1     392.7    25    35    1       -0.188e-07   0.0006293     0.1714   1.6048   0.0177   0.0024
             2     407.5    20    35    1                                  0.0449   1.6048   0.0166   0.0014

    3        1     415.9    20    35    1        0.616e-08   0.0006278     0.0246   1.4570   0.0034   0.0006
             2     420.2    20    35    1                                  0.0166   1.4576   0.0043   0.0002

    4        1     422.1    20    35    1       -0.774e-07   0.0006278     0.0042   1.1090   0.0009   0.0003
             2     423.1    20    35    1                                  0.0028   1.1090   0.0042   0.0000

    5        1     423.6    20    35    1       -0.214e-07   0.0006276     0.0016   0.6899   0.0007   0.0002
             2     423.8    20    35    1                                  0.0010   0.6899   0.0023   0.0000

    6        1     423.9    20    35    1       -0.890e-08   0.0006276     0.0004   0.3378   0.0007   0.0001
             2     423.9    20    35    1                                  0.0004   0.3378   0.0014   0.0000

    7        1     424.0    20    35    1       -0.472e-08   0.0006276     0.0001   0.0736   0.0009   0.0001
             2     424.0    20    35    1                                  0.0002   0.0736   0.0011   0.0000

    8        1     424.0    20    35    1       -0.145e-08   0.0006276    -0.0001   0.0292   0.0016   0.0000
             2     424.0    20    35    1                                  0.0002   0.0292   0.0011   0.0000

    9        1     424.0    20    35    1        0.299e-09   0.0006276    -0.0001   0.0101   0.0010   0.0000
             2     424.0    20    35    1                                  0.0002   0.0101   0.0010   0.0000

   10        1     424.0    20    35    1        0.878e-09   0.0006278    -0.0001   0.0036   0.0010   0.0000
             2     424.0    20    35    1                                  0.0002   0.0036   0.0010   0.0000



 side boundary temperature summary     time =     0.0000 seconds
 boundary slab node no.      1


axial zone       ( 1)        ( 2)        (
 (inches)

 0.0 -  4.5     218.27      218.27
 4.5 -  9.0     236.02      236.01
 9.0 - 13.5     253.76      253.75
13.5 - 18.0     266.74      266.72
18.0 - 22.5     273.48      273.46
22.5 - 27.0     280.23      280.21
27.0 - 31.5     286.97      286.95
31.5 - 36.0     293.71      293.69
36.0 - 40.5     300.46      300.44
40.5 - 45.0     307.20      307.18
45.0 - 49.5     313.94      313.92
49.5 - 54.0     315.92      315.90
54.0 - 58.5     316.44      316.42
```

```
  58.5 - 63.0      316.96       316.94
  63.0 - 67.5      317.49       317.46
  67.5 - 72.0      318.01       317.99
  72.0 - 76.5      318.53       318.51
  76.5 - 81.0      319.05       319.03
  81.0 - 85.5      319.29       319.27
  85.5 - 90.0      316.99       316.97
  90.0 - 94.5      314.69       314.67
  94.5 - 99.0      312.38       312.36
  99.0 -103.5      310.08       310.06
 103.5 -108.0      307.78       307.76
 108.0 -112.5      305.47       305.45
 112.5 -117.0      303.17       303.15
 117.0 -121.5      298.12       298.10
 121.5 -126.0      290.32       290.30
 126.0 -130.5      282.53       282.51
 130.5 -135.0      274.73       274.71
 135.0 -139.5      266.93       266.92
 139.5 -144.0      259.13       259.12
 144.0 -148.5      251.33       251.33
 148.5 -153.0      243.53       243.53


 calculated rod temperatures at time =    0.0000 seconds
 rod no.   16
 assembly   1                 (fuel type  2 - cylinder)
0rod o.d. - 0.422 (in.)    zone-(fuel dia.(in.)) -  1-(0.357)

                                              *   fuel temperatures(f.)
                                              *
   axial zone  heat flux   type          hsurf *   fluid    clad
      (in.)   (mbtu/hr-ft2)          (b/h-f-ft2) *
    0.0 -   4.5    0.0000    2              10.1      235.4    235.4
    4.5 -   9.0    0.0000    2              10.5      278.4    278.2
    9.0 -  13.5    0.0000    2              10.8      311.9    311.7
   13.5 -  18.0    0.0000    2              11.0      332.4    332.2
   18.0 -  22.5    0.0000    2              11.1      343.8    343.6
   22.5 -  27.0    0.0000    2              11.2      351.4    351.2
   27.0 -  31.5    0.0000    2              11.2      358.5    358.3
   31.5 -  36.0    0.0000    2              11.3      365.4    365.2
   36.0 -  40.5    0.0000    2              11.4      371.8    371.6
   40.5 -  45.0    0.0000    2              11.4      377.6    377.4
   45.0 -  49.5    0.0000    2              11.5      383.2    383.0
   49.5 -  54.0    0.0000    2              11.5      385.2    385.0
   54.0 -  58.5    0.0000    2              11.5      385.8    385.6
   58.5 -  63.0    0.0000    2              11.5      386.2    386.1
   63.0 -  67.5    0.0000    2              11.5      386.7    386.5
   67.5 -  72.0    0.0000    2              11.5      387.1    387.0
   72.0 -  76.5    0.0000    2              11.5      387.6    387.4
   76.5 -  81.0    0.0000    2              11.5      388.0    387.8
   81.0 -  85.5    0.0000    2              11.5      388.1    388.0
   85.5 -  90.0    0.0000    2              11.5      386.3    386.2
   90.0 -  94.5    0.0000    2              11.5      384.4    384.2
   94.5 -  99.0    0.0000    2              11.5      382.4    382.3
   99.0 - 103.5    0.0000    2              11.4      380.4    380.3
  103.5 - 108.0    0.0000    2              11.4      378.5    378.3
  108.0 - 112.5    0.0000    2              11.4      375.6    375.5
  112.5 - 117.0    0.0000    2              11.4      371.8    371.7
  117.0 - 121.5    0.0000    2              11.3      365.7    365.5
```

```
 121.5 - 126.0    0.0000    2             11.2     357.1    357.0
 126.0 - 130.5    0.0000    2             11.1     344.6    344.5
 130.5 - 135.0    0.0000    2             10.9     327.7    327.6
 135.0 - 139.5    0.0000    2             10.8     309.6    309.5
 139.5 - 144.0    0.0000    2             10.6     290.3    290.2
 144.0 - 148.5    0.0000    2             10.3     256.0    256.0
 148.5 - 153.0    0.0000    2             10.2     244.3    244.3


 calculated rod temperatures at time =    0.0000 seconds
 rod no.   27
 assembly   1                  (fuel type  2 - cylinder)
0rod o.d. - 0.422 (in.)     zone-(fuel dia.(in.)) -  1-(0.367)

                                                *   fuel temperatures(f.)
                                                *
   axial zone  heat flux   type           hsurf *  fluid    clad
      (in.)   (mbtu/hr-ft2)            (b/h-f-ft2) *
   0.0 -   4.5    0.0000    2             10.1     240.0    240.0
   4.5 -   9.0    0.0000    2             10.6     290.2    290.1
   9.0 -  13.5    0.0000    2             11.0     328.5    328.4
  13.5 -  18.0    0.0000    2             11.2     351.6    351.5
  18.0 -  22.5    0.0000    2             11.3     364.5    364.4
  22.5 -  27.0    0.0000    2             11.4     372.5    372.4
  27.0 -  31.5    0.0000    2             11.4     379.7    379.6
  31.5 -  36.0    0.0000    2             11.5     386.7    386.6
  36.0 -  40.5    0.0000    2             11.5     393.1    393.0
  40.5 -  45.0    0.0000    2             11.6     398.8    398.7
  45.0 -  49.5    0.0000    2             11.6     404.2    404.1
  49.5 -  54.0    0.0000    2             11.7     406.2    406.1
  54.0 -  58.5    0.0000    2             11.7     406.8    406.7
  58.5 -  63.0    0.0000    2             11.7     407.3    407.2
  63.0 -  67.5    0.0000    2             11.7     407.7    407.6
  67.5 -  72.0    0.0000    2             11.7     408.1    408.0
  72.0 -  76.5    0.0000    2             11.7     408.6    408.5
  76.5 -  81.0    0.0000    2             11.7     409.0    408.9
  81.0 -  85.5    0.0000    2             11.7     409.1    409.0
  85.5 -  90.0    0.0000    2             11.7     407.4    407.4
  90.0 -  94.5    0.0000    2             11.7     405.6    405.5
  94.5 -  99.0    0.0000    2             11.6     403.7    403.6
  99.0 - 103.5    0.0000    2             11.6     401.8    401.7
 103.5 - 108.0    0.0000    2             11.6     399.9    399.8
 108.0 - 112.5    0.0000    2             11.6     396.9    396.9
 112.5 - 117.0    0.0000    2             11.5     392.7    392.6
 117.0 - 121.5    0.0000    2             11.5     386.3    386.2
 121.5 - 126.0    0.0000    2             11.4     377.5    377.5
 126.0 - 130.5    0.0000    2             11.3     363.8    363.7
 130.5 - 135.0    0.0000    2             11.1     344.3    344.2
 135.0 - 139.5    0.0000    2             10.9     323.1    323.1
 139.5 - 144.0    0.0000    2             10.7     300.5    300.5
 144.0 - 148.5    0.0000    2             10.3     258.3    258.3
 148.5 - 153.0    0.0000    2             10.2     244.7    244.7


 calculated rod temperatures at time =    0.0000 seconds
 rod no.   36
 assembly   1                  (fuel type  2 - cylinder)
0rod o.d. - 0.422 (in.)     zone-(fuel dia.(in.)) -  1-(0.367)

                                                *   fuel temperatures(f.)
```

```
                                                   *
axial zone  heat flux   type              hsurf  *  fluid    clad
   (in.)   (mbtu/hr-ft2)             (b/h-f-ft2) *
  0.0 -   4.5   0.0000     2              10.2      243.2    243.1
  4.5 -   9.0   0.0000     2              10.7      298.4    298.3
  9.0 -  13.5   0.0000     2              11.1      340.0    339.8
 13.5 -  18.0   0.0000     2              11.3      364.8    364.7
 18.0 -  22.5   0.0000     2              11.4      378.8    378.7
 22.5 -  27.0   0.0000     2              11.5      387.0    386.9
 27.0 -  31.5   0.0000     2              11.6      394.3    394.2
 31.5 -  36.0   0.0000     2              11.6      401.5    401.3
 36.0 -  40.5   0.0000     2              11.7      407.8    407.7
 40.5 -  45.0   0.0000     2              11.7      413.4    413.2
 45.0 -  49.5   0.0000     2              11.8      418.7    418.5
 49.5 -  54.0   0.0000     2              11.8      420.7    420.6
 54.0 -  58.5   0.0000     2              11.8      421.4    421.3
 58.5 -  63.0   0.0000     2              11.8      421.8    421.7
 63.0 -  67.5   0.0000     2              11.8      422.3    422.1
 67.5 -  72.0   0.0000     2              11.8      422.7    422.6
 72.0 -  76.5   0.0000     2              11.8      423.1    423.0
 76.5 -  81.0   0.0000     2              11.8      423.5    423.4
 81.0 -  85.5   0.0000     2              11.8      423.7    423.5
 85.5 -  90.0   0.0000     2              11.8      422.1    422.0
 90.0 -  94.5   0.0000     2              11.8      420.3    420.2
 94.5 -  99.0   0.0000     2              11.8      418.4    418.3
 99.0 - 103.5   0.0000     2              11.7      416.6    416.5
103.5 - 108.0   0.0000     2              11.7      414.7    414.6
108.0 - 112.5   0.0000     2              11.7      411.7    411.6
112.5 - 117.0   0.0000     2              11.7      407.2    407.1
117.0 - 121.5   0.0000     2              11.6      400.6    400.5
121.5 - 126.0   0.0000     2              11.5      391.7    391.6
126.0 - 130.5   0.0000     2              11.4      377.1    377.0
130.5 - 135.0   0.0000     2              11.2      355.9    355.8
135.0 - 139.5   0.0000     2              11.0      332.7    332.7
139.5 - 144.0   0.0000     2              10.8      307.9    307.8
144.0 - 148.5   0.0000     2              10.3      268.1    268.0
148.5 - 153.0   0.0000     2              10.2      244.9    244.9
```

```
-5000
   1      nitrogen esad input, validation analyses
prop    11    1
        1.        100.     100.9     .0154      .240     14.08      .0463
        2.        200.     157.9     .0174      .241     16.67      .0518
        3.        300.     182.1     .0193      .243     19.23      .0580
        4.        400.     206.5     .0212      .245     21.74      .0630
        5.        500.     231.1     .0231      .247     24.27      .0680
        6.        600.     256.0     .0250      .250     26.81      .0720
        7.        700.     281.1     .0268      .253     29.33      .0770
        8.        800.     306.7     .0286      .256     31.85      .0810
       10.        900.     332.5     .0303      .259     34.36      .0850
       15.       1000.     358.6     .0319      .262     36.90      .0889
       20.       2000.     617.2     .0471      .286     62.11      .1242
   lss304        .11      488.       9.8
chan     1   34
     153.0      80.0
   1    1   29    0    1
   1    1    0    0    1
     1.0768.7116.4972   2 .141 .563
     2.17711.3261.326   3 .141 .563    4 .141 .563
     3.0886.6629.6629   5 .141 .563
     4.17711.3261.326   5 .141 .563    7 .141 .563
     5.17711.3261.326   6 .141 .563    8 .141 .563
     6.0768.7116.4972   9 .079 .563
     7.15351.423.9943   8 .141 .563   11 .079 .563
     8.17711.3261.326   9 .141 .563   12 .141 .563
     9.15351.423.9943  10 .079 .563   13 .141 .563
    10.0768.7116.4972  14 .141 .563
    11.15351.423.9943  12 .141 .563   16 .141 .563
    12.15351.423.9943  13 .079 .563   17 .079 .563
    13.15351.423.9943  14 .141 .563   18 .079 .563
    14.17711.3261.326  15 .141 .563   19 .141 .563
    15.0768.7116.4972  20 .079 .563
    16.17711.3261.326  17 .141 .563   22 .141 .563
    17.15351.423.9943  18 .079 .563   23 .141 .563
    18.15351.423.9943  19 .141 .563   24 .141 .563
    19.17711.3261.326  20 .141 .563   25 .141 .563
    20.15351.423.9943  21 .079 .563   26 .141 .563
    21.0768.7116.4972  27 .141 .563
    22.17711.3261.326  23 .141 .563   29 .141 1.68
    23.17711.3261.326  24 .141 .563   29 .141 1.59
    24.17711.3261.326  25 .141 .563   29 .141 1.55
    25.17711.3261.326  26 .141 .563   29 .141 1.47
    26.17711.3261.326  27 .141 .563   29 .141 1.36
    27.17711.3261.326  28 .141 .563   29 .141 1.24
    28.0886.6629.6629  29 .141 1.07
2  299.47010.015.203

rods     1    1    2             1
   1    1   36    0
 2 36 .422  0.0    1 .125
 1 35 .422  1.0    1  .25     2  .25
 1 34 .422  1.0    1 .125     2  .25     3 .125
 1 33 .422  1.0    2  .25     4  .25     .
 1 32 .422  1.0    2  .25     3  .25     4  .25     5  .25
 1 31 .422  1.0    3 .125     5  .25     6 .125
 1 30 .422  1.0    4  .25     7  .25
 1 29 .422  1.0    4  .25     5  .25     7  .25     8  .25
 1 28 .422  1.0    5  .25     6  .25     8  .25     9  .25
```

```
   2 27 .422  0.0    6 .125    9  .25   10 .125
   2 26 .422  0.0    7  .25   11  .25
   1 25 .422  1.0    7  .25    8  .25   11  .25   12  .25
   1 24 .422  1.0    8  .25    9  .25   12  .25   13  .25
   1 23 .422  1.0    9  .25   10  .25   13  .25   14  .25
   1 22 .422  1.0   10 .125   14  .25   15 .125
   1 21 .422  1.0   11  .25   16  .25
   1 20 .422  1.0   11  .25   12  .25   16  .25   17  .25
   2 19 .422  0.0   12  .25   13  .25   17  .25   18  .25
   1 18 .422  1.0   13  .25   14  .25   18  .25   19  .25
   1 17 .422  1.0   14  .25   15  .25   19  .25   20  .25
   2 16 .422  0.0   15 .125   20  .25   21 .125
   1 15 .422  1.0   16  .25   22  .25
   1 14 .422  1.0   16  .25   17  .25   22  .25   23  .25
   1 13 .422  1.0   17  .25   18  .25   23  .25   24  .25
   1 12 .422  1.0   18  .25   19  .25   24  .25   25  .25
   1 11 .422  1.0   19  .25   20  .25   25  .25   26  .25
   1 10 .422  1.0   20  .25   21  .25   26  .25   27  .25
   1  9 .422  1.0   21 .125   27  .25   28 .125
   1  8 .422  1.0   22  .25   29  .25
   1  7 .422  1.0   22  .25   23  .25   29  .50
   1  6 .422  1.0   23  .25   24  .25   29  .50
   1  5 .422  1.0   24  .25   25  .25   29  .50
   1  4 .422  1.0   25  .25   26  .25   29  .50
   1  3 .422  1.0   26  .25   27  .25   29  .50
   1  2 .422  1.0   27  .25   28  .25   29  .50
   1  1 .422  1.0   28 .125   29 .375
    2.8.0717 685..36699.540.0779 409..0243  10.  .422    0
    2.8.0717 685..36699.540.0779 409..0243  10.  .422    0
  slab     0    1    1
      1    1  0.0
      1     13.05     5.203
      1    1    1   29    1

  radg     1    1    0
      1    1    1    1
  heat     2    0    1
                3.66              3.66
               1000.             1000.
    1.0
  drag     2    0
   100. -1.0                100. -1.0
   64.  -1.0                 64. -1.0
  bdry     1    1    1    0
      1      0.01                         1.0
      1    7   .0205.4.0902262.1.3157313.0.5412321.4.7647319.2.9922281.8
                1.0280.5
      1    15.498    1  0.0
      1  1.0    1  1.0    1
  calc     1
     .0                                           .1
        15
  oper     1         3                                                   1
        14.7      230.     .00005     .00230      230.       .005      0.0
     12
     0.   0..0588  .80.1176 1.05.2353 1.13.3529 1.13.4709 1.13
  .5882 1.13.7059 1.13.8235 1.00.9411 .319.9412   0.  1.0  0.
  outp     1
  endd
```

```
data from iterative solution using the recirculation module
time =    0.0000    dt = ******    implicit dt = 0.0000    explicit dt = 0.8966    mode =  0


iteration  sweep          peak clad              total flow     pressure                  error
   no.      no.   ---------------------------    (lbm/s)      drop(psi)     -----------------------------------
                  temp(f)  fluid  rod  ass.                                 total     flow    fluid     rod
                                                                            energy            energy   energy

    1        1     482.3     27    35    1      0.318e-11    0.0044829    91.5772   1.1814   0.0086   0.0316
             2     482.6     26    35    1                                 0.2796   1.1814   0.0734   0.0303

    2        1     483.4     25    35    1      0.129e-11    0.0043283     0.1305   1.3044   0.0185   0.0188
             2     486.4     25    35    1                                 0.0131   1.3044   0.0066   0.0193

    3        1     487.1     25    35    1      0.507e-12    0.0043249     0.0161   2.3611   0.0055   0.0017
             2     488.4     24    35    1                                 0.0033   2.3611   0.0042   0.0024

    4        1     488.7     24    35    1      0.169e-12    0.0043248     0.0051   2.2438   0.0023   0.0012
             2     489.3     23    35    1                                 0.0013   2.2438   0.0023   0.0010

    5        1     489.5     23    35    1      0.834e-13    0.0043249     0.0020   0.7570   0.0008   0.0006
             2     489.8     23    35    1                                 0.0007   0.7570   0.0010   0.0004

    6        1     489.8     23    35    1      0.188e-13    0.0043250     0.0006   0.6934   0.0004   0.0003
             2     489.9     22    35    1                                 0.0005   0.6934   0.0004   0.0002

    7        1     490.0     22    35    1     -0.122e-13    0.0043251     0.0002   0.5455   0.0004   0.0002
             2     490.0     22    35    1                                 0.0005   0.5455   0.0004   0.0001

    8        1     490.0     22    35    1     -0.190e-13    0.0043251     0.0000   0.3601   0.0003   0.0002
             2     490.0     22    35    1                                 0.0004   0.3601   0.0004   0.0001

    9        1     490.1     22    35    1     -0.161e-13    0.0043251    -0.0001   0.2017   0.0003   0.0001
             2     490.1     22    35    1                                 0.0004   0.2017   0.0003   0.0001

   10        1     490.1     22    35    1     -0.808e-14    0.0043251    -0.0001   0.1039   0.0003   0.0001
             2     490.1     22    35    1                                 0.0004   0.1039   0.0003   0.0001

   11        1     490.1     22    35    1     -0.644e-14    0.0043252    -0.0001   0.0534   0.0003   0.0001
             2     490.1     22    35    1                                 0.0004   0.0534   0.0003   0.0001

   12        1     490.1     22    35    1     -0.121e-14    0.0043252    -0.0001   0.0291   0.0003   0.0001
             2     490.1     22    35    1                                 0.0004   0.0291   0.0003   0.0001

   13        1     490.1     22    35    1     -0.252e-15    0.0043252    -0.0001   0.0167   0.0003   0.0001
             2     490.1     22    35    1                                 0.0004   0.0167   0.0003   0.0001

   14        1     490.1     22    35    1     -0.100e-14    0.0043252    -0.0001   0.0101   0.0003   0.0001
             2     490.1     22    35    1                                 0.0004   0.0101   0.0003   0.0001

   15        1     490.1     22    35    1      0.531e-15    0.0043252    -0.0001   0.0064   0.0003   0.0001
             2     490.1     22    35    1                                 0.0004   0.0064   0.0003   0.0001


 side boundary temperature summary     time =    0.0000 seconds
 boundary slab node no.     1
```

```
 axial zone      ( 1)        ( 2)        (
  (inches)

   0.0 -  4.5    214.65      214.64
   4.5 -  9.0    233.14      233.13
   9.0 - 13.5    251.63      251.62
  13.5 - 18.0    264.99      264.98
  18.0 - 22.5    271.63      271.61
  22.5 - 27.0    278.27      278.25
  27.0 - 31.5    284.91      284.89
  31.5 - 36.0    291.55      291.53
  36.0 - 40.5    298.19      298.17
  40.5 - 45.0    304.83      304.81
  45.0 - 49.5    311.47      311.45
  49.5 - 54.0    313.86      313.84
  54.0 - 58.5    314.96      314.94
  58.5 - 63.0    316.05      316.03
  63.0 - 67.5    317.15      317.13
  67.5 - 72.0    318.24      318.22
  72.0 - 76.5    319.34      319.32
  76.5 - 81.0    320.43      320.41
  81.0 - 85.5    321.39      321.37
  85.5 - 90.0    321.10      321.08
  90.0 - 94.5    320.81      320.79
  94.5 - 99.0    320.52      320.50
  99.0 -103.5    320.23      320.21
 103.5 -108.0    319.94      319.92
 108.0 -112.5    319.65      319.63
 112.5 -117.0    319.36      319.34
 117.0 -121.5    316.80      316.78
 121.5 -126.0    311.96      311.95
 126.0 -130.5    307.13      307.11
 130.5 -135.0    302.29      302.28
 135.0 -139.5    297.45      297.44
 139.5 -144.0    292.62      292.61
 144.0 -148.5    287.78      287.77
 148.5 -153.0    282.94      282.94

 calculated rod temperatures at time =    0.0000 seconds
 rod no.   16
 assembly   1                 (fuel type  2 - cylinder)
0rod o.d. - 0.422 (in.)     zone-(fuel dia.(in.)) -  1-(0.367)

                                                 *   fuel temperatures(f.)
                                                 *
  axial zone  heat flux   type           hsurf   *   fluid    clad
     (in.)   (mbtu/hr-ft2)            (b/h-f-ft2) *
   0.0 -   4.5    0.0000    2              1.9       268.6    268.1
   4.5 -   9.0    0.0000    2              1.9       293.2    293.7
   9.0 -  13.5    0.0000    2              2.0       323.0    323.6
  13.5 -  18.0    0.0000    2              2.0       347.7    348.1
  18.0 -  22.5    0.0000    2              2.1       366.1    366.2
  22.5 -  27.0    0.0000    2              2.1       379.4    379.3
  27.0 -  31.5    0.0000    2              2.1       390.0    389.8
  31.5 -  36.0    0.0000    2              2.1       399.0    398.7
  36.0 -  40.5    0.0000    2              2.2       406.4    406.1
  40.5 -  45.0    0.0000    2              2.2       412.4    412.1
  45.0 -  49.5    0.0000    2              2.2       417.6    417.2
  49.5 -  54.0    0.0000    2              2.2       420.8    420.4
```

```
   54.0 -  58.5   0.0000   2             2.2      422.9     422.4
   58.5 -  63.0   0.0000   2             2.2      424.4     423.8
   63.0 -  67.5   0.0000   2             2.2      425.6     425.0
   67.5 -  72.0   0.0000   2             2.2      426.6     426.0
   72.0 -  76.5   0.0000   2             2.2      427.4     426.9
   76.5 -  81.0   0.0000   2             2.2      428.2     427.6
   81.0 -  85.5   0.0000   2             2.2      428.8     428.2
   85.5 -  90.0   0.0000   2             2.2      428.9     428.3
   90.0 -  94.5   0.0000   2             2.2      428.8     428.2
   94.5 -  99.0   0.0000   2             2.2      428.6     428.0
   99.0 - 103.5   0.0000   2             2.2      428.2     427.6
  103.5 - 108.0   0.0000   2             2.2      427.7     427.1
  108.0 - 112.5   0.0000   2             2.2      426.3     425.7
  112.5 - 117.0   0.0000   2             2.2      423.8     423.1
  117.0 - 121.5   0.0000   2             2.2      419.8     419.1
  121.5 - 126.0   0.0000   2             2.2      414.2     413.4
  126.0 - 130.5   0.0000   2             2.1      405.2     404.4
  130.5 - 135.0   0.0000   2             2.1      392.2     391.2
  135.0 - 139.5   0.0000   2             2.1      377.0     376.1
  139.5 - 144.0   0.0000   2             2.1      360.8     359.9
  144.0 - 148.5   0.0000   2             2.0      335.6     334.5
  148.5 - 153.0   0.0000   2             2.0      323.5     323.0


 calculated rod temperatures at time =    0.0000 seconds
 rod no.   27
 assembly   1                  (fuel type  2 - cylinder)
0rod o.d. - 0.422 (in.)     zone-(fuel dia.(in.)) -  1-(0.367)

                                                 *   fuel temperatures(f.)
                                                 *
  axial zone  heat flux   type            hsurf  *   fluid      clad
     (in.)   (mbtu/hr-ft2)             (b/h-f-ft2) *
    0.0 -   4.5   0.0000   2             1.9      276.7     276.7
    4.5 -   9.0   0.0000   2             1.9      300.9     302.2
    9.0 -  13.5   0.0000   2             2.0      333.5     335.2
   13.5 -  18.0   0.0000   2             2.1      363.5     365.0
   18.0 -  22.5   0.0000   2             2.1      387.8     388.9
   22.5 -  27.0   0.0000   2             2.1      405.7     406.4
   27.0 -  31.5   0.0000   2             2.2      419.4     419.8
   31.5 -  36.0   0.0000   2             2.2      430.4     430.7
   36.0 -  40.5   0.0000   2             2.2      439.2     439.3
   40.5 -  45.0   0.0000   2             2.2      446.1     446.1
   45.0 -  49.5   0.0000   2             2.2      451.7     451.6
   49.5 -  54.0   0.0000   2             2.2      455.6     455.5
   54.0 -  58.5   0.0000   2             2.3      458.3     458.1
   58.5 -  63.0   0.0000   2             2.3      460.2     459.9
   63.0 -  67.5   0.0000   2             2.3      461.6     461.3
   67.5 -  72.0   0.0000   2             2.3      462.8     462.4
   72.0 -  76.5   0.0000   2             2.3      463.7     463.4
   76.5 -  81.0   0.0000   2             2.3      464.5     464.1
   81.0 -  85.5   0.0000   2             2.3      465.1     464.7
   85.5 -  90.0   0.0000   2             2.3      465.4     465.0
   90.0 -  94.5   0.0000   2             2.3      465.5     465.1
   94.5 -  99.0   0.0000   2             2.3      465.4     465.0
   99.0 - 103.5   0.0000   2             2.3      465.1     464.7
  103.5 - 108.0   0.0000   2             2.3      464.7     464.3
  108.0 - 112.5   0.0000   2             2.3      463.5     463.0
  112.5 - 117.0   0.0000   2             2.3      461.0     460.4
```

```
 117.0 - 121.5   0.0000    2                2.2     457.1    456.5
 121.5 - 126.0   0.0000    2                2.2     451.9    451.2
 126.0 - 130.5   0.0000    2                2.2     443.0    442.1
 130.5 - 135.0   0.0000    2                2.2     429.0    427.8
 135.0 - 139.5   0.0000    2                2.2     411.8    410.4
 139.5 - 144.0   0.0000    2                2.1     392.5    391.1
 144.0 - 148.5   0.0000    2                2.1     361.9    360.0
 148.5 - 153.0   0.0000    2                2.0     342.6    341.3


 calculated rod temperatures at time =    0.0000 seconds
 rod no.   36
 assembly   1                (fuel type  2 - cylinder)
0rod o.d. - 0.422 (in.)     zone-(fuel dia.(in.)) -  1-(0.367)

                                                *   fuel temperatures(f.)
                                                *
   axial zone  heat flux   type          hsurf  *   fluid    clad
      (in.)   (mbtu/hr-ft2)          (b/h-f-ft2) *
   0.0 -   4.5   0.0000    2                1.9     280.5    280.8
   4.5 -   9.0   0.0000    2                2.0     304.2    305.9
   9.0 -  13.5   0.0000    2                2.0     337.6    340.0
  13.5 -  18.0   0.0000    2                2.1     370.6    373.0
  18.0 -  22.5   0.0000    2                2.1     399.0    400.9
  22.5 -  27.0   0.0000    2                2.2     420.5    421.8
  27.0 -  31.5   0.0000    2                2.2     436.9    437.8
  31.5 -  36.0   0.0000    2                2.2     449.8    450.3
  36.0 -  40.5   0.0000    2                2.3     459.8    460.1
  40.5 -  45.0   0.0000    2                2.3     467.4    467.6
  45.0 -  49.5   0.0000    2                2.3     473.5    473.5
  49.5 -  54.0   0.0000    2                2.3     478.0    477.9
  54.0 -  58.5   0.0000    2                2.3     481.2    481.0
  58.5 -  63.0   0.0000    2                2.3     483.4    483.1
  63.0 -  67.5   0.0000    2                2.3     485.1    484.7
  67.5 -  72.0   0.0000    2                2.3     486.3    485.9
  72.0 -  76.5   0.0000    2                2.3     487.3    486.9
  76.5 -  81.0   0.0000    2                2.3     488.1    487.7
  81.0 -  85.5   0.0000    2                2.3     488.8    488.4
  85.5 -  90.0   0.0000    2                2.3     489.2    488.7
  90.0 -  94.5   0.0000    2                2.3     489.4    488.9
  94.5 -  99.0   0.0000    2                2.3     489.4    488.9
  99.0 - 103.5   0.0000    2                2.3     489.2    488.7
 103.5 - 108.0   0.0000    2                2.3     488.9    488.4
 108.0 - 112.5   0.0000    2                2.3     487.8    487.2
 112.5 - 117.0   0.0000    2                2.3     485.4    484.7
 117.0 - 121.5   0.0000    2                2.3     481.7    480.9
 121.5 - 126.0   0.0000    2                2.3     476.0    475.9
 126.0 - 130.5   0.0000    2                2.3     468.1    466.9
 130.5 - 135.0   0.0000    2                2.2     453.9    452.4
 135.0 - 139.5   0.0000    2                2.2     436.0    434.2
 139.5 - 144.0   0.0000    2                2.2     415.3    413.3
 144.0 - 148.5   0.0000    2                2.1     382.7    379.9
 148.5 - 153.0   0.0000    2                2.1     359.0    356.9
```

```
+5000
    1      vacuum emad input, validation analyses
prop    11    1
        1.       100.      100.9     .0154      .240      14.08     .0463
        2.       200.      157.9     .0174      .241      16.67     .0518
        3.       300.      182.1     .0193      .243      19.23     .0580
        4.       400.      206.5     .0212      .245      21.74     .0630
        5.       500.      231.1     .0231      .247      24.27     .0680
        6.       600.      256.0     .0250      .250      26.81     .0720
        7.       700.      281.1     .0268      .253      29.33     .0770
        8.       800.      306.7     .0286      .256      31.85     .0810
       10.       900.      332.5     .0303      .259      34.36     .0850
       15.      1000.      358.6     .0319      .262      36.90     .0889
       20.      2000.      617.2     .0471      .286      62.11     .1242
    1ss304        .11      486.       9.8
chan     1   34
     153.0       90.0
    1    1   29    0    1
    1    1    0    0    1
    1.0768.7116.4972   2 .141 .563
    2.17711.3261.326   3 .141 .563    4 .141 .563
    3.0886.6629.6629   5 .141 .563
    4.17711.3261.326   5 .141 .563    7 .141 .563
    5.17711.3261.326   6 .141 .563    8 .141 .563
    6.0768.7116.4972   9 .079 .563
    7.15351.423.9943   8 .141 .563   11 .079 .563
    8.17711.3261.326   9 .141 .563   12 .141 .563
    9.15351.423.9943  10 .079 .563   13 .141 .563
   10.0768.7116.4972  14 .141 .563
   11.15351.423.9943  12 .141 .563   16 .141 .563
   12.15351.423.9943  13 .079 .563   17 .079 .563
   13.15351.423.9943  14 .141 .563   18 .079 .563
   14.17711.3261.326  15 .141 .563   19 .141 .563
   15.0768.7116.4972  20 .079 .563
   16.17711.3261.326  17 .141 .563   22 .141 .563
   17.15351.423.9943  18 .079 .563   23 .141 .563
   18.15351.423.9943  19 .141 .563   24 .141 .563
   19.17711.3261.326  20 .141 .563   25 .141 .563
   20.15351.423.9943  21 .079 .563   26 .141 .563
   21.0768.7116.4972  27 .141 .563
   22.17711.3261.326  23 .141 .563   29 .141 1.68
   23.17711.3261.326  24 .141 .563   29 .141 1.59
   24.17711.3261.326  25 .141 .563   29 .141 1.55
   25.17711.3261.326  26 .141 .563   29 .141 1.47
   26.17711.3261.326  27 .141 .563   29 .141 1.36
   27.17711.3261.326  28 .141 .563   29 .141 1.24
   28.0886.6629.6629  29 .141 1.07
2  299.47010.015.283

rods     1    1    2            1
    1    1   36    0
  2 36 .422  0.0   1 .125
  1 35 .422  1.0   1  .25    2  .25
  1 34 .422  1.0   1 .125    2  .25    3 .125
  1 33 .422  1.0   2  .25    4  .25
  1 32 .422  1.0   2  .25    3  .25    4  .25    5  .25
  1 31 .422  1.0   3 .125    5  .25    6 .125
  1 30 .422  1.0   4  .25    7  .25
  1 29 .422  1.0   4  .25    5  .25    7  .25    8  .25
  1 28 .422  1.0   5  .25    6  .25    8  .25    9  .25
```

```
 2 27 .422  0.0    6 .125    9  .25   10 .125
 2 26 .422  0.0    7  .25   11  .25
 1 25 .422  1.0    7  .25    8  .25   11  .25   12  .25
 1 24 .422  1.0    8  .25    9  .25   12  .25   13  .25
 1 23 .422  1.0    9  .25   10  .25   13  .25   14  .25
 1 22 .422  1.0   10 .125   14  .25   15 .125
 1 21 .422  1.0   11  .25   16  .25
 1 20 .422  1.0   11  .25   12  .25   16  .25   17  .25
 2 19 .422  0.0   12  .25   13  .25   17  .25   18  .25
 1 18 .422  1.0   13  .25   14  .25   18  .25   19  .25
 1 17 .422  1.0   14  .25   15  .25   19  .25   20  .25
 2 16 .422  0.0   15 .125   20  .25   21 .125
 1 15 .422  1.0   16  .25   22  .25
 1 14 .422  1.0   16  .25   17  .25   22  .25   23  .25
 1 13 .422  1.0   17  .25   18  .25   23  .25   24  .25
 1 12 .422  1.0   18  .25   19  .25   24  .25   25  .25
 1 11 .422  1.0   19  .25   20  .25   25  .25   26  .25
 1 10 .422  1.0   20  .25   21  .25   26  .25   27  .25
 1  9 .422  1.0   21 .125   27  .25   28 .125
 1  8 .422  1.0   22  .25   29  .25
 1  7 .422  1.0   22  .25   23  .25   29  .50
 1  6 .422  1.0   23  .25   24  .25   29  .50
 1  5 .422  1.0   24  .25   25  .25   29  .50
 1  4 .422  1.0   25  .25   26  .25   29  .50
 1  3 .422  1.0   26  .25   27  .25   29  .50
 1  2 .422  1.0   27  .25   28  .25   29  .50
 1  1 .422  1.0   28 .125   29 .375
  2.6.0717 685..36699.540.0779 409..0243  10. .422     0
  2.6.0717 685..36699.540.0779 409..0243  10. .422     0
slab     0    1    1
   1    1  0.0
   1     13.05      5.203
   1    1    1   29    1

radg     1    1    0
   1    1    1    1
heat     2    0    1
               1.00                1.00
              1000.               1000.
 1.0
drag     2    0
 100. -1.0                 100. -1.0
 64.  -1.0                  64. -1.0
bdry     1    1    1    0
   1      0.01                          1.0
   1    7    .0207.9.0902262.0.3157316.3.5412318.1.7647301.7.9922238.5
             1.0236.3
   1    15.498    1  0.0
   1  1.0    1  1.0    1
calc     1
  .0                                            .1
      15
oper     1         3                                                  1
     14.7      230.     .00005    .00230      230.      .005       0.0
.  12
  0.    0..0588  .80.1176 1.05.2353 1.13.3529 1.13.4709 1.13
.5882 1.13.7059 1.13.8235 1.00.9411 .319.9412   0.  1.0   0.
outp     1
endd
```

```
data from iterative solution using the recirculation module
time =    0.0000    dt = ******    implicit dt = 0.0000    explicit dt = ******    mode =  0


iteration  sweep           peak clad              total flow    pressure                error
   no.      no.   ----------------------------    (lbm/s)      drop(psi)    -------------------------------------
                  temp(f)  fluid  rod  ass.                                   total     flow    fluid     rod
                                                                              energy            energy   energy

    1        1     492.0    26    35    1      0.317e-11  -0.0000260     18.2264   4.5391   0.0138   0.0122
             2     492.2    25    35    1                                 0.2451   4.5391   0.1110   0.0118

    2        1     502.2    20    35    1      0.168e-11   0.0000000      0.0129   0.9988   0.0266   0.0144
             2     503.7    20    35    1                                 0.0001   0.9988   0.0116   0.0031

    3        1     505.0    20    35    1      0.716e-12   0.0000000      0.0011   0.9973   0.0071   0.0019
             2     505.6    20    35    1                                 0.0004   0.9973   0.0043   0.0011

    4        1     505.9    20    35    1      0.162e-12   0.0000000     -0.0009   0.9942   0.0025   0.0007
             2     506.0    20    35    1                                 0.0001   0.9942   0.0024   0.0004

    5        1     506.0    20    35    1     -0.668e-13   0.0000000      0.0000   0.3335   0.0013   0.0002
             2     506.1    19    35    1                                 0.0000   0.3335   0.0020   0.0001

    6        1     506.1    20    35    1     -0.114e-12   0.0000000      0.0000   0.0996   0.0015   0.0001
             2     506.1    19    35    1                                 0.0000   0.0996   0.0018   0.0001

    7        1     506.1    20    35    1     -0.960e-13   0.0000000      0.0000   0.0298   0.0015   0.0001
             2     506.1    19    35    1                                 0.0000   0.0298   0.0017   0.0000

    8        1     506.1    20    35    1     -0.522e-13   0.0000000      0.0000   0.0087   0.0015   0.0001
             2     506.1    19    35    1                                 0.0000   0.0087   0.0017   0.0001


cobra-sfs code results
case    1       vacuum emad input, validation analyses                          date  06/11/07 time  10:38:37


  side boundary temperature summary      time =     0.0000 seconds
  boundary slab node no.      1


 axial zone      (  1)        (  2)        (
  (inches)

  0.0 -  4.5     216.72       216.72
  4.5 -  9.0     234.37       234.36
  9.0 - 13.5     252.02       252.00
 13.5 - 18.0     265.09       265.07
 18.0 - 22.5     272.17       272.15
 22.5 - 27.0     279.25       279.23
 27.0 - 31.5     286.33       286.31
 31.5 - 36.0     293.42       293.40
 36.0 - 40.5     300.50       300.48
 40.5 - 45.0     307.58       307.56
```

```
  45.0 - 49.5     314.66      314.64
  49.5 - 54.0     316.50      316.48
  54.0 - 58.5     316.74      316.71
  58.5 - 63.0     316.97      316.95
  63.0 - 67.5     317.20      317.18
  67.5 - 72.0     317.44      317.42
  72.0 - 76.5     317.67      317.65
  76.5 - 81.0     317.91      317.89
  81.0 - 85.5     317.91      317.89
  85.5 - 90.0     315.75      315.73
  90.0 - 94.5     313.59      313.57
  94.5 - 99.0     311.43      311.41
  99.0 -103.5     309.27      309.25
 103.5 -108.0     307.12      307.10
 108.0 -112.5     304.96      304.94
 112.5 -117.0     302.80      302.78
 117.0 -121.5     297.63      297.61
 121.5 -126.0     289.46      289.44
 126.0 -130.5     281.29      281.27
 130.5 -135.0     273.11      273.10
 135.0 -139.5     264.94      264.93
 139.5 -144.0     256.77      256.76
 144.0 -148.5     248.59      248.59
 148.5 -153.0     240.42      240.42


 calculated rod temperatures at time =    0.0000 seconds
 rod no.   16
 assembly   1                   (fuel type  2 - cylinder)
0rod o.d. - 0.422 (in.)     zone-(fuel dia.(in.)) -  1-(0.367)

                                                    *   fuel temperatures(f.)
                                                    *
   axial zone  heat flux   type             hsurf   *   fluid     clad
      (in.)   (mbtu/hr-ft2)             (b/h-f-ft2) *
   0.0 -   4.5    0.0000     2                0.5       253.0     252.8
   4.5 -   9.0    0.0000     2                0.5       325.1     324.7
   9.0 -  13.5    0.0000     2                0.6       368.1     367.6
  13.5 -  18.0    0.0000     2                0.6       389.8     389.2
  18.0 -  22.5    0.0000     2                0.6       401.5     400.9
  22.5 -  27.0    0.0000     2                0.6       407.9     407.3
  27.0 -  31.5    0.0000     2                0.6       414.3     413.7
  31.5 -  36.0    0.0000     2                0.6       420.6     420.0
  36.0 -  40.5    0.0000     2                0.6       426.1     425.5
  40.5 -  45.0    0.0000     2                0.6       430.7     430.1
  45.0 -  49.5    0.0000     2                0.6       435.3     434.7
  49.5 -  54.0    0.0000     2                0.6       436.6     436.0
  54.0 -  58.5    0.0000     2                0.6       436.7     436.1
  58.5 -  63.0    0.0000     2                0.6       436.9     436.3
  63.0 -  67.5    0.0000     2                0.6       437.0     436.4
  67.5 -  72.0    0.0000     2                0.6       437.2     436.6
  72.0 -  76.5    0.0000     2                0.6       437.3     436.7
  76.5 -  81.0    0.0000     2                0.6       437.5     436.9
  81.0 -  85.5    0.0000     2                0.6       437.5     436.9
  85.5 -  90.0    0.0000     2                0.6       436.1     435.5
  90.0 -  94.5    0.0000     2                0.6       434.7     434.0
  94.5 -  99.0    0.0000     2                0.6       433.2     432.6
  99.0 - 103.5    0.0000     2                0.6       431.8     431.2
 103.5 - 108.0    0.0000     2                0.6       430.4     429.8
```

```
 108.0 - 112.5    0.0000    2               0.6      427.6    426.9
 112.5 - 117.0    0.0000    2               0.6      423.2    422.6
 117.0 - 121.5    0.0000    2               0.6      416.8    416.2
 121.5 - 126.0    0.0000    2               0.6      408.4    407.8
 126.0 - 130.5    0.0000    2               0.6      393.1    392.5
 130.5 - 135.0    0.0000    2               0.6      369.6    369.1
 135.0 - 139.5    0.0000    2               0.6      344.3    343.8
 139.5 - 144.0    0.0000    2               0.5      316.6    316.2
 144.0 - 148.5    0.0000    2               0.5      248.8    248.8
 148.5 - 153.0    0.0000    2               0.5      240.4    240.4


 calculated rod temperatures at time =    0.0000 seconds
 rod no.   27
 assembly  1                   (fuel type  2 - cylinder)
0rod o.d. - 0.422 (in.)     zone-(fuel dia.(in.)) -  1-(0.367)

                                               *  fuel temperatures(f.)
                                               *
   axial zone  heat flux   type          hsurf *  fluid    clad
      (in.)   (mbtu/hr-ft2)        (b/h-f-ft2) *
   0.0 -   4.5    0.0000    2               0.5      267.3    267.2
   4.5 -   9.0    0.0000    2               0.6      357.0    356.9
   9.0 -  13.5    0.0000    2               0.6      407.4    407.2
  13.5 -  18.0    0.0000    2               0.6      431.5    431.3
  18.0 -  22.5    0.0000    2               0.6      444.6    444.3
  22.5 -  27.0    0.0000    2               0.6      450.9    450.6
  27.0 -  31.5    0.0000    2               0.6      457.2    456.9
  31.5 -  36.0    0.0000    2               0.6      463.5    463.2
  36.0 -  40.5    0.0000    2               0.6      468.6    468.4
  40.5 -  45.0    0.0000    2               0.6      472.7    472.4
  45.0 -  49.5    0.0000    2               0.6      476.7    476.5
  49.5 -  54.0    0.0000    2               0.6      477.8    477.5
  54.0 -  58.5    0.0000    2               0.6      478.0    477.7
  58.5 -  63.0    0.0000    2               0.6      478.1    477.8
  63.0 -  67.5    0.0000    2               0.6      478.2    477.9
  67.5 -  72.0    0.0000    2               0.6      478.4    478.1
  72.0 -  76.5    0.0000    2               0.6      478.5    478.2
  76.5 -  81.0    0.0000    2               0.6      478.6    478.4
  81.0 -  85.5    0.0000    2               0.6      478.6    478.4
  85.5 -  90.0    0.0000    2               0.6      477.4    477.1
  90.0 -  94.5    0.0000    2               0.6      476.1    475.8
  94.5 -  99.0    0.0000    2               0.6      474.9    474.6
  99.0 - 103.5    0.0000    2               0.6      473.7    473.4
 103.5 - 108.0    0.0000    2               0.6      472.4    472.1
 108.0 - 112.5    0.0000    2               0.6      469.3    469.1
 112.5 - 117.0    0.0000    2               0.6      464.4    464.1
 117.0 - 121.5    0.0000    2               0.6      457.6    457.3
 121.5 - 126.0    0.0000    2               0.6      449.0    448.7
 126.0 - 130.5    0.0000    2               0.6      431.6    431.3
 130.5 - 135.0    0.0000    2               0.6      403.7    403.4
 135.0 - 139.5    0.0000    2               0.6      373.1    372.9
 139.5 - 144.0    0.0000    2               0.6      339.2    339.0
 144.0 - 148.5    0.0000    2               0.5      248.9    248.9
 148.5 - 153.0    0.0000    2               0.5      240.5    240.5


 calculated rod temperatures at time =    0.0000 seconds
 rod no.   36
```

```
 assembly   1                   (fuel type  2 - cylinder)
0rod o.d. - 0.422 (in.)     zone-(fuel dia.(in.)) -  1-(0.367)

                                                 *   fuel temperatures(f.)
                                                 *
  axial zone  heat flux   type            hsurf  *   fluid    clad
     (in.)   (mbtu/hr-ft2)             (b/h-f-ft2) *
   0.0 -   4.5    0.0000    2                0.5     276.9    276.8
   4.5 -   9.0    0.0000    2                0.6     377.7    377.5
   9.0 -  13.5    0.0000    2                0.6     432.4    432.1
  13.5 -  18.0    0.0000    2                0.6     458.1    457.7
  18.0 -  22.5    0.0000    2                0.6     471.9    471.5
  22.5 -  27.0    0.0000    2                0.6     478.2    477.9
  27.0 -  31.5    0.0000    2                0.6     484.5    484.1
  31.5 -  36.0    0.0000    2                0.6     490.8    490.4
  36.0 -  40.5    0.0000    2                0.6     495.7    495.4
  40.5 -  45.0    0.0000    2                0.6     499.4    499.1
  45.0 -  49.5    0.0000    2                0.6     503.2    502.8
  49.5 -  54.0    0.0000    2                0.6     504.2    503.8
  54.0 -  58.5    0.0000    2                0.6     504.3    504.0
  58.5 -  63.0    0.0000    2                0.6     504.5    504.1
  63.0 -  67.5    0.0000    2                0.6     504.6    504.2
 . 67.5 -  72.0    0.0000    2                0.6     504.7    504.3
  72.0 -  76.5    0.0000    2                0.6     504.9    504.5
  76.5 -  81.0    0.0000    2                0.6     505.0    504.6
  81.0 -  85.5    0.0000    2                0.6     505.0    504.6
  85.5 -  90.0    0.0000    2                0.6     503.8    503.4
  90.0 -  94.5    0.0000    2                0.6     502.7    502.3
  94.5 -  99.0    0.0000    2                0.6     501.5    501.1
  99.0 - 103.5    0.0000    2                0.6     500.4    500.0
 103.5 - 108.0    0.0000    2                0.6     499.2    498.8
 108.0 - 112.5    0.0000    2                0.6     496.0    495.6
 112.5 - 117.0    0.0000    2                0.6     490.7    490.3
 117.0 - 121.5    0.0000    2                0.6     483.7    483.3
 121.5 - 126.0    0.0000    2                0.6     474.9    474.5
 126.0 - 130.5    0.0000    2                0.6     456.3    455.9
 130.5 - 135.0    0.0000    2                0.6     425.7    425.4
 135.0 - 139.5    0.0000    2                0.6     392.0    391.7
 139.5 - 144.0    0.0000    2                0.6     354.2    353.9
 144.0 - 148.5    0.0000    2                0.5     249.1    249.0
 148.5 - 153.0    0.0000    2                0.5     240.5    240.5
```

APPENDIX B

ELECTRICALLY HEATED PWR SINGLE ASSEMBLY SPENT FUEL TEST SIMULATIONS INPUT, OUTPUT, AND CONVERGENCE LISTS

APPENDIX B

ELECTRICALLY HEATED PWR SINGLE ASSEMBLY SPENT FUEL TEST SIMULATIONS INPUT, OUTPUT, AND CONVERGENCE LISTS

	Page Number		
Test Case	Input	Convergence List	Output
Vertical, nitrogen	B.2	B.14	B.15
Inclined, nitrogen	B.18	B.30	B.31
Horizontal, nitrogen	B.34	B.46	A.46

```
+8000
   1    1     agns vertical nitrogen full-load validation analyses
prop    11    2
        1.       100.      133.9     .0154       .240     14.08      .0463
        2.       200.      157.9     .0174       .241     16.67      .0518
        3.       300.      182.1     .0193       .243     19.23      .0580
        4.       400.      206.5     .0212       .245     21.74      .0630
        5.       500.      231.1     .0231       .247     24.27      .0680
        6.       600.      256.0     .0250       .250     26.81      .0720
        7.       700.      281.1     .0268       .253     29.33      .0770
        8.       800.      306.7     .0286       .256     31.85      .0810
       10.       900.      332.5     .0303       .259     34.36      .0850
       15.      1000.      358.6     .0319       .262     36.90      .0889
       20.      2000.      617.2     .0471       .286     62.11      .1242
   1  can                            13.
   2steel                           100.
chan     2   24
     165.3         0.0
   1     1  256    0
   1     1    0    0    1
   1.21091.321.3299    2.2855 .538    17.2855 .538
   2.21861.241.6597    3.2855 .581    18 .161 .433
   3.21861.241.6597    4.2855 .581    19 .161 .433
   4.21861.241.6597    5.2855 .581    20 .161 .433
   5.21861.241.6597    6.2855 .581    21 .161 .433
   6.21861.241.6597    7.2855 .581    22 .161 .433
   7.21861.241.6597    8.2855 .581    23 .161 .433
   8.21861.241.6597    9.2855 .581    24 .161 .433
   9.21861.241.6597   10.2855 .581    25 .161 .433
  10.21861.241.6597   11.2855 .581    26 .161 .433
  11.21861.241.6597   12.2855 .581    27 .161 .433
  12.21861.241.6597   13.2855 .581    28 .161 .433
  13.21861.241.6597   14.2855 .581    29 .161 .433
  14.21861.241.6597   15.2855 .581    30 .161 .433
  15.21861.241.6597   16.2855 .581    31 .161 .433
  16.21091.321.3299   32.2855 .538
  17.21861.241.6597   18 .161 .581    33.2855 .433
  18 .1991.3201.320   19 .161 .581    34 .161 .581
  19 .1991.3201.320   20 .161 .581    35 .161 .581
  20 .1991.3201.320   21 .161 .581    36 .161 .581
  21 .1991.3201.320   22 .161 .581    37 .161 .581
  22 .1991.3201.320   23 .161 .581    38 .161 .581
  23 .1991.3201.320   24 .161 .581    39 .161 .581
  24 .1991.3201.320   25 .161 .581    40 .161 .581
  25 .1991.3201.320   26 .161 .581    41 .161 .581
  26 .1991.3201.320   27 .161 .581    42 .161 .581
  27 .1991.3201.320   28 .161 .581    43 .161 .581
  28 .1991.3201.320   29 .161 .581    44 .161 .581
  29 .1991.3201.320   30 .161 .581    45 .161 .581
  30 .1991.3201.320   31 .161 .581    46 .161 .581
  31 .1991.3201.320   32 .161 .433    47 .161 .581
  32.21861.241.6597   48.2855 .581
  33.21861.241.6597   34 .161 .581    49.2855 .433
  34 .1991.3201.320   35 .161 .581    50 .161 .581
  35.18461.3821.382   36 .121 .581    51 .121 .581
  36.18461.3821.382   37 .161 .581    52 .121 .581
  37 .1991.3201.320   38 .161 .581    53 .161 .581
  38 .1991.3201.320   39 .161 .581    54 .161 .581
  39 .1991.3201.320   40 .161 .581    55 .161 .581
  40 .1991.3201.320   41 .161 .581    56 .161 .581
```

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41 .1991.3201.320   42 .161 .581   57 .161 .581
42 .1991.3201.320   43 .161 .581   58 .161 .581
43 .1991.3201.320   44 .161 .581   59 .161 .581
44 .1991.3201.320   45 .161 .581   60 .161 .581
45.18461.3821.382   46 .121 .581   61 .121 .581
46.18461.3821.382   47 .161 .581   62 .121 .581
47 .1991.3201.320   48 .161 .433   63 .161 .581
48.21861.241.6597   64.2855 .581
49.21861.241.6597   50 .161 .581   65.2855 .433
50 .1991.3201.320   51 .161 .581   66 .161 .581
51.18461.3821.382   52 .121 .581   67 .161 .581
52.18461.3821.382   53 .161 .581   68 .161 .581
53 .1991.3201.320   54 .161 .581   69 .161 .581
54 .1991.3201.320   55 .161 .581   70 .161 .581
55 .1991.3201.320   56 .161 .581   71 .161 .581
56 .1991.3201.320   57 .161 .581   72 .161 .581
57 .1991.3201.320   58 .161 .581   73 .161 .581
58 .1991.3201.320   59 .161 .581   74 .161 .581
59 .1991.3201.320   60 .161 .581   75 .161 .581
60 .1991.3201.320   61 .161 .581   76 .161 .581
61.18461.3821.382   62 .121 .581   77 .161 .581
62.18461.3821.382   63 .161 .581   78 .161 .581
63 .1991.3201.320   64 .161 .433   79 .161 .581
64.21861.241.6597   80.2855 .581
65.21861.241.6597   66 .161 .581   81.2855 .433
66 .1991.3201.320   67 .161 .581   82 .161 .581
67 .1991.3201.320   68 .161 .581   83 .161 .581
68 .1991.3201.320   69 .161 .581   84 .161 .581
69.18461.3821.382   70 .121 .581   85 .121 .581
70.18461.3821.382   71 .161 .581   86 .121 .581
71 .1991.3201.320   72 .161 .581   87 .161 .581
72 .1991.3201.320   73 .161 .581   88 .161 .581
73 .1991.3201.320   74 .161 .581   89 .161 .581
74 .1991.3201.320   75 .161 .581   90 .161 .581
75.18461.3821.382   76 .121 .581   91 .121 .581
76.18461.3821.382   77 .161 .581   92 .121 .581
77 .1991.3201.320   78 .161 .581   93 .161 .581
78 .1991.3201.320   79 .161 .581   94 .161 .581
79.18461.3821.382   80 .121 .433   95 .121 .581
80.20421.304.7220   96.2455 .581
81.21861.241.6597   82 .161 .581   97.2855 .433
82 .1991.3201.320   83 .161 .581   98 .161 .581
83 .1991.3201.320   84 .161 .581   99 .161 .581
84 .1991.3201.320   85 .161 .581  100 .161 .581
85.18461.3821.382   86 .121 .581  101 .161 .581
86.18461.3821.382   87 .161 .581  102 .161 .581
87 .1991.3201.320   88 .161 .581  103 .161 .581
88 .1991.3201.320   89 .161 .581  104 .161 .581
89 .1991.3201.320   90 .161 .581  105 .161 .581
90 .1991.3201.320   91 .161 .581  106 .161 .581
91.18461.3821.382   92 .121 .581  107 .161 .581
92.18461.3821.382   93 .161 .581  108 .161 .581
93 .1991.3201.320   94 .161 .581  109 .161 .581
94 .1991.3201.320   95 .161 .581  110 .161 .581
95.18461.3821.382   96 .121 .433  111 .161 .581
96.20421.304.7220  112.2455 .581
97.21861.241.6597   98 .161 .581  113.2855 .433
98 .1991.3201.320   99 .161 .581  114 .161 .581
99 .1991.3201.320  100 .161 .581  115 .161 .581
100 .1991.3201.320 101 .161 .581  116 .161 .581
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101 .1991.3201.320  102 .161 .581  117 .161 .581
102 .1991.3201.320  103 .161 .581  118 .161 .581
103 .1991.3201.320  104 .161 .581  119 .161 .581
104 .1991.3201.320  105 .161 .581  120 .161 .581
105 .1991.3201.320  106 .161 .581  121 .161 .581
106 .1991.3201.320  107 .161 .581  122 .161 .581
107 .1991.3201.320  108 .161 .581  123 .161 .581
108 .1991.3201.320  109 .161 .581  124 .161 .581
109 .1991.3201.320  110 .161 .581  125 .161 .581
110 .1991.3201.320  111 .161 .581  126 .161 .581
111 .1991.3201.320  112 .161 .433  127 .161 .581
112.21861.241.6597  128.2855 .581
113.21861.241.6597  114 .161 .581  129.2855 .433
114 .1991.3201.320  115 .161 .581  130 .161 .581
115 .1991.3201.320  116 .161 .581  131 .161 .581
116 .1991.3201.320  117 .161 .581  132 .161 .581
117 .1991.3201.320  118 .161 .581  133 .161 .581
118 .1991.3201.320  119 .161 .581  134 .161 .581
119 .1991.3201.320  120 .161 .581  135 .161 .581
120.18461.3821.382  121 .121 .581  136 .121 .581
121.18461.3821.382  122 .161 .581  137 .121 .581
122 .1991.3201.320  123 .161 .581  138 .161 .581
123 .1991.3201.320  124 .161 .581  139 .161 .581
124 .1991.3201.320  125 .161 .581  140 .161 .581
125 .1991.3201.320  126 .161 .581  141 .161 .581
126 .1991.3201.320  127 .161 .581  142 .161 .581
127 .1991.3201.320  128 .161 .433  143 .161 .581
128.21861.241.6597  144.2855 .581
129.21861.241.6597  130 .161 .581  145.2855 .433
130 .1991.3201.320  131 .161 .581  146 .161 .581
131 .1991.3201.320  132 .161 .581  147 .161 .581
132 .1991.3201.320  133 .161 .581  148 .161 .581
133 .1991.3201.320  134 .161 .581  149 .161 .581
134 .1991.3201.320  135 .161 .581  150 .161 .581
135 .1991.3201.320  136 .161 .581  151 .161 .581
136.18461.3821.382  137 .121 .581  152 .161 .581
137.18461.3821.382  138 .161 .581  153 .161 .581
138 .1991.3201.320  139 .161 .581  154 .161 .581
139 .1991.3201.320  140 .161 .581  155 .161 .581
140 .1991.3201.320  141 .161 .581  156 .161 .581
141 .1991.3201.320  142 .161 .581  157 .161 .581
142 .1991.3201.320  143 .161 .581  158 .161 .581
143 .1991.3201.320  144 .161 .433  159 .161 .581
144.21861.241.6597  160.2855 .581
145.21861.241.6597  146 .161 .581  161.2855 .433
146 .1991.3201.320  147 .161 .581  162 .161 .581
147 .1991.3201.320  148 .161 .581  163 .161 .581
148 .1991.3201.320  149 .161 .581  164 .161 .581
149 .1991.3201.320  150 .161 .581  165 .161 .581
150 .1991.3201.320  151 .161 .581  166 .161 .581
151 .1991.3201.320  152 .161 .581  167 .161 .581
152 .1991.3201.320  153 .161 .581  168 .161 .581
153 .1991.3201.320  154 .161 .581  169 .161 .581
154 .1991.3201.320  155 .161 .581  170 .161 .581
155 .1991.3201.320  156 .161 .581  171 .161 .581
156 .1991.3201.320  157 .161 .581  172 .161 .581
157 .1991.3201.320  158 .161 .581  173 .161 .581
158 .1991.3201.320  159 .161 .581  174 .161 .581
159 .1991.3201.320  160 .161 .433  175 .161 .581
160.21861.241.6597  176.2855 .581
```

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161.21861.241.6597  162 .161 .581  177.2855 .433
162 .1991.3201.320  163 .161 .581  178 .161 .581
163 .1991.3201.320  164 .161 .581  179 .161 .581
164 .1991.3201.320  165 .161 .581  180 .161 .581
165.18461.3821.382  166 .121 .581  181 .121 .581
166.18461.3821.382  167 .161 .581  182 .121 .581
167 .1991.3201.320  168 .161 .581  183 .161 .581
168 .1991.3201.320  169 .161 .581  184 .161 .581
169 .1991.3201.320  170 .161 .581  185 .161 .581
170 .1991.3201.320  171 .161 .581  186 .161 .581
171.18461.3821.382  172 .121 .581  187 .121 .581
172.18461.3821.382  173 .161 .581  188 .121 .581
173 .1991.3201.320  174 .161 .581  189 .161 .581
174 .1991.3201.320  175 .161 .581  190 .161 .581
175.18461.3821.382  176 .121 .433  191 .161 .581
176.20421.304.7226  192.2455 .581
177.21861.241.6597  178 .161 .581  193.2855 .433
178 .1991.3201.320  179 .161 .581  194 .161 .581
179 .1991.3201.320  180 .161 .581  195 .161 .581
180 .1991.3201.320  181 .161 .581  196 .161 .581
181.18461.3821.382  182 .121 .581  197 .161 .581
182.18461.3821.382  183 .161 .581  198 .161 .581
183 .1991.3201.320  184 .161 .581  199 .161 .581
184 .1991.3201.320  185 .161 .581  200 .161 .581
185 .1991.3201.320  186 .161 .581  201 .161 .581
186 .1991.3201.320  187 .161 .581  202 .161 .581
187.18461.3821.382  188 .121 .581  203 .161 .581
188.18461.3821.382  189 .161 .581  204 .161 .581
189 .1991.3201.320  190 .161 .581  205 .161 .581
190 .1991.3201.320  191 .161 .581  206 .161 .581
191.18461.3821.382  192 .121 .433  207 .161 .581
192.20421.304.7226  208.2455 .581
193.21861.241.6597  194 .161 .581  209.2855 .433
194 .1991.3201.320  195 .161 .581  210 .161 .581
195.18461.3821.382  196 .121 .581  211 .121 .581
196.18461.3821.382  197 .161 .581  212 .121 .581
197 .1991.3201.320  198 .161 .581  213 .161 .581
198 .1991.3201.320  199 .161 .581  214 .161 .581
199 .1991.3201.320  200 .161 .581  215 .161 .581
200 .1991.3201.320  201 .161 .581  216 .161 .581
201 .1991.3201.320  202 .161 .581  217 .161 .581
202 .1991.3201.320  203 .161 .581  218 .161 .581
203 .1991.3201.320  204 .161 .581  219 .161 .581
204 .1991.3201.320  205 .161 .581  220 .161 .581
205.18461.3821.382  206 .121 .581  221 .121 .581
206.18461.3821.382  207 .161 .581  222 .121 .581
207 .1991.3201.320  208 .161 .433  223 .161 .581
208.21861.241.6597  224.2855 .581
209.21861.241.6597  210 .161 .581  225.2855 .433
210 .1991.3201.320  211 .161 .581  226 .161 .581
211.18461.3821.382  212 .121 .581  227 .161 .581
212.18461.3821.382  213 .161 .581  228 .161 .581
213.19901.3201.320  214 .161 .581  229 .161 .581
214.19901.3201.320  215 .161 .581  230 .161 .581
215.19901.3201.320  216 .161 .581  231 .161 .581
216.19901.3201.320  217 .161 .581  232 .161 .581
217.19901.3201.320  218 .161 .581  233 .161 .581
218.19901.3201.320  219 .161 .581  234 .161 .581
219.19901.3201.320  220 .161 .581  235 .161 .581
220.19901.3201.320  221 .161 .581  236 .161 .581
```

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    221.18461.3821.382  222 .121 .581  237 .161 .581
    222.18461.3821.382  223 .161 .581  238 .161 .581
    223 .1991.3201.320  224 .161 .433  239 .161 .581
    224.21861.241.6597  240.2855 .581
    225.21861.241.6597  226 .161 .581  241.2855 .538
    226.19901.3201.320  227 .161 .581  242 .161 .433
    227.19901.3201.320  228 .161 .581  243 .161 .433
    228.19901.3201.320  229 .161 .581  244 .161 .433
    229.19901.3201.320  230 .161 .581  245 .161 .433
    230.19901.3201.320  231 .161 .581  246 .161 .433
    231.19901.3201.320  232 .161 .581  247 .161 .433
    232.19901.3201.320  233 .161 .581  248 .161 .433
    233.19901.3201.320  234 .161 .581  249 .161 .433
    234.19901.3201.320  235 .161 .581  250 .161 .433
    235.19901.3201.320  236 .161 .581  251 .161 .433
    236.19901.3201.320  237 .161 .581  252 .161 .433
    237.19901.3201.320  238 .161 .581  253 .161 .433
    238.19901.3201.320  239 .161 .581  254 .161 .433
    239.19901.3201.320  240 .161 .433  255 .161 .433
    240.21861.241.6597  256.2855 .538
    241.21091.321.3299  242.2855 .538
    242.21861.241.6597  243.2855 .581
    243.21861.241.6597  244.2855 .581
    244.21861.241.6597  245.2855 .581
    245.21861.241.6597  246.2855 .581
    246.21861.241.6597  247.2855 .581
    247.21861.241.6597  248.2855 .581
    248.21861.241.6597  249.2855 .581
    249.21861.241.6597  250.2855 .581
    250.21861.241.6597  251.2855 .581
    251.21861.241.6597  252.2855 .581
    252.21861.241.6597  253.2855 .581
    253.21861.241.6597  254.2855 .581
    254.21861.241.6597  255.2855 .581
    255.21861.241.6597  256.2855 .538
    256.21091.321.3299
      2    2   16
      0    1    0    0    1
2    18.1564.688    0.     21.500 5.44    82.121 5.44    96.188 2.03
2    28.1564.688    0.     32.121 5.44   106.188 2.03
2    38.1564.688    0.     41.500 5.44   116.188 2.03
2    48.1564.688    0.     52.121 5.44   126.188 2.03
2    58.1564.688    0.     61.500 5.44   136.188 2.03
2    68.1564.688    0.     72.121 5.44   146.188 2.03
2    78.1564.688    0.     81.500 5.44   156.188 2.03
2    88.1564.688    0.    166.188 2.03
2    910.926.872    0.    102.563 4.13
2   1010.926.872    0.
2   1110.926.872    0.    122.563 4.13
2   1210.926.872    0.
2   1310.926.872    0.    142.563 4.13
2   1410.926.872    0.
2   1510.926.872    0.    162.563 4.13
2   1610.926.872    0.

rods      1    1    1    0    0    1
     1    1  225
     1  .42   1.    1  .25    2  .25   17  .25   18  .25
     2  .42   1.    2  .25    3  .25   18  .25   19  .25
     3  .42   1.    3  .25    4  .25   19  .25   20  .25
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 5  .42  1.   5 .25   6 .25  21 .25  22 .25
 6  .42  1.   6 .25   7 .25  22 .25  23 .25
 7  .42  1.   7 .25   8 .25  23 .25  24 .25
 8  .42  1.   8 .25   9 .25  24 .25  25 .25
 9  .42  1.   9 .25  10 .25  25 .25  26 .25
10  .42  1.  10 .25  11 .25  26 .25  27 .25
11  .42  1.  11 .25  12 .25  27 .25  28 .25
12  .42  1.  12 .25  13 .25  28 .25  29 .25
13  .42  1.  13 .25  14 .25  29 .25  30 .25
14  .42  1.  14 .25  15 .25  30 .25  31 .25
15  .42  1.  15 .25  16 .25  31 .25  32 .25
16  .42  1.  17 .25  18 .25  33 .25  34 .25
17  .42  1.  18 .25  19 .25  34 .25  35 .25
18  .42  1.  19 .25  20 .25  35 .25  36 .25
19  .42  1.  20 .25  21 .25  36 .25  37 .25
20  .42  1.  21 .25  22 .25  37 .25  38 .25
21  .42  1.  22 .25  23 .25  38 .25  39 .25
22  .42  1.  23 .25  24 .25  39 .25  40 .25
23  .42  1.  24 .25  25 .25  40 .25  41 .25
24  .42  1.  25 .25  26 .25  41 .25  42 .25
25  .42  1.  26 .25  27 .25  42 .25  43 .25
26  .42  1.  27 .25  28 .25  43 .25  44 .25
27  .42  1.  28 .25  29 .25  44 .25  45 .25
28  .42  1.  29 .25  30 .25  45 .25  46 .25
29  .42  1.  30 .25  31 .25  46 .25  47 .25
30  .42  1.  31 .25  32 .25  47 .25  48 .25
31  .42  1.  33 .25  34 .25  49 .25  50 .25
32  .42  1.  34 .25  35 .25  50 .25  51 .25
33 0.42  0.  35 .25  36 .25  51 .25  52 .25
34  .42  1.  36 .25  37 .25  52 .25  53 .25
35  .42  1.  37 .25  38 .25  53 .25  54 .25
36  .42  1.  38 .25  39 .25  54 .25  55 .25
37  .42  1.  39 .25  40 .25  55 .25  56 .25
38  .42  1.  40 .25  41 .25  56 .25  57 .25
39  .42  1.  41 .25  42 .25  57 .25  58 .25
40  .42  1.  42 .25  43 .25  58 .25  59 .25
41  .42  1.  43 .25  44 .25  59 .25  60 .25
42  .42  1.  44 .25  45 .25  60 .25  61 .25
43 0.42  0.  45 .25  46 .25  61 .25  62 .25
44  .42  1.  46 .25  47 .25  62 .25  63 .25
45  .42  1.  47 .25  48 .25  63 .25  64 .25
46  .42  1.  49 .25  50 .25  65 .25  66 .25
47  .42  1.  50 .25  51 .25  66 .25  67 .25
48  .42  1.  51 .25  52 .25  67 .25  68 .25
49  .42  1.  52 .25  53 .25  68 .25  69 .25
50  .42  1.  53 .25  54 .25  69 .25  70 .25
51  .42  1.  54 .25  55 .25  70 .25  71 .25
52  .42  1.  55 .25  56 .25  71 .25  72 .25
53  .42  1.  56 .25  57 .25  72 .25  73 .25
54  .42  1.  57 .25  58 .25  73 .25  74 .25
55  .42  1.  58 .25  59 .25  74 .25  75 .25
56  .42  1.  59 .25  60 .25  75 .25  76 .25
57  .42  1.  60 .25  61 .25  76 .25  77 .25
58  .42  1.  61 .25  62 .25  77 .25  78 .25
59  .42  1.  62 .25  63 .25  78 .25  79 .25
60  .42  1.  63 .25  64 .25  79 .25  80 .25
61  .42  0.  65 .25  66 .25  81 .25  82 .25
62  .42  1.  66 .25  67 .25  82 .25  83 .25
63  .42  1.  67 .25  68 .25  83 .25  84 .25
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 64  .42  1.   68  .25   69  .25   84  .25   85  .25
 65 0.42  0.   69  .25   70  .25   85  .25   86  .25
 66  .42  1.   70  .25   71  .25   86  .25   87  .25
 67  .42  1.   71  .25   72  .25   87  .25   88  .25
 68  .42  1.   72  .25   73  .25   88  .25   89  .25
 69  .42  1.   73  .25   74  .25   89  .25   90  .25
 70  .42  1.   74  .25   75  .25   90  .25   91  .25
 71 0.42  0.   75  .25   76  .25   91  .25   92  .25
 72  .42  1.   76  .25   77  .25   92  .25   93  .25
 73  .42  1.   77  .25   78  .25   93  .25   94  .25
 74  .42  1.   78  .25   79  .25   94  .25   95  .25
 75 0.42  0.   79  .25   80  .25   95  .25   96  .25
 76  .42  1.   81  .25   82  .25   97  .25   98  .25
 77  .42  1.   82  .25   83  .25   98  .25   99  .25
 78  .42  1.   83  .25   84  .25   99  .25  100  .25
 79  .42  1.   84  .25   85  .25  100  .25  101  .25
 80  .42  1.   85  .25   86  .25  101  .25  102  .25
 81  .42  1.   86  .25   87  .25  102  .25  103  .25
 82  .42  1.   87  .25   88  .25  103  .25  104  .25
 83  .42  1.   88  .25   89  .25  104  .25  105  .25
 84  .42  1.   89  .25   90  .25  105  .25  106  .25
 85  .42  1.   90  .25   91  .25  106  .25  107  .25
 86  .42  1.   91  .25   92  .25  107  .25  108  .25
 87  .42  1.   92  .25   93  .25  108  .25  109  .25
 88  .42  1.   93  .25   94  .25  109  .25  110  .25
 89  .42  1.   94  .25   95  .25  110  .25  111  .25
 90  .42  1.   95  .25   96  .25  111  .25  112  .25
 91  .42  1.   97  .25   98  .25  113  .25  114  .25
 92  .42  0.   98  .25   99  .25  114  .25  115  .25
 93  .42  1.   99  .25  100  .25  115  .25  116  .25
 94  .42  1.  100  .25  101  .25  116  .25  117  .25
 95  .42  1.  101  .25  102  .25  117  .25  118  .25
 96  .42  1.  102  .25  103  .25  118  .25  119  .25
 97  .42  1.  103  .25  104  .25  119  .25  120  .25
 98  .42  1.  104  .25  105  .25  120  .25  121  .25
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100  .42  1.  106  .25  107  .25  122  .25  123  .25
101  .42  1.  107  .25  108  .25  123  .25  124  .25
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103  .42  1.  109  .25  110  .25  125  .25  126  .25
104  .42  0.  110  .25  111  .25  126  .25  127  .25
105  .42  1.  111  .25  112  .25  127  .25  128  .25
106  .42  1.  113  .25  114  .25  129  .25  130  .25
107  .42  1.  114  .25  115  .25  130  .25  131  .25
108  .42  1.  115  .25  116  .25  131  .25  132  .25
109  .42  1.  116  .25  117  .25  132  .25  133  .25
110  .42  1.  117  .25  118  .25  133  .25  134  .25
111  .42  1.  118  .25  119  .25  134  .25  135  .25
112  .42  1.  119  .25  120  .25  135  .25  136  .25
113 0.42  0.  120  .25  121  .25  136  .25  137  .25
114  .42  1.  121  .25  122  .25  137  .25  138  .25
115  .42  1.  122  .25  123  .25  138  .25  139  .25
116  .42  1.  123  .25  124  .25  139  .25  140  .25
117  .42  1.  124  .25  125  .25  140  .25  141  .25
118  .42  1.  125  .25  126  .25  141  .25  142  .25
119  .42  1.  126  .25  127  .25  142  .25  143  .25
120  .42  1.  127  .25  128  .25  143  .25  144  .25
121  .42  1.  129  .25  130  .25  145  .25  146  .25
122  .42  1.  130  .25  131  .25  146  .25  147  .25
123  .42  1.  131  .25  132  .25  147  .25  148  .25
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124	.42	1.	132	.25	133	.25	148	.25	149	.25
125	.42	1.	133	.25	134	.25	149	.25	150	.25
126	.42	1.	134	.25	135	.25	150	.25	151	.25
127	.42	1.	135	.25	136	.25	151	.25	152	.25
128	.42	1.	136	.25	137	.25	152	.25	153	.25
129	.42	1.	137	.25	138	.25	153	.25	154	.25
130	.42	1.	138	.25	139	.25	154	.25	155	.25
131	.42	1.	139	.25	140	.25	155	.25	156	.25
132	.42	1.	140	.25	141	.25	156	.25	157	.25
133	.42	1.	141	.25	142	.25	157	.25	158	.25
134	.42	1.	142	.25	143	.25	158	.25	159	.25
135	.42	1.	143	.25	144	.25	159	.25	160	.25
136	.42	1.	145	.25	146	.25	161	.25	162	.25
137	.42	1.	146	.25	147	.25	162	.25	163	.25
138	.42	1.	147	.25	148	.25	163	.25	164	.25
139	.42	1.	148	.25	149	.25	164	.25	165	.25
140	.42	1.	149	.25	150	.25	165	.25	166	.25
141	.42	1.	150	.25	151	.25	166	.25	167	.25
142	.42	1.	151	.25	152	.25	167	.25	168	.25
143	.42	1.	152	.25	153	.25	168	.25	169	.25
144	.42	1.	153	.25	154	.25	169	.25	170	.25
145	.42	1.	154	.25	155	.25	170	.25	171	.25
146	.42	1.	155	.25	156	.25	171	.25	172	.25
147	.42	1.	156	.25	157	.25	172	.25	173	.25
148	.42	1.	157	.25	158	.25	173	.25	174	.25
149	.42	1.	158	.25	159	.25	174	.25	175	.25
150	.42	1.	159	.25	160	.25	175	.25	176	.25
151	.42	0.	161	.25	162	.25	177	.25	178	.25
152	.42	1.	162	.25	163	.25	178	.25	179	.25
153	.42	1.	163	.25	164	.25	179	.25	180	.25
154	.42	1.	164	.25	165	.25	180	.25	181	.25
155	0.42	0.	165	.25	166	.25	181	.25	182	.25
156	.42	1.	166	.25	167	.25	182	.25	183	.25
157	.42	1.	167	.25	168	.25	183	.25	184	.25
158	.42	1.	168	.25	169	.25	184	.25	185	.25
159	.42	1.	169	.25	170	.25	185	.25	186	.25
160	.42	1.	170	.25	171	.25	186	.25	187	.25
161	0.42	0.	171	.25	172	.25	187	.25	188	.25
162	.42	1.	172	.25	173	.25	188	.25	189	.25
163	.42	1.	173	.25	174	.25	189	.25	190	.25
164	.42	1.	174	.25	175	.25	190	.25	191	.25
165	0.42	0.	175	.25	176	.25	191	.25	192	.25
166	.42	1.	177	.25	178	.25	193	.25	194	.25
167	.42	1.	178	.25	179	.25	194	.25	195	.25
168	.42	1.	179	.25	180	.25	195	.25	196	.25
169	.42	1.	180	.25	181	.25	196	.25	197	.25
170	.42	1.	181	.25	182	.25	197	.25	198	.25
171	.42	1.	182	.25	183	.25	198	.25	199	.25
172	.42	1.	183	.25	184	.25	199	.25	200	.25
173	.42	1.	184	.25	185	.25	200	.25	201	.25
174	.42	1.	185	.25	186	.25	201	.25	202	.25
175	.42	1.	186	.25	187	.25	202	.25	203	.25
176	.42	1.	187	.25	188	.25	203	.25	204	.25
177	.42	1.	188	.25	189	.25	204	.25	205	.25
178	.42	1.	189	.25	190	.25	205	.25	206	.25
179	.42	1.	190	.25	191	.25	206	.25	207	.25
180	.42	1.	191	.25	192	.25	207	.25	208	.25
181	.42	1.	193	.25	194	.25	209	.25	210	.25
182	.42	1.	194	.25	195	.25	210	.25	211	.25
183	0.42	0.	195	.25	196	.25	211	.25	212	.25

```
  184  .42   1.  196  .25  197  .25  212  .25  213  .25
  185  .42   1.  197  .25  198  .25  213  .25  214  .25
  186  .42   1.  198  .25  199  .25  214  .25  215  .25
  187  .42   1.  199  .25  200  .25  215  .25  216  .25
  188  .42   1.  200  .25  201  .25  216  .25  217  .25
  189  .42   1.  201  .25  202  .25  217  .25  218  .25
  190  .42   1.  202  .25  203  .25  218  .25  219  .25
  191  .42   1.  203  .25  204  .25  219  .25  220  .25
  192  .42   1.  204  .25  205  .25  220  .25  221  .25
  193 0.42   0.  205  .25  206  .25  221  .25  222  .25
  194  .42   1.  206  .25  207  .25  222  .25  223  .25
  195  .42   1.  207  .25  208  .25  223  .25  224  .25
  196  .42   1.  209  .25  210  .25  225  .25  226  .25
  197  .42   1.  210  .25  211  .25  226  .25  227  .25
  198  .42   1.  211  .25  212  .25  227  .25  228  .25
  199  .42   1.  212  .25  213  .25  228  .25  229  .25
  200  .42   1.  213  .25  214  .25  229  .25  230  .25
  201  .42   1.  214  .25  215  .25  230  .25  231  .25
  202  .42   1.  215  .25  216  .25  231  .25  232  .25
  203  .42   1.  216  .25  217  .25  232  .25  233  .25
  204  .42   1.  217  .25  218  .25  233  .25  234  .25
  205  .42   1.  218  .25  219  .25  234  .25  235  .25
  206  .42   1.  219  .25  220  .25  235  .25  236  .25
  207  .42   1.  220  .25  221  .25  236  .25  237  .25
  208  .42   1.  221  .25  222  .25  237  .25  238  .25
  209  .42   1.  222  .25  223  .25  238  .25  239  .25
  210  .42   1.  223  .25  224  .25  239  .25  240  .25
  211  .42   1.  225  .25  226  .25  241  .25  242  .25
  212  .42   1.  226  .25  227  .25  242  .25  243  .25
  213  .42   1.  227  .25  228  .25  243  .25  244  .25
  214  .42   1.  228  .25  229  .25  244  .25  245  .25
  215  .42   1.  229  .25  230  .25  245  .25  246  .25
  216  .42   1.  230  .25  231  .25  246  .25  247  .25
  217  .42   1.  231  .25  232  .25  247  .25  248  .25
  218  .42   1.  232  .25  233  .25  248  .25  249  .25
  219  .42   1.  233  .25  234  .25  249  .25  250  .25
  220  .42   1.  234  .25  235  .25  250  .25  251  .25
  221  .42   1.  235  .25  236  .25  251  .25  252  .25
  222  .42   1.  236  .25  237  .25  252  .25  253  .25
  223  .42   1.  237  .25  238  .25  253  .25  254  .25
  224  .42   1.  238  .25  239  .25  254  .25  255  .25
  225  .42   1.  239  .25  240  .25  255  .25  256  .25
    2    0    0
  3.0 .059 655. .350  10.  0.1 400. .0251000. .420
slab     2    3   16
    1                    3878.
    2                   989.
    1    1  .95            2    2    1    8    1
    2    1  .95            1    3    1
    3    1  .95            1    4    1
    4    1  .95            1    5    1
    5    1  .95            1    6    1
    6    1  .95            1    7    1
    7    1  .95            1    8    1
    8    1  .95
    9    2 1.74            2   10    2   16    2
   10    2 1.74            1   11    2
   11    2 1.74            1   12    2
   12    2 1.74            1   13    2
   13    2 1.74            1   14    2
```

```
 14    2 1.74              1   15    2
 15    2 1.74              1   16    2
 16    2 1.74
  1     34.20      .5561
  2    12.145      4.614       989.
  3     .0130      6.684
  1    9    1    1    1    1    2    1    1    3    1    1    4    1
            1    5    1    1    6    1    1    7    1    1    8    1
            2    1    2
  2    9    1    9    1    1   10    1    1   11    1    1   12    1
            1   13    1    1   14    1    1   15    1    1   16    1
            2    2    2
  3    9    1   16    1    1   32    1    1   48    1    1   64    1
            1   80    1    1   96    1    1  112    1    1  128    1
            2    3    2
  4    9    1  144    1    1  160    1    1  176    1    1  192    1
            1  208    1    1  224    1    1  240    1    1  256    1
            2    4    2
  5    9    1  249    1    1  250    1    1  251    1    1  249    1
            1  253    1    1  254    1    1  255    1    1  256    1
            2    5    2
  6    9    1  241    1    1  242    1    1  243    1    1  244    1
            1  245    1    1  246    1    1  247    1    1  248    1
            2    6    2
  7    9    1  129    1    1  145    1    1  161    1    1  177    1
            1  193    1    1  209    1    1  225    1    1  241    1
            2    7    2
  8    9    1    1    1    1   17    1    1   33    1    1   49    1
            1   65    1    1   81    1    1   97    1    1  113    1
            2    8    2
  9    1    2   09    3
 10    1    2   10    3
 11    1    2   11    3
 12    1    2   12    3
 13    1    2   13    3
 14    1    2   14    3
 15    1    2   15    3
 16    1    2   16    3

radg     2    1    1
  1   16
   14.614  .25   1.0016   2.0      3.0      4.0      5.0      6.0
                 7.0      8.0      9.6808   10.2656  11.0085  12.0
                 13.0     14.0     15.0     16.0435
   24.614  .25   1.0      2.0016   3.0      4.0      5.0      6.0
                 7.0      8.0      9.2656   10.6808  11.0435  12.0
                 13.0     14.0     15.0     16.0085
   34.614  .25   1.0      2.0      3.0016   4.0      5.0      6.0
                 7.0      8.0      9.0      10.0435  11.6808  12.2656
                 13.0085  14.0     15.0     16.0
   44.614  .25   1.0      2.0      3.0      4.0016   5.0      6.0
                 7.0      8.0      9.0      10.0085  11.2656  12.6808
                 13.0435  14.0     15.0     16.0
   54.614  .25   1.0      2.0      3.0      4.0      5.0016   6.0
                 7.0      8.0      9.0      10.0     11.0     12.0435
                 13.6808  14.2656  15.0085  16.0
   64.614  .25   1.0      2.0      3.0      4.0      5.0      6.0016
                 7.0      8.0      9.0      10.0     11.0     12.0085
                 13.2656  14.6808  15.0435  16.0
   74.614  .25   1.0      2.0      3.0      4.0      5.0      6.0
```

```
                7.0016    8.0       9.0085    10.0      11.0      12.0
               13.0      14.0435   15.6808   16.2656
  84.614  .25   1.0       2.0       3.0       4.0       5.0       6.0
                7.0       8.0016    9.0435   10.0      11.0      12.0
               13.0      14.0085   15.2656   16.6808
  96.684  .6    1.4700    2.1833    3.0       4.0       5.0       6.0
                7.6059    8.03      9.0271   10.0734   11.0637   12.0
               13.0      14.0134   15.0637   16.0695
 106.684  .6    1.1833    2.4700    3.0300    4.0059    5.0       6.0
                7.0       8.0       9.0734   10.0271   11.0695   12.0637
               13.0134   14.0      15.0      16.0637
 116.684  .6    1.0059    2.03      3.47      4.1833    5.0       6.0
                7.0       8.0       9.0637   10.0695   11.0271   12.0734
               13.0637   14.0      15.0      16.0134
 126.684  .6    1.0       2.0       3.1833    4.47      5.03      6.0059
                7.0       8.0       9.0000   10.0637   11.0734   12.0271
               13.0695   14.0637   15.0134   16.0
 136.684  .6    1.0       2.0       3.0059    4.0300    5.47      6.1833
                7.0       8.0       9.0      10.0134   11.0637   12.0695
               13.0271   14.0734   15.0637   16.0
 146.684  .6    1.0       2.0       3.0       4.0       5.1833    6.4700
                7.0300    8.0059    9.0134   10.0      11.0      12.0637
               13.0734   14.0271   15.0695   16.0637
 156.684  .6    1.0       2.0       3.0       4.0       5.0059    6.03
                7.47      8.1833    9.0637   10.0      11.0      12.0134
               13.0637   14.0695   15.0271   16.0734
 166.684  .6    1.03      2.0059    3.0       4.0       5.0       6.0
                7.1833    8.4700    9.0695   10.0637   11.0134   12.0
               13.0      14.0637   15.0734   16.0271
    1    1    8    1    2    3    4    5    6    7    8
    2   -1   16    1    2    3    4    5    6    7    8    9   10   11   12
                  13   14   15   16
heat     1    0    1
              3.66                3.66
  1.0  1.0
drag     2    2
 100. -1.0                100. -1.0  .05
 100. -1.0                100. -1.0  50.
    1   16    0
    7   16  240 .066   2. .155   2. .276   8. .393   2. .454   8. .699   8.
                .979   8.
    7    1   17 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
                .979   4.
    7   32   33 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
                .979   4.
    7   48   49 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
                .979   4.
    7   64   65 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
                .979   4.
    7   80   81 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
                .979   4.
    7   96   97 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
                .979   4.
    7  112  113 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
                .979   4.
    7  128  129 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
                .979   4.
    7  144  145 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
                .979   4.
    7  160  161 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
```

```
               .979   4.
    7  176  177 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
               .979   4.
    7  192  193 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
               .979   4.
    7  208  209 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
               .979   4.
    7  224  225 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
               .979   4.
    7  240  256 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
               .979   4.
    2    1    0
    1    1   16 0.01 30.0
bdry    5    1    0    2
    1    .001                          1.
    2   8.10e-6                        1.
    3   2.61e-6                        1.
    4   1.64e-6                        1.
    5   1.00e-4                        1.
    1   24-.014 126..0377 188. .069 220..1056 249..1526 276..2058 298.
          .2514 313..3119 327..3724 337..4365 345..4965 348..5576 350.
          .6993 347..7902 344..8507 338..9112 329..9796 314.1.012 304.
          1.038 293.1.082 273.1.123 248.1.154 218.1.173 188.1.192 149.
    9    1 7.07    1
    1   1.    1   1.    1
   10    1 7.07    1
    1   1.    1   1.    1
   11    1 7.07    1
    1   1.    1   1.    1
   12    1 7.07    1
    1   1.    1   1.    1
   13    1 7.07    1
    1   1.    1   1.    1
   14    1 7.07    1
    1   1.    1   1.    1
   15    1 7.07    1
    1   1.    1   1.    1
   16    1 7.07    1
    1   1.    1   1.    1
    1 379. 254.    2    2168.0136.
    1   1.    3
    2   1.    1
    1   1.    2
    2   1.    1    8    1    2  .95   2.    2    2  .95   2.    3    2  .95   2.
                        4    2  .95   2.    5    2  .95   2.    6    2  .95   2.
                        7    2  .95   2.    8    2  .95   2.
    21340. 240.    2    2258.0156.
    1   1.    3
    2   1.    1
    1   1.    4
    2 2.56    5
calc    1    0    0
                                       0.1
        20
oper    1    2    3    1                                                   1
  20.          282.     .0001 .002105807     250.    .000000        0.0
   1. -.33
1.000
    6
   0.    0..1043    0..1044    1..9758    1..9759    0.   1.0  0.0
```

```
outp 1101
endd


 data from iterative solution using the recirculation module
 time =    0.0000    dt = ******    implicit dt = 0.0000    explicit dt = 3.2888    mode =  0


 iteration  sweep          peak clad            total flow     pressure                    error
    no.      no.   ---------------------------    (lbm/s)     drop(psi)    ------------------------------------
                   temp(f)  fluid  rod  ass.                                 total     flow    fluid     rod
                                                                             energy            energy   energy

    1        1      519.7    24    128    1    0.498e-10   0.0048675     13.5006   1.3823   0.0482   0.0118
             2      522.2    24    128    1                              -0.0252   1.3823   0.0256   0.0046

    2        1      526.0    24    128    1    0.218e-10   0.0047013     -0.0557   3.1935   0.0557   0.0038
             2      530.3    23    128    1                               0.0128   3.1935   0.0256   0.0049

    3        1      538.2    24    128    1    0.894e-12   0.0047092      0.0444   1.4453   0.0062   0.0013
             2      543.9    23    128    1                               0.0203   1.4453   0.0229   0.0013

    4        1      544.9    22    128    1   -0.245e-10   0.0047134     -0.0187   1.1330   0.0028   0.0004
             2      548.3    22    128    1                               0.0149   1.1330   0.0163   0.0008

    5        1      548.9    22    128    1   -0.674e-10   0.0047165      0.0233   1.1794   0.0018   0.0002
             2      550.8    21    128    1                               0.0108   1.1794   0.0119   0.0005

    6        1      550.9    21    128    1   -0.109e-09   0.0047193      0.0125   1.0867   0.0024   0.0001
             2      551.7    21    128    1                               0.0075   1.0867   0.0048   0.0002

    7        1      551.8    21    128    1   -0.935e-10   0.0047215     -0.0036   1.1215   0.0025   0.0001
             2      552.1    21    128    1                               0.0058   1.1215   0.0049   0.0001

    8        1      552.2    21    128    1   -0.467e-10   0.0047232      0.0030   1.1085   0.0024   0.0001
             2      552.2    21    128    1                               0.0053   1.1085   0.0034   0.0001

    9        1      552.2    21    128    1   -0.102e-10   0.0047245      0.0017   1.0738   0.0024   0.0001
             2      552.2    21    128    1                               0.0051   1.0738   0.0034   0.0001

   10        1      552.2    21    128    1    0.768e-11   0.0047255      0.0041   0.9731   0.0023   0.0001
             2      552.0    21    128    1                               0.0053   0.9731   0.0029   0.0001

   11        1      552.0    21    128    1    0.125e-10   0.0047264      0.0015   0.9550   0.0022   0.0001
             2      551.9    21    128    1                               0.0055   0.9550   0.0022   0.0001

   12        1      551.9    21    128    1    0.112e-10   0.0047271      0.0019   0.9279   0.0021   0.0001
             2      551.7    21    128    1                               0.0058   0.9279   0.0018   0.0001

   13        1      551.7    21    128    1    0.827e-11   0.0047277      0.0050   0.8909   0.0021   0.0001
             2      551.6    21    128    1                               0.0062   0.8909   0.0016   0.0001

   14        1      551.6    21    128    1    0.551e-11   0.0047282      0.0029   0.8216   0.0020   0.0001
             2      551.5    21    128    1                               0.0064   0.8216   0.0017   0.0001

   15        1      551.5    22    128    1    0.345e-11   0.0047287      0.0033   0.5836   0.0020   0.0001
             2      551.4    22    128    1                               0.0066   0.5836   0.0018   0.0001

   16        1      551.4    22    128    1    0.208e-11   0.0047291      0.0048   0.4248   0.0020   0.0001
             2      551.4    22    128    1                               0.0067   0.4248   0.0019   0.0001
```

```
  17        1      551.4     22   128     1        0.119e-11    0.0047294        0.0040   0.3177   0.0020   0.0001
            2      551.3     22   128     1                                     0.0069   0.3177   0.0020   0.0001

  18        1      551.3     22   128     1        0.618e-12    0.0047297        0.0041   0.2446   0.0020   0.0001
            2      551.3     22   128     1                                     0.0069   0.2446   0.0020   0.0001

  19        1      551.3     22   128     1        0.262e-12    0.0047300        0.0045   0.1937   0.0020   0.0001
            2      551.3     22   128     1                                     0.0070   0.1937   0.0020   0.0001

  20        1      551.3     22   128     1        0.371e-13    0.0047302        0.0044   0.1574   0.0020   0.0001
            2      551.3     22   128     1                                     0.0070   0.1574   0.0020   0.0001


slab temperature summary          time =    0.0000 seconds
(assembly no. - channel no.)


axial zone     (  1)      (  2)      (  3)      (  4)      (  5)      (  6)      (  7)      (  8)      (  9)      ( 10)
 (inches)

 0.0 -  6.9    166.81     166.79     166.78     166.78     166.77     166.80     166.83     166.84     168.34     168.34
 6.9 - 13.8    197.83     197.82     197.85     197.86     197.90     197.87     197.89     197.88     213.24     213.24
13.8 - 20.7    226.21     226.22     226.30     226.31     226.33     226.27     226.27     226.26     247.75     247.75
20.7 - 27.5    263.46     263.55     263.54     263.56     263.58     263.51     263.31     263.26     272.05     272.05
27.5 - 34.4    296.77     296.89     296.84     296.86     296.87     296.80     296.51     296.45     290.41     290.41
34.4 - 41.3    325.37     325.51     325.43     325.46     325.46     325.39     325.08     325.01     305.67     305.67
41.3 - 48.2    349.43     349.56     349.47     349.50     349.51     349.44     349.12     349.06     317.51     317.51
48.2 - 55.1    369.46     369.59     369.48     369.53     369.54     369.47     369.15     369.09     327.12     327.12
55.1 - 62.0    385.78     385.90     385.77     385.83     385.85     385.80     385.47     385.41     334.03     334.03
62.0 - 68.9    399.14     399.24     399.11     399.18     399.20     399.15     398.83     398.76     339.98     339.98
68.9 - 75.8    409.92     410.01     409.87     409.95     409.98     409.94     409.61     409.55     345.09     345.09
75.8 - 82.6    418.01     418.09     417.93     418.02     418.06     418.02     417.70     417.63     347.21     347.21
82.6 - 89.5    424.18     424.25     424.09     424.18     424.22     424.19     423.87     423.80     348.89     348.89
89.5 - 96.4    428.72     428.79     428.62     428.72     428.76     428.74     428.41     428.34     349.95     349.95
96.4 -103.3    431.65     431.71     431.53     431.64     431.69     431.66     431.34     431.27     349.10     349.10
103.3 -110.2   433.56     433.62     433.44     433.54     433.60     433.58     433.25     433.18     348.23     348.23
110.2 -117.1   434.73     434.79     434.60     434.71     434.76     434.74     434.42     434.34     347.35     347.35
117.1 -124.0   435.22     435.27     435.08     435.19     435.25     435.23     434.90     434.83     346.12     346.12
124.0 -130.9   435.08     435.13     434.94     435.05     435.11     435.09     434.76     434.69     344.72     344.72
130.9 -137.7   434.01     434.07     433.87     433.98     434.04     434.03     433.70     433.62     341.87     341.87
137.7 -144.6   431.82     431.88     431.68     431.79     431.85     431.84     431.50     431.43     337.57     337.57
144.6 -151.5   427.97     428.02     427.82     427.93     427.99     427.98     427.64     427.56     331.37     331.37
151.5 -158.4   420.50     420.54     420.34     420.46     420.51     420.50     420.17     420.10     323.32     323.32
158.4 -165.3   401.78     401.79     401.68     401.77     401.78     401.77     401.63     401.60     314.29     314.29



side boundary temperature summary     time =    0.0000 seconds
boundary slab node no.     9


axial zone     (  1)      (  2)      (
 (inches)

 0.0 -  6.9    168.34     167.77
 6.9 - 13.8    213.24     213.35
```

```
 13.8 - 20.7     247.75      247.86
 20.7 - 27.5     272.05      272.11
 27.5 - 34.4     290.41      290.43
 34.4 - 41.3     305.67      305.69
 41.3 - 48.2     317.51      317.50
 48.2 - 55.1     327.12      327.10
 55.1 - 62.0     334.03      333.99
 62.0 - 68.9     339.98      339.92
 68.9 - 75.8     345.09      345.05
 75.8 - 82.6     347.21      347.13
 82.6 - 89.5     348.89      348.80
 89.5 - 96.4     349.95      349.88
 96.4 -103.3     349.10      349.01
103.3 -110.2     348.23      348.13
110.2 -117.1     347.35      347.25
117.1 -124.0     346.12      346.01
124.0 -130.9     344.72      344.64
130.9 -137.7     341.87      341.79
137.7 -144.6     337.57      337.48
144.6 -151.5     331.37      331.29
151.5 -158.4     323.32      323.23
158.4 -165.3     314.29      314.10


 calculated rod temperatures at time =    0.0000 seconds
 rod no.    1
 assembly   1                   (fuel type  1 - cylinder)
0rod o.d. - 0.420 (in.)     zone-(fuel dia.(in.)) -  1-(0.350)

                                                  *   fuel temperatures(f.)
                                                  *
   axial zone  heat flux   type          hsurf    *   fluid    clad
      (in.)   (mbtu/hr-ft2)            (b/h-f-ft2) *
   0.0 -   6.9    0.0000    1              1.1        171.4    171.7
   6.9 -  13.8    0.0000    1              1.1        189.7    189.6
  13.8 -  20.7    0.0000    1              1.2        213.3    212.1
  20.7 -  27.5    0.0000    1              1.2        258.6    266.3
  27.5 -  34.4    0.0000    1              1.3        297.0    305.1
  34.4 -  41.3    0.0000    1              1.3        329.6    338.4
  41.3 -  48.2    0.0000    1              1.3        357.3    366.8
  48.2 -  55.1    0.0000    1              1.4        380.5    390.6
  55.1 -  62.0    0.0000    1              1.4        399.6    410.2
  62.0 -  68.9    0.0000    1              1.4        415.2    426.2
  68.9 -  75.8    0.0000    1              1.4        427.8    439.3
  75.8 -  82.6    0.0000    1              1.4        437.6    449.3
  82.6 -  89.5    0.0000    1              1.5        445.1    457.1
  89.5 -  96.4    0.0000    1              1.5        450.7    463.0
  96.4 - 103.3    0.0000    1              1.5        454.7    467.1
 103.3 - 110.2    0.0000    1              1.5        457.3    470.0
 110.2 - 117.1    0.0000    1              1.5        459.1    471.9
 117.1 - 124.0    0.0000    1              1.5        460.1    473.0
 124.0 - 130.9    0.0000    1              1.5        460.4    473.4
 130.9 - 137.7    0.0000    1              1.5        459.9    473.0
 137.7 - 144.6    0.0000    1              1.5        458.3    471.6
 144.6 - 151.5    0.0000    1              1.5        455.4    468.8
 151.5 - 158.4    0.0000    1              1.5        449.8    463.5
 158.4 - 165.3    0.0000    1              1.4        423.5    429.4
```

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 calculated rod temperatures at time =    0.0000 seconds
 rod no.  128
 assembly   1                  (fuel type  1 - cylinder)
0rod o.d. - 0.420 (in.)     zone-(fuel dia.(in.)) -  1-(0.350)

                                                    *   fuel temperatures(f.)
                                                    *
   axial zone  heat flux   type              hsurf  *   fluid     clad
      (in.)   (mbtu/hr-ft2)               (b/h-f-ft2) *
    0.0 -   6.9    0.0000     1                1.3      179.3     179.3
    6.9 -  13.8    0.0000     1                1.3      179.9     180.0
   13.8 -  20.7    0.0000     1                1.3      183.5     184.0
   20.7 -  27.5    0.0000     1                1.4      237.8     247.5
   27.5 -  34.4    0.0000     1                1.5      290.9     300.0
   34.4 -  41.3    0.0000     1                1.5      339.6     347.7
   41.3 -  48.2    0.0000     1                1.6      382.3     389.4
   48.2 -  55.1    0.0000     1                1.7      418.4     424.5
   55.1 -  62.0    0.0000     1                1.7      448.3     453.5
   62.0 -  68.9    0.0000     1                1.7      472.5     477.0
   68.9 -  75.8    0.0000     1                1.8      492.0     495.8
   75.8 -  82.6    0.0000     1                1.8      507.4     510.7
   82.6 -  89.5    0.0000     1                1.8      519.4     522.2
   89.5 -  96.4    0.0000     1                1.8      528.7     531.1
   96.4 - 103.3    0.0000     1                1.8      535.7     537.8
  103.3 - 110.2    0.0000     1                1.8      540.6     542.6
  110.2 - 117.1    0.0000     1                1.8      544.6     546.3
  117.1 - 124.0    0.0000     1                1.8      547.2     548.8
  124.0 - 130.9    0.0000     1                1.8      548.9     550.4
  130.9 - 137.7    0.0000     1                1.8      549.8     551.3
  137.7 - 144.6    0.0000     1                1.8      550.0     551.3
  144.6 - 151.5    0.0000     1                1.8      549.2     550.5
  151.5 - 158.4    0.0000     1                1.8      547.3     548.4
  158.4 - 165.3    0.0000     1                1.8      500.8     502.2
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+8000
   1    1     agns inclined nitrogen full-load validation analyses
prop    11    2
        1.       100.      133.9     .0154       .240      14.08       .0463
        2.       200.      157.9     .0174       .241      16.67       .0518
        3.       300.      182.1     .0193       .243      19.23       .0580
        4.       400.      206.5     .0212       .245      21.74       .0630
        5.       500.      231.1     .0231       .247      24.27       .0680
        6.       600.      256.0     .0250       .250      26.81       .0720
        7.       700.      281.1     .0268       .253      29.33       .0770
        8.       800.      306.7     .0286       .256      31.85       .0810
       10.       900.      332.5     .0303       .259      34.36       .0850
       15.      1000.      358.6     .0319       .262      36.90       .0889
       20.      2000.      617.2     .0471       .286      62.11       .1242
   1  can                            13.
   2steel                           100.
chan     2   24
     165.3       65.0
   1    1  256    0
   1    1    0    0    1
   1.21091.321.3299   2.2855 .538   17.2855 .538
   2.21861.241.6597   3.2855 .581   18 .181 .433
   3.21861.241.6597   4.2855 .581   19 .181 .433
   4.21861.241.6597   5.2855 .581   20 .181 .433
   5.21861.241.6597   6.2855 .581   21 .181 .433
   6.21861.241.6597   7.2855 .581   22 .181 .433
   7.21861.241.6597   8.2855 .581   23 .181 .433
   8.21861.241.6597   9.2855 .581   24 .181 .433
   9.21861.241.6597  10.2855 .581   25 .181 .433
  10.21861.241.6597  11.2855 .581   26 .181 .433
  11.21861.241.6597  12.2855 .581   27 .181 .433
  12.21861.241.6597  13.2855 .581   28 .181 .433
  13.21861.241.6597  14.2855 .581   29 .181 .433
  14.21861.241.6597  15.2855 .581   30 .181 .433
  15.21861.241.6597  16.2855 .581   31 .181 .433
  16.21091.321.3299  32.2855 .538
  17.21861.241.6597  18 .181 .581   33.2855 .433
  18 .1991.3201.320  19 .181 .581   34 .181 .581
  19 .1991.3201.320  20 .181 .581   35 .181 .581
  20 .1991.3201.320  21 .181 .581   36 .181 .581
  21 .1991.3201.320  22 .181 .581   37 .181 .581
  22 .1991.3201.320  23 .181 .581   38 .181 .581
  23 .1991.3201.320  24 .181 .581   39 .181 .581
  24 .1991.3201.320  25 .181 .581   40 .181 .581
  25 .1991.3201.320  26 .181 .581   41 .181 .581
  26 .1991.3201.320  27 .181 .581   42 .181 .581
  27 .1991.3201.320  28 .181 .581   43 .181 .581
  28 .1991.3201.320  29 .181 .581   44 .181 .581
  29 .1991.3201.320  30 .181 .581   45 .181 .581
  30 .1991.3201.320  31 .181 .581   46 .181 .581
  31 .1991.3201.320  32 .181 .433   47 .181 .581
  32.21861.241.6597  48.2855 .581
  33.21861.241.6597  34 .181 .581   49.2855 .433
  34 .1991.3201.320  35 .181 .581   50 .181 .581
  35.18461.3821.382  36 .121 .581   51 .121 .581
  36.18461.3821.382  37 .181 .581   52 .121 .581
  37 .1991.3201.320  38 .181 .581   53 .181 .581
  38 .1991.3201.320  39 .181 .581   54 .181 .581
  39 .1991.3201.320  40 .181 .581   55 .181 .581
  40 .1991.3201.320  41 .181 .581   56 .181 .581
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41 .1991.3201.320  42 .161 .581   57 .161 .581
42 .1991.3201.320  43 .161 .581   58 .161 .581
43 .1991.3201.320  44 .161 .581   59 .161 .581
44 .1991.3201.320  45 .161 .581   60 .161 .581
45.18461.3821.382  46 .121 .581   61 .121 .581
46.18461.3821.382  47 .161 .581   62 .121 .581
47 .1991.3201.320  48 .161 .433   63 .161 .581
48.21861.241.6597  64.2855 .581
49.21861.241.6597  50 .161 .581   65.2855 .433
50 .1991.3201.320  51 .161 .581   66 .161 .581
51.18461.3821.382  52 .121 .581   67 .161 .581
52.18461.3821.382  53 .161 .581   68 .161 .581
53 .1991.3201.320  54 .161 .581   69 .161 .581
54 .1991.3201.320  55 .161 .581   70 .161 .581
55 .1991.3201.320  56 .161 .581   71 .161 .581
56 .1991.3201.320  57 .161 .581   72 .161 .581
57 .1991.3201.320  58 .161 .581   73 .161 .581
58 .1991.3201.320  59 .161 .581   74 .161 .581
59 .1991.3201.320  60 .161 .581   75 .161 .581
60 .1991.3201.320  61 .161 .581   76 .161 .581
61.18461.3821.382  62 .121 .581   77 .161 .581
62.18461.3821.382  63 .161 .581   78 .161 .581
63 .1991.3201.320  64 .161 .433   79 .161 .581
64.21861.241.6597  80.2855 .581
65.21861.241.6597  66 .101 .581   81.2855 .433
66 .1991.3201.320  67 .161 .581   82 .161 .581
67 .1991.3201.320  68 .161 .581   83 .161 .581
68 .1991.3201.320  69 .161 .581   84 .161 .581
69.18461.3821.382  70 .121 .581   85 .121 .581
70.18461.3821.382  71 .161 .581   86 .121 .581
71 .1991.3201.320  72 .161 .581   87 .161 .581
72 .1991.3201.320  73 .161 .581   88 .161 .581
73 .1991.3201.320  74 .161 .581   89 .161 .581
74 .1991.3201.320  75 .161 .581   90 .161 .581
75.18461.3821.382  76 .121 .581   91 .121 .581
76.18461.3821.382  77 .161 .581   92 .121 .581
77 .1991.3201.320  78 .161 .581   93 .161 .581
78 .1991.3201.320  79 .161 .581   94 .161 .581
79.18461.3821.382  80 .121 .433   95 .121 .581
80.20421.304.7226  96.2455 .581
81.21861.241.6597  82 .161 .581   97.2855 .433
82 .1991.3201.320  83 .161 .581   98 .161 .581
83 .1991.3201.320  84 .161 .581   99 .161 .581
84 .1991.3201.320  85 .161 .581  100 .161 .581
85.18461.3821.382  86 .121 .581  101 .161 .581
86.18461.3821.382  87 .161 .581  102 .161 .581
87 .1991.3201.320  88 .161 .581  103 .161 .581
88 .1991.3201.320  89 .161 .581  104 .161 .581
89 .1991.3201.320  90 .161 .581  105 .161 .581
90 .1991.3201.320  91 .161 .581  106 .161 .581
91.18461.3821.382  92 .121 .581  107 .161 .581
92.18461.3821.382  93 .161 .581  108 .161 .581
93 .1991.3201.320  94 .161 .581  109 .161 .581
94 .1991.3201.320  95 .161 .581  110 .161 .581
95.18461.3821.382  96 .121 .433  111 .161 .581
96.20421.304.7226 112.2455 .581
97.21861.241.6597  98 .161 .581  113.2855 .433
98 .1991.3201.320  99 .161 .581  114 .161 .581
99 .1991.3201.320 100 .161 .581  115 .161 .581
100 .1991.3201.320 101 .161 .581  116 .161 .581
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101 .1991.3201.320  102 .161 .581  117 .161 .581
102 .1991.3201.320  103 .161 .581  118 .161 .581
103 .1991.3201.320  104 .161 .581  119 .161 .581
104 .1991.3201.320  105 .161 .581  120 .161 .581
105 .1991.3201.320  106 .161 .581  121 .161 .581
106 .1991.3201.320  107 .161 .581  122 .161 .581
107 .1991.3201.320  108 .161 .581  123 .161 .581
108 .1991.3201.320  109 .161 .581  124 .161 .581
109 .1991.3201.320  110 .161 .581  125 .161 .581
110 .1991.3201.320  111 .161 .581  126 .161 .581
111 .1991.3201.320  112 .161 .433  127 .161 .581
112.21861.241.6597  128.2855 .581
113.21861.241.6597  114 .161 .581  129.2855 .433
114 .1991.3201.320  115 .161 .581  130 .161 .581
115 .1991.3201.320  116 .161 .581  131 .161 .581
116 .1991.3201.320  117 .161 .581  132 .161 .581
117 .1991.3201.320  118 .161 .581  133 .161 .581
118 .1991.3201.320  119 .161 .581  134 .161 .581
119 .1991.3201.320  120 .161 .581  135 .161 .581
120.18461.3821.382  121 .121 .581  136 .121 .581
121.18461.3821.382  122 .161 .581  137 .121 .581
122 .1991.3201.320  123 .161 .581  138 .161 .581
123 .1991.3201.320  124 .161 .581  139 .161 .581
124 .1991.3201.320  125 .161 .581  140 .161 .581
125 .1991.3201.320  126 .161 .581  141 .161 .581
126 .1991.3201.320  127 .161 .581  142 .161 .581
127 .1991.3201.320  128 .161 .433  143 .161 .581
128.21861.241.6597  144.2855 .581
129.21861.241.6597  130 .161 .581  145.2855 .433
130 .1991.3201.320  131 .161 .581  146 .161 .581
131 .1991.3201.320  132 .161 .581  147 .161 .581
132 .1991.3201.320  133 .161 .581  148 .161 .581
133 .1991.3201.320  134 .161 .581  149 .161 .581
134 .1991.3201.320  135 .161 .581  150 .161 .581
135 .1991.3201.320  136 .161 .581  151 .161 .581
136.18461.3821.382  137 .121 .581  152 .161 .581
137.18461.3821.382  138 .161 .581  153 .161 .581
138 .1991.3201.320  139 .161 .581  154 .161 .581
139 .1991.3201.320  140 .161 .581  155 .161 .581
140 .1991.3201.320  141 .161 .581  156 .161 .581
141 .1991.3201.320  142 .161 .581  157 .161 .581
142 .1991.3201.320  143 .161 .581  158 .161 .581
143 .1991.3201.320  144 .161 .433  159 .161 .581
144.21861.241.6597  160.2855 .581
145.21861.241.6597  146 .161 .581  161.2855 .433
146 .1991.3201.320  147 .161 .581  162 .161 .581
147 .1991.3201.320  148 .161 .581  163 .161 .581
148 .1991.3201.320  149 .161 .581  164 .161 .581
149 .1991.3201.320  150 .161 .581  165 .161 .581
150 .1991.3201.320  151 .161 .581  166 .161 .581
151 .1991.3201.320  152 .161 .581  167 .161 .581
152 .1991.3201.320  153 .161 .581  168 .161 .581
153 .1991.3201.320  154 .161 .581  169 .161 .581
154 .1991.3201.320  155 .161 .581  170 .161 .581
155 .1991.3201.320  156 .161 .581  171 .161 .581
156 .1991.3201.320  157 .161 .581  172 .161 .581
157 .1991.3201.320  158 .161 .581  173 .161 .581
158 .1991.3201.320  159 .161 .581  174 .161 .581
159 .1991.3201.320  160 .161 .433  175 .161 .581
160.21861.241.6597  176.2855 .581
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161.21861.241.6597  162 .161 .581  177.2855 .433
162 .1991.3201.320  163 .161 .581  178 .161 .581
163 .1991.3201.320  164 .161 .581  179 .161 .581
164 .1991.3201.320  165 .161 .581  180 .161 .581
165.18461.3821.382  166 .121 .581  181 .121 .581
166.18461.3821.382  167 .161 .581  182 .121 .581
167 .1991.3201.320  168 .161 .581  183 .161 .581
168 .1991.3201.320  169 .161 .581  184 .161 .581
169 .1991.3201.320  170 .161 .581  185 .161 .581
170 .1991.3201.320  171 .161 .581  186 .161 .581
171.18461.3821.382  172 .121 .581  187 .121 .581
172.18461.3821.382  173 .161 .581  188 .121 .581
173 .1991.3201.320  174 .161 .581  189 .161 .581
174 .1991.3201.320  175 .161 .581  190 .161 .581
175.18461.3821.382  176 .121 .433  191 .161 .581
176.20421.304.7226  192.2455 .581
177.21861.241.6597  178 .161 .581  193.2855 .433
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2   28.1564.688   0.    32.121 5.44   106.188 2.03
2   38.1564.688   0.    41.500 5.44   116.188 2.03
2   48.1564.688   0.    52.121 5.44   126.188 2.03
2   58.1564.688   0.    61.500 5.44   136.188 2.03
2   68.1564.688   0.    72.121 5.44   146.188 2.03
2   78.1564.688   0.    81.500 5.44   156.188 2.03
2   88.1564.688   0.   166.188 2.03
2  910.926.872    0.   102.563 4.13
2 1010.926.872    0.
2 1110.926.872    0.   122.563 4.13
2 1210.926.872    0.
2 1310.926.872    0.   142.563 4.13
2 1410.926.872    0.
2 1510.926.872    0.   162.563 4.13
2 1610.926.872    0.

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    1    1  225
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  201  .42   1.  214  .25  215  .25  230  .25  231  .25
  202  .42   1.  215  .25  216  .25  231  .25  232  .25
  203  .42   1.  216  .25  217  .25  232  .25  233  .25
  204  .42   1.  217  .25  218  .25  233  .25  234  .25
  205  .42   1.  218  .25  219  .25  234  .25  235  .25
  206  .42   1.  219  .25  220  .25  235  .25  236  .25
  207  .42   1.  220  .25  221  .25  236  .25  237  .25
  208  .42   1.  221  .25  222  .25  237  .25  238  .25
  209  .42   1.  222  .25  223  .25  238  .25  239  .25
  210  .42   1.  223  .25  224  .25  239  .25  240  .25
  211  .42   1.  225  .25  226  .25  241  .25  242  .25
  212  .42   1.  226  .25  227  .25  242  .25  243  .25
  213  .42   1.  227  .25  228  .25  243  .25  244  .25
  214  .42   1.  228  .25  229  .25  244  .25  245  .25
  215  .42   1.  229  .25  230  .25  245  .25  246  .25
  216  .42   1.  230  .25  231  .25  246  .25  247  .25
  217  .42   1.  231  .25  232  .25  247  .25  248  .25
  218  .42   1.  232  .25  233  .25  248  .25  249  .25
  219  .42   1.  233  .25  234  .25  249  .25  250  .25
  220  .42   1.  234  .25  235  .25  250  .25  251  .25
  221  .42   1.  235  .25  236  .25  251  .25  252  .25
  222  .42   1.  236  .25  237  .25  252  .25  253  .25
  223  .42   1.  237  .25  238  .25  253  .25  254  .25
  224  .42   1.  238  .25  239  .25  254  .25  255  .25
  225  .42   1.  239  .25  240  .25  255  .25  256  .25
    2    0    0
  3.0 .059 655. .350  10.  0.1 409. .0251000. .420
slab    2    3   16
    1                     3670.
    2                    989.
    1    1  .95             2    2    1    8    1
    2    1  .95             1    3    1
    3    1  .95             1    4    1
    4    1  .95             1    5    1
    5    1  .95             1    6    1
    6    1  .95             1    7    1
    7    1  .95             1    8    1
    8    1  .95
    9    2 1.74             2   10    2   16    2
   10    2 1.74             1   11    2
   11    2 1.74             1   12    2
   12    2 1.74             1   13    2
   13    2 1.74             1   14    2
```

```
  14    2 1.74              1   15    2
  15    2 1.74              1   16    2
  16    2 1.74
   1     34.20      .5561
   2    12.145      4.614
   3     .0130      6.684
   1    9    1    1    1    1    2    1    1    3    1    1    4    1
             1    5    1    1    6    1    1    7    1    1    8    1
             2    1    2
   2    9    1    9    1    1   10    1    1   11    1    1   12    1
             1   13    1    1   14    1    1   15    1    1   16    1
             2    2    2
   3    9    1   16    1    1   32    1    1   48    1    1   64    1
             1   80    1    1   96    1    1  112    1    1  128    1
             2    3    2
   4    9    1  144    1    1  160    1    1  176    1    1  192    1
             1  208    1    1  224    1    1  240    1    1  256    1
             2    4    2
   5    9    1  249    1    1  250    1    1  251    1    1  249    1
             1  253    1    1  254    1    1  255    1    1  256    1
             2    5    2
   6    9    1  241    1    1  242    1    1  243    1    1  244    1
             1  245    1    1  246    1    1  247    1    1  248    1
             2    6    2
   7    9    1  129    1    1  145    1    1  161    1    1  177    1
             1  193    1    1  209    1    1  225    1    1  241    1
             2    7    2
   8    9    1    1    1    1   17    1    1   33    1    1   49    1
             1   65    1    1   81    1    1   97    1    1  113    1
             2    8    2
   9    1    2   09    3
  10    1    2   10    3
  11    1    2   11    3
  12    1    2   12    3
  13    1    2   13    3
  14    1    2   14    3
  15    1    2   15    3
  16    1    2   16    3

radg    2    1    1
   1   16
   14.614  .25   1.0016    2.0       3.0       4.0       5.0       6.0
                 7.0       8.0       9.6808    10.2656   11.0085   12.0
                 13.0      14.0      15.0      16.0435
   24.614  .25   1.0       2.0016    3.0       4.0       5.0       6.0
                 7.0       8.0       9.2656    10.6808   11.0435   12.0
                 13.0      14.0      15.0      16.0085
   34.614  .25   1.0       2.0       3.0016    4.0       5.0       6.0
                 7.0       8.0       9.0       10.0435   11.6808   12.2656
                 13.0085   14.0      15.0      16.0
   44.614  .25   1.0       2.0       3.0       4.0016    5.0       6.0
                 7.0       8.0       9.0       10.0085   11.2656   12.6808
                 13.0435   14.0      15.0      16.0
   54.614  .25   1.0       2.0       3.0       4.0       5.0016    6.0
                 7.0       8.0       9.0       10.0      11.0      12.0435
                 13.6808   14.2656   15.0085   16.0
   64.614  .25   1.0       2.0       3.0       4.0       5.0       6.0016
                 7.0       8.0       9.0       10.0      11.0      12.0085
                 13.2656   14.6808   15.0435   16.0
   74.614  .25   1.0       2.0       3.0       4.0       5.0       6.0
```

```
                 7.0018    8.0       9.0085    10.0      11.0      12.0
                13.0      14.0435   15.0808   16.2656
   86.614  .25   1.0       2.0       3.0       4.0       5.0       6.0
                 7.0       8.0018    9.0435   10.0      11.0      12.0
                13.0      14.0085   15.2656   16.0808
   96.684  .6    1.4700    2.1833    3.0       4.0       5.0       6.0
                 7.0859    8.03      9.0271   10.0734   11.0637   12.0
                13.0      14.0134   15.0637   16.0695
  106.684  .6    1.1833    2.4700    3.0300    4.0859    5.0       6.0
                 7.0       8.0       9.0734   10.0271   11.0695   12.0637
                13.0134   14.0      15.0      16.0637
  116.684  .6    1.0859    2.03      3.47      4.1833    5.0       6.0
                 7.0       8.0       9.0637   10.0695   11.0271   12.0734
                13.0637   14.0      15.0      16.0134
  126.684  .6    1.0       2.0       3.1833    4.47      5.03      6.0859
                 7.0       8.0       9.0000   10.0637   11.0734   12.0271
                13.0695   14.0637   15.0134   16.0
  136.684  .6    1.0       2.0       3.0859    4.0300    5.47      6.1833
                 7.0       8.0       9.0      10.0134   11.0637   12.0695
                13.0271   14.0734   15.0637   16.0
  146.684  .6    1.0       2.0       3.0       4.0       5.1833    6.4700
                 7.0300    8.0859    9.0134   10.0      11.0      12.0637
                13.0734   14.0271   15.0695   16.0637
  156.684  .6    1.0       2.0       3.0       4.0       5.0859    6.03
                 7.47      8.1833    9.0637   10.0      11.0      12.0134
                13.0637   14.0695   15.0271   16.0734
  166.684  .6    1.03      2.0859    3.0       4.0       5.0       6.0
                 7.1833    8.4700    9.0695   10.0637   11.0134   12.0
                13.0      14.0637   15.0734   16.0271
    1    1    8    1    2    3    4    5    6    7    8
    2   -1   16    1    2    3    4    5    6    7    8    9   10   11   12
                  13   14   15   16
heat      1    0    1
               3.66               3.66
  1.0  1.0
drag      2    2
 100. -1.0                100. -1.0  .05
 100. -1.0                100. -1.0  50.
    1   16    0
    7   16  240 .066   2. .155   2. .278   8. .393   2. .454   8. .699   8.
                .979   8.
    7    1   17 .066   1. .155   1. .278   4. .393   1. .454   4. .699   4.
                .979   4.
    7   32   33 .066   1. .155   1. .278   4. .393   1. .454   4. .699   4.
                .979   4.
    7   48   49 .066   1. .155   1. .278   4. .393   1. .454   4. .699   4.
                .979   4.
    7   64   65 .066   1. .155   1. .278   4. .393   1. .454   4. .699   4.
                .979   4.
    7   80   81 .066   1. .155   1. .278   4. .393   1. .454   4. .699   4.
                .979   4.
    7   96   97 .066   1. .155   1. .278   4. .393   1. .454   4. .699   4.
                .979   4.
    7  112  113 .066   1. .155   1. .278   4. .393   1. .454   4. .699   4.
                .979   4.
    7  128  129 .066   1. .155   1. .278   4. .393   1. .454   4. .699   4.
                .979   4.
    7  144  145 .066   1. .155   1. .278   4. .393   1. .454   4. .699   4.
                .979   4.
    7  160  161 .066   1. .155   1. .278   4. .393   1. .454   4. .699   4.
```

```
                .979    4.
     7  176   177 .066    1. .155    1. .276    4. .393    1. .454    4. .699    4.
                .979    4.
     7  192   193 .066    1. .155    1. .276    4. .393    1. .454    4. .699    4.
                .979    4.
     7  208   209 .066    1. .155    1. .276    4. .393    1. .454    4. .699    4.
                .979    4.
     7  224   225 .066    1. .155    1. .276    4. .393    1. .454    4. .699    4.
                .979    4.
     7  240   256 .066    1. .155    1. .276    4. .393    1. .454    4. .699    4.
                .979    4.
     2    1     0
     1    1    16 0.01 30.0
bdry      5     4     8     2
     1    .001
     2   9.98e-6
     3   3.22e-6
     4   1.98e-6
     5   1.00e-4
     1   11-.012137.5.000 199.0.033 237.0.151 293.0.306 336.0.578 360.0
           0.726368.00.850365.01.000332.01.122277.01.186176.0
     2   11-.012137.5.000 184.0.033 216.0.151 288.0.306 333.0.578 355.0
           0.726363.00.850361.01.000333.01.122277.01.186176.0
     3   11-.012137.5.000 155.0.033 183.0.151 263.0.306 319.0.578 355.0
           0.726362.00.850356.01.000320.01.122267.01.186176.0
     4   10-.012137.5.033 165.0.151 243.0.306 306.0.578 346.0.726 353.0
           0.850345.01.000308.01.122259.01.186176.0
     9    1 7.07    1
     1   1.     1   1.    1
    10    1 7.07    1
     1   1.     1   1.    1
    11    1 7.07    2
     1   1.     1   1.    1
    12    1 7.07    3
     1   1.     1   1.    1
    13    1 7.07    4
     1   1.     1   1.    1
    14    1 7.07    4
     1   1.     1   1.    1
    15    1 7.07    3
     1   1.     1   1.    1
    16    1 7.07    2
     1   1.     1   1.    1
     1 379.  254.   2     2137.5137.5
     1   1.     3
     2   1.     1
     1   1.     2
     2   1.     1     8     1     2  .95    2.     2     2  .95    2.     3     2  .95    2.
                            4     2  .95    2.     5     2  .95    2.     8     2  .95    2.
                            7     2  .95    2.     8     2  .95    2.
     21340. 240.    2     2271.2176.0
     1   1.     3
     2   1.     1
     1   1:     4
     2 2.50     5
calc      1     0     0
                                              0.1
        25
oper      1     2     3     1                                                       1
  20.            282.    .0001 .002014776    250.    .000000        0.0
```

```
   1. -.33
1.000
   6
   0.   0..1043   0..1044   1..9758   1..9759   0.  1.0  0.0
outp 1101
endd


 data from iterative solution using the recirculation module
 time =    0.0000    dt = ******    implicit dt = 0.0000    explicit dt = 5.2009    mode =  0


 iteration  sweep           peak clad              total flow     pressure                  error
    no.      no.   ---------------------------      (lbm/s)      drop(psi)    -----------------------------------
                   temp(f)  fluid  rod  ass.                                  total     flow    fluid     rod
                                                                              energy            energy   energy

      1       1     516.7    24    98    1      0.496e-10    0.0020492     20.0468   1.9321   0.0371   0.0169
              2     519.6    24    98    1                                  0.0036   1.9321   0.0177   0.0040

      2       1     525.9    24    98    1      0.216e-10    0.0019821     -0.0059   2.4043   0.0575   0.0037
              2     540.6    23    98    1                                  0.0356   2.4043   0.0984   0.0064

      3       1     544.0    22    98    1     -0.302e-10    0.0019761      0.0533   1.1280   0.0314   0.0018
              2     550.1    21    98    1                                  0.0052   1.1280   0.0958   0.0012

      4       1     551.5    21    98    1      0.324e-10    0.0019848     -0.0507   1.5833   0.0704   0.0007
              2     553.7    21    98    1                                  0.0104   1.5833   0.0484   0.0007

      5       1     554.3    20    98    1      0.251e-11    0.0019865      0.0193   1.6377   0.0161   0.0002
              2     555.3    20    98    1                                  0.0096   1.6377   0.0760   0.0003

      6       1     555.5    20    98    1      0.848e-11    0.0019911      0.0022   1.5974   0.0693   0.0002
              2     555.9    20    98    1                                  0.0072   1.5974   0.0360   0.0002

      7       1     556.0    20    98    1     -0.105e-10    0.0019911      0.0039   1.5178   0.0195   0.0002
              2     556.1    20    98    1                                  0.0039   1.5178   0.0781   0.0002

      8       1     556.1    20    98    1     -0.243e-10    0.0019932     -0.0030   1.1606   0.0366   0.0002
              2     556.1    20    98    1                                 -0.0019   1.1606   0.0868   0.0002

      9       1     556.1    20    98    1     -0.224e-12    0.0019928     -0.0036   1.3176   0.0113   0.0002
              2     555.9    20    98    1                                  0.0043   1.3176   0.0397   0.0002

     10       1     556.0    20    98    1      0.688e-12    0.0019922      0.0070   1.0839   0.0062   0.0002
              2     556.0    20    98    1                                  0.0040   1.0839   0.0542   0.0002

     11       1     556.0    20    98    1      0.286e-11    0.0019916     -0.0001   1.1281   0.0284   0.0002
              2     556.0    20    98    1                                  0.0033   1.1281   0.0343   0.0002

     12       1     556.0    20    98    1      0.255e-11    0.0019914      0.0006   1.0851   0.0089   0.0002
              2     556.0    20    98    1                                  0.0018   1.0851   0.0716   0.0002

     13       1     556.0    20    98    1      0.128e-10    0.0019914      0.0006   1.3363   0.0323   0.0002
              2     555.9    20    98    1                                  0.0038   1.3363   0.0234   0.0002

     14       1     555.9    20    98    1      0.574e-11    0.0019916      0.0016   1.1389   0.0066   0.0002
              2     555.9    20    98    1                                  0.0044   1.1389   0.0327   0.0002
```

```
   15        1      555.9    20    98    1     -0.147e-10    0.0019913     0.0017   1.0244   0.0035   0.0002
             2      555.9    20    98    1                                 0.0035   1.0244   0.0555   0.0002

   16        1      555.9    20    98    1      0.799e-11    0.0019912     0.0015   0.9096   0.0260   0.0002
             2      555.9    20    98    1                                 0.0043   0.9096   0.0228   0.0002

   17        1      555.9    20    98    1     -0.997e-11    0.0019906     0.0019   1.0186   0.0038   0.0002
             2      555.9    20    98    1                                 0.0034   1.0186   0.0043   0.0002

   18        1      555.9    20    98    1     -0.103e-10    0.0019908     0.0007   1.0698   0.0307   0.0002
             2      555.9    20    98    1                                 0.0037   1.0698   0.0317   0.0002

   19        1      555.9    20    98    1     -0.179e-11    0.0019910     0.0028   1.0891   0.0006   0.0002
             2      555.9    20    98    1                                 0.0029   1.0891   0.0629   0.0002

   20        1      555.9    20    98    1      0.168e-10    0.0019913     0.0003   0.9223   0.0308   0.0002
             2      555.9    20    98    1                                 0.0044   0.9223   0.0314   0.0002

   21        1      555.9    20    98    1      0.234e-11    0.0019916     0.0021   1.1140   0.0086   0.0002
             2      555.9    20    98    1                                 0.0040   1.1140   0.0512   0.0002

   22        1      555.9    20    98    1      0.511e-11    0.0019915     0.0014   1.1300   0.0134   0.0002
             2      555.9    20    98    1                                 0.0044   1.1300   0.0129   0.0002

   23        1      555.9    20    98    1      0.278e-12    0.0019914     0.0020   0.7929   0.0022   0.0002
             2      555.9    20    98    1                                 0.0045   0.7929   0.0223   0.0002

   24        1      555.9    20    98    1     -0.206e-10    0.0019909     0.0021   1.0291   0.0036   0.0002
             2      555.9    20    98    1                                 0.0033   1.0291   0.0562   0.0002

   25        1      555.9    20    98    1      0.102e-10    0.0019916     0.0007   0.8727   0.0280   0.0002
             2      555.9    20    98    1                                 0.0040   0.8727   0.0325   0.0002


axial zone    ( 1)     ( 2)     ( 3)     ( 4)     ( 5)     ( 6)     ( 7)     ( 8)     ( 9)     ( 10)
 (inches)

  0.0 -  6.9  166.83   166.79   164.85   162.98   161.03   161.93   163.31   164.97   223.07   223.07
  6.9 - 13.8  200.29   200.23   197.57   194.60   192.58   192.73   195.08   197.78   250.68   250.68
 13.8 - 20.7  232.74   232.71   230.19   227.09   224.83   224.95   227.50   230.34   270.61   270.61
 20.7 - 27.5  280.22   280.28   276.07   275.25   272.93   273.03   275.36   277.92   290.38   290.38
 27.5 - 34.4  320.49   320.57   318.57   316.01   313.77   313.83   315.99   318.33   303.07   303.07
 34.4 - 41.3  352.58   352.66   350.82   348.49   346.37   346.41   348.41   350.57   314.67   314.67
 41.3 - 48.2  377.63   377.70   376.02   373.90   371.91   371.94   373.79   375.77   326.23   326.23
 48.2 - 55.1  396.51   396.57   395.02   393.12   391.26   391.28   392.97   394.79   336.52   336.52
 55.1 - 62.0  409.25   409.31   407.84   406.09   404.32   404.33   405.92   407.61   340.28   340.28
 62.0 - 68.9  418.41   418.46   417.06   415.46   413.79   413.80   415.27   416.83   343.97   343.97
 68.9 - 75.8  425.32   425.36   424.04   422.60   421.04   421.04   422.39   423.82   347.64   347.64
 75.8 - 82.6  430.78   430.83   429.58   428.31   426.86   426.85   428.08   429.36   351.32   351.32
 82.6 - 89.5  435.29   435.34   434.18   433.06   431.73   431.73   432.83   433.96   355.00   355.00
 89.5 - 96.4  439.08   439.13   438.05   437.08   435.86   435.85   436.83   437.82   358.66   358.66
 96.4 -103.3  442.03   442.07   441.01   440.07   438.87   438.85   439.81   440.78   361.45   361.45
103.3 -110.2  444.27   444.32   443.22   442.24   440.99   440.97   441.97   442.99   363.71   363.71
110.2 -117.1  446.04   446.09   444.95   443.90   442.58   442.56   443.62   444.71   365.95   365.95
117.1 -124.0  447.20   447.24   446.05   444.91   443.51   443.48   444.62   445.81   367.92   367.92
124.0 -130.9  447.04   447.09   445.81   444.52   442.95   442.93   444.22   445.57   366.95   366.95
130.9 -137.7  446.05   446.10   444.75   443.30   441.55   441.52   442.97   444.50   365.94   365.94
137.7 -144.6  443.70   443.76   442.33   440.72   438.80   438.76   440.38   442.07   364.04   364.04
144.6 -151.5  437.99   438.04   436.60   434.84   432.75   432.71   434.48   436.34   354.97   354.97
```

```
151.5 -158.4     427.75     427.80     426.34     424.42     422.14     422.09     424.04     426.09     345.82     345.82
158.4 -165.3     403.37     403.37     401.96     399.75     397.16     397.12     399.54     401.89     336.75     336.75
```

```
 side boundary temperature summary     time =    0.0000 seconds
 boundary slab node no.     9


axial zone      ( 1)       ( 2)       (
 (inches)

  0.0 -  6.9    223.07     222.99
  6.9 - 13.8    250.60     251.00
 13.8 - 20.7    270.61     270.77
 20.7 - 27.5    290.38     290.55
 27.5 - 34.4    303.06     303.13
 34.4 - 41.3    314.67     314.68
 41.3 - 48.2    326.23     326.24
 48.2 - 55.1    336.52     336.57
 55.1 - 62.0    340.28     340.25
 62.0 - 68.9    343.97     343.93
 68.9 - 75.8    347.64     347.60
 75.8 - 82.6    351.32     351.20
 82.6 - 89.5    355.00     354.96
 89.5 - 96.4    358.66     358.63
 96.4 -103.3    361.45     361.41
103.3 -110.2    363.71     363.67
110.2 -117.1    365.95     365.92
117.1 -124.0    367.92     367.92
124.0 -130.9    366.95     366.92
130.9 -137.7    365.94     365.91
137.7 -144.6    364.64     364.60
144.6 -151.5    354.97     354.92
151.5 -158.4    345.82     345.76
158.4 -165.3    336.75     336.58
```

```
 calculated rod temperatures at time =    0.0000 seconds
 rod no.    1
 assembly   1                 (fuel type  1 - cylinder)
0rod o.d. - 0.420 (in.)     zone-(fuel dia.(in.)) -  1-(0.350)

                                            *  fuel temperatures(f.)
                                            *
  axial zone  heat flux   type         hsurf *  fluid    clad
    (in.)   (mbtu/hr-ft2)          (b/h-f-ft2) *
   0.0 -   6.9    0.0000    1             1.1     162.7    162.4
   6.9 -  13.8    0.0000    1             1.1     189.6    188.5
  13.8 -  20.7    0.0000    1             1.2     219.0    217.9
  20.7 -  27.5    0.0000    1             1.2     280.5    288.7
  27.5 -  34.4    0.0000    1             1.3     327.9    337.5
  34.4 -  41.3    0.0000    1             1.4     364.9    375.5
```

```
   41.3 -  48.2    0.0000    1                1.4      393.3    404.5
   48.2 -  55.1    0.0000    1                1.4      414.5    426.2
   55.1 -  62.0    0.0000    1                1.4      429.2    441.1
   62.0 -  68.9    0.0000    1                1.4      439.6    451.7
   68.9 -  75.8    0.0000    1                1.5      447.2    459.5
   75.8 -  82.6    0.0000    1                1.5      453.2    465.4
   82.6 -  89.5    0.0000    1                1.5      457.9    470.2
   89.5 -  96.4    0.0000    1                1.5      461.9    474.1
   96.4 - 103.3    0.0000    1                1.5      465.0    477.2
  103.3 - 110.2    0.0000    1                1.5      467.3    479.5
  110.2 - 117.1    0.0000    1                1.5      469.1    481.3
  117.1 - 124.0    0.0000    1                1.5      470.4    482.6
  124.0 - 130.9    0.0000    1                1.5      470.4    482.7
  130.9 - 137.7    0.0000    1                1.5      469.7    482.0
  137.7 - 144.6    0.0000    1                1.5      467.8    480.2
  144.6 - 151.5    0.0000    1                1.5      463.0    475.6
  151.5 - 158.4    0.0000    1                1.5      454.6    467.6
  158.4 - 165.3    0.0000    1                1.4      419.1    423.4


  calculated rod temperatures at time =     0.0000 seconds
  rod no.  128
  assembly   1                  (fuel type  1 - cylinder)
 0rod o.d. - 0.420 (in.)     zone-(fuel dia.(in.)) -  1-(0.350)

                                                  *   fuel temperatures(f.)
                                                  *
    axial zone  heat flux   type          hsurf   *   fluid     clad
       (in.)   (mbtu/hr-ft2)          (b/h-f-ft2) *
     0.0 -   6.9    0.0000    1                1.3      154.9    155.0
     6.9 -  13.8    0.0000    1                1.3      162.2    162.6
    13.8 -  20.7    0.0000    1                1.3      176.8    177.7
    20.7 -  27.5    0.0000    1                1.4      276.5    285.1
    27.5 -  34.4    0.0000    1                1.6      355.4    362.2
    34.4 -  41.3    0.0000    1                1.6      413.4    418.6
    41.3 -  48.2    0.0000    1                1.7      454.6    458.6
    48.2 -  55.1    0.0000    1                1.8      483.8    487.0
    55.1 -  62.0    0.0000    1                1.8      504.1    506.7
    62.0 -  68.9    0.0000    1                1.8      518.1    520.3
    68.9 -  75.8    0.0000    1                1.8      527.9    529.8
    75.8 -  82.6    0.0000    1                1.8      535.1    536.8
    82.6 -  89.5    0.0000    1                1.8      540.4    542.0
    89.5 -  96.4    0.0000    1                1.8      544.7    546.2
    96.4 - 103.3    0.0000    1                1.8      547.9    549.4
   103.3 - 110.2    0.0000    1                1.9      550.5    551.9
   110.2 - 117.1    0.0000    1                1.9      552.4    553.7
   117.1 - 124.0    0.0000    1                1.9      553.8    555.1
   124.0 - 130.9    0.0000    1                1.9      554.4    555.7
   130.9 - 137.7    0.0000    1                1.9      554.3    555.6
   137.7 - 144.6    0.0000    1                1.9      553.4    554.6
   144.6 - 151.5    0.0000    1                1.9      551.0    552.1
   151.5 - 158.4    0.0000    1                1.8      548.3    547.3
   158.4 - 165.3    0.0000    1                1.8      483.2    479.6
```

```
+8000
   1    1     agns horizontal nitrogen full-load validation analyses
prop    11    2
        1.       100.      133.9     .0154      .240     14.66      .0463
        2.       200.      157.9     .0174      .241     16.67      .0516
        3.       300.      182.1     .0193      .243     19.23      .0580
        4.       400.      206.5     .0212      .245     21.74      .0630
        5.       500.      231.1     .0231      .247     24.27      .0680
        6.       600.      256.0     .0250      .250     26.81      .0720
        7.       700.      281.1     .0268      .253     29.33      .0770
        8.       800.      306.7     .0286      .256     31.85      .0810
       10.       900.      332.5     .0303      .259     34.36      .0850
       15.      1000.      358.6     .0319      .262     36.90      .0889
       20.      2000.      617.2     .0471      .286     62.11      .1242
   1  can                            13.
   2steel                           100.
chan     2   24
    165.3       90.0
   1    1  256    0
   1    1    0    0    1
   1.21091.321.3299    2.2855 .538   17.2855 .538
   2.21861.241.6597    3.2855 .581   18 .161 .433
   3.21861.241.6597    4.2855 .581   19 .161 .433
   4.21861.241.6597    5.2855 .581   20 .161 .433
   5.21861.241.6597    6.2855 .581   21 .161 .433
   6.21861.241.6597    7.2855 .581   22 .161 .433
   7.21861.241.6597    8.2855 .581   23 .161 .433
   8.21861.241.6597    9.2855 .581   24 .161 .433
   9.21861.241.6597   10.2855 .581   25 .161 .433
  10.21861.241.6597   11.2855 .581   26 .161 .433
  11.21861.241.6597   12.2855 .581   27 .161 .433
  12.21861.241.6597   13.2855 .581   28 .161 .433
  13.21861.241.6597   14.2855 .581   29 .161 .433
  14.21861.241.6597   15.2855 .581   30 .161 .433
  15.21861.241.6597   16.2855 .581   31 .161 .433
  16.21091.321.3299   32.2855 .538
  17.21861.241.6597   18 .161 .581   33.2855 .433
  18 .1991.3201.320   19 .161 .581   34 .161 .581
  19 .1991.3201.320   20 .161 .581   35 .161 .581
  20 .1991.3201.320   21 .161 .581   36 .161 .581
  21 .1991.3201.320   22 .161 .581   37 .161 .581
  22 .1991.3201.320   23 .161 .581   38 .161 .581
  23 .1991.3201.320   24 .161 .581   39 .161 .581
  24 .1991.3201.320   25 .161 .581   40 .161 .581
  25 .1991.3201.320   26 .161 .581   41 .161 .581
  26 .1991.3201.320   27 .161 .581   42 .161 .581
  27 .1991.3201.320   28 .161 .581   43 .161 .581
  28 .1991.3201.320   29 .161 .581   44 .161 .581
  29 .1991.3201.320   30 .161 .581   45 .161 .581
  30 .1991.3201.320   31 .161 .581   46 .161 .581
  31 .1991.3201.320   32 .161 .433   47 .161 .581
  32.21861.241.6597   48.2855 .581
  33.21861.241.6597   34 .161 .581   49.2855 .433
  34 .1991.3201.320   35 .161 .581   50 .161 .581
  35.18461.3821.382   36 .121 .581   51 .121 .581
  36.18461.3821.382   37 .161 .581   52 .121 .581
  37 .1991.3201.320   38 .161 .581   53 .161 .581
  38 .1991.3201.320   39 .161 .581   54 .161 .581
  39 .1991.3201.320   40 .161 .581   55 .161 .581
  40 .1991.3201.320   41 .161 .581   56 .161 .581
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41 .1991.3201.320   42 .161 .581   57 .161 .581
42 .1991.3201.320   43 .161 .581   58 .161 .581
43 .1991.3201.320   44 .161 .581   59 .161 .581
44 .1991.3201.320   45 .161 .581   60 .161 .581
45.18461.3821.382   46 .121 .581   61 .121 .581
46.18461.3821.382   47 .161 .581   62 .121 .581
47 .1991.3201.320   48 .161 .433   63 .161 .581
48.21861.241.6597   64.2855 .581
49.21861.241.6597   50 .161 .581   65.2855 .433
50 .1991.3201.320   51 .161 .581   66 .161 .581
51.18461.3821.382   52 .121 .581   67 .161 .581
52.18461.3821.382   53 .161 .581   68 .161 .581
53 .1991.3201.320   54 .161 .581   69 .161 .581
54 .1991.3201.320   55 .161 .581   70 .161 .581
55 .1991.3201.320   56 .161 .581   71 .161 .581
56 .1991.3201.320   57 .161 .581   72 .161 .581
57 .1991.3201.320   58 .161 .581   73 .161 .581
58 .1991.3201.320   59 .161 .581   74 .161 .581
59 .1991.3201.320   60 .161 .581   75 .161 .581
60 .1991.3201.320   61 .161 .581   76 .161 .581
61.18461.3821.382   62 .121 .581   77 .161 .581
62.18461.3821.382   63 .161 .581   78 .161 .581
63 .1991.3201.320   64 .161 .433   79 .161 .581
64.21861.241.6597   80.2855 .581
65.21861.241.6597   66 .161 .581   81.2855 .433
66 .1991.3201.320   67 .161 .581   82 .161 .581
67 .1991.3201.320   68 .161 .581   83 .161 .581
68 .1991.3201.320   69 .161 .581   84 .161 .581
69.18461.3821.382   70 .121 .581   85 .121 .581
70.18461.3821.382   71 .161 .581   86 .121 .581
71 .1991.3201.320   72 .161 .581   87 .161 .581
72 .1991.3201.320   73 .161 .581   88 .161 .581
73 .1991.3201.320   74 .161 .581   89 .161 .581
74 .1991.3201.320   75 .161 .581   90 .161 .581
75.18461.3821.382   76 .121 .581   91 .121 .581
76.18461.3821.382   77 .161 .581   92 .121 .581
77 .1991.3201.320   78 .161 .581   93 .161 .581
78 .1991.3201.320   79 .161 .581   94 .161 .581
79.18461.3821.382   80 .121 .433   95 .121 .581
80.20421.304.7226   96.2455 .581
81.21861.241.6597   82 .161 .581   97.2855 .433
82 .1991.3201.320   83 .161 .581   98 .161 .581
83 .1991.3201.320   84 .161 .581   99 .161 .581
84 .1991.3201.320   85 .161 .581  100 .161 .581
85.18461.3821.382   86 .121 .581  101 .161 .581
86.18461.3821.382   87 .161 .581  102 .161 .581
87 .1991.3201.320   88 .161 .581  103 .161 .581
88 .1991.3201.320   89 .161 .581  104 .161 .581
89 .1991.3201.320   90 .161 .581  105 .161 .581
90 .1991.3201.320   91 .161 .581  106 .161 .581
91.18461.3821.382   92 .121 .581  107 .161 .581
92.18461.3821.382   93 .161 .581  108 .161 .581
93 .1991.3201.320   94 .161 .581  109 .161 .581
94 .1991.3201.320   95 .161 .581  110 .161 .581
95.18461.3821.382   96 .121 .433  111 .161 .581
96.20421.304.7226  112.2455 .581
97.21861.241.6597   98 .161 .581  113.2855 .433
98 .1991.3201.320   99 .161 .581  114 .161 .581
99 .1991.3201.320  100 .161 .581  115 .161 .581
100 .1991.3201.320 101 .161 .581  116 .161 .581
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101 .1991.3201.320  102 .161 .581  117 .161 .581
102 .1991.3201.320  103 .161 .581  118 .161 .581
103 .1991.3201.320  104 .161 .581  119 .161 .581
104 .1991.3201.320  105 .161 .581  120 .161 .581
105 .1991.3201.320  106 .161 .581  121 .161 .581
106 .1991.3201.320  107 .161 .581  122 .161 .581
107 .1991.3201.320  108 .161 .581  123 .161 .581
108 .1991.3201.320  109 .161 .581  124 .161 .581
109 .1991.3201.320  110 .161 .581  125 .161 .581
110 .1991.3201.320  111 .161 .581  126 .161 .581
111 .1991.3201.320  112 .161 .433  127 .161 .581
112.21861.241.6597  128.2855 .581
113.21861.241.6597  114 .161 .581  129.2855 .433
114 .1991.3201.320  115 .161 .581  130 .161 .581
115 .1991.3201.320  116 .161 .581  131 .161 .581
116 .1991.3201.320  117 .161 .581  132 .161 .581
117 .1991.3201.320  118 .161 .581  133 .161 .581
118 .1991.3201.320  119 .161 .581  134 .161 .581
119 .1991.3201.320  120 .161 .581  135 .161 .581
120.18461.3821.382  121 .121 .581  136 .121 .581
121.18461.3821.382  122 .161 .581  137 .121 .581
122 .1991.3201.320  123 .161 .581  138 .161 .581
123 .1991.3201.320  124 .161 .581  139 .161 .581
124 .1991.3201.320  125 .161 .581  140 .161 .581
125 .1991.3201.320  126 .161 .581  141 .161 .581
126 .1991.3201.320  127 .161 .581  142 .161 .581
127 .1991.3201.320  128 .161 .433  143 .161 .581
128.21861.241.6597  144.2855 .581
129.21861.241.6597  130 .161 .581  145.2855 .433
130 .1991.3201.320  131 .161 .581  146 .161 .581
131 .1991.3201.320  132 .161 .581  147 .161 .581
132 .1991.3201.320  133 .161 .581  148 .161 .581
133 .1991.3201.320  134 .161 .581  149 .161 .581
134 .1991.3201.320  135 .161 .581  150 .161 .581
135 .1991.3201.320  136 .161 .581  151 .161 .581
136.18461.3821.382  137 .121 .581  152 .161 .581
137.18461.3821.382  138 .161 .581  153 .161 .581
138 .1991.3201.320  139 .161 .581  154 .161 .581
139 .1991.3201.320  140 .161 .581  155 .161 .581
140 .1991.3201.320  141 .161 .581  156 .161 .581
141 .1991.3201.320  142 .161 .581  157 .161 .581
142 .1991.3201.320  143 .161 .581  158 .161 .581
143 .1991.3201.320  144 .161 .433  159 .161 .581
144.21861.241.6597  160.2855 .581
145.21861.241.6597  146 .161 .581  161.2855 .433
146 .1991.3201.320  147 .161 .581  162 .161 .581
147 .1991.3201.320  148 .161 .581  163 .161 .581
148 .1991.3201.320  149 .161 .581  164 .161 .581
149 .1991.3201.320  150 .161 .581  165 .161 .581
150 .1991.3201.320  151 .161 .581  166 .161 .581
151 .1991.3201.320  152 .161 .581  167 .161 .581
152 .1991.3201.320  153 .161 .581  168 .161 .581
153 .1991.3201.320  154 .161 .581  169 .161 .581
154 .1991.3201.320  155 .161 .581  170 .161 .581
155 .1991.3201.320  156 .161 .581  171 .161 .581
156 .1991.3201.320  157 .161 .581  172 .161 .581
157 .1991.3201.320  158 .161 .581  173 .161 .581
158 .1991.3201.320  159 .161 .581  174 .161 .581
159 .1991.3201.320  160 .161 .433  175 .161 .581
160.21861.241.6597  176.2855 .581
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161.21861.241.6597  162 .161 .581  177.2855 .433
162 .1991.3201.320  163 .161 .581  178 .161 .581
163 .1991.3201.320  164 .161 .581  179 .161 .581
164 .1991.3201.320  165 .161 .581  180 .161 .581
165.18461.3821.382  166 .121 .581  181 .121 .581
166.18461.3821.382  167 .161 .581  182 .121 .581
167 .1991.3201.320  168 .161 .581  183 .161 .581
168 .1991.3201.320  169 .161 .581  184 .161 .581
169 .1991.3201.320  170 .161 .581  185 .161 .581
170 .1991.3201.320  171 .161 .581  186 .161 .581
171.18461.3821.382  172 .121 .581  187 .121 .581
172.18461.3821.382  173 .161 .581  188 .121 .581
173 .1991.3201.320  174 .161 .581  189 .161 .581
174 .1991.3201.320  175 .161 .581  190 .161 .581
175.18461.3821.382  176 .121 .433  191 .161 .581
176.20421.304.7226  192.2455 .581
177.21861.241.6597  178 .161 .581  193.2855 .433
178 .1991.3201.320  179 .161 .581  194 .161 .581
179 .1991.3201.320  180 .161 .581  195 .161 .581
180 .1991.3201.320  181 .161 .581  196 .161 .581
181.18461.3821.382  182 .121 .581  197 .161 .581
182.18461.3821.382  183 .161 .581  198 .161 .581
183 .1991.3201.320  184 .161 .581  199 .161 .581
184 .1991.3201.320  185 .161 .581  200 .161 .581
185 .1991.3201.320  186 .161 .581  201 .161 .581
186 .1991.3201.320  187 .161 .581  202 .161 .581
187.18461.3821.382  188 .121 .581  203 .161 .581
188.18461.3821.382  189 .161 .581  204 .161 .581
189 .1991.3201.320  190 .161 .581  205 .161 .581
190 .1991.3201.320  191 .161 .581  206 .161 .581
191.18461.3821.382  192 .121 .433  207 .161 .581
192.20421.304.7226  208.2455 .581
193.21861.241.6597  194 .161 .581  209.2855 .433
194 .1991.3201.320  195 .161 .581  210 .161 .581
195.18461.3821.382  196 .121 .581  211 .121 .581
196.18461.3821.382  197 .161 .581  212 .121 .581
197 .1991.3201.320  198 .161 .581  213 .161 .581
198 .1991.3201.320  199 .161 .581  214 .161 .581
199 .1991.3201.320  200 .161 .581  215 .161 .581
200 .1991.3201.320  201 .161 .581  216 .161 .581
201 .1991.3201.320  202 .161 .581  217 .161 .581
202 .1991.3201.320  203 .161 .581  218 .161 .581
203 .1991.3201.320  204 .161 .581  219 .161 .581
204 .1991.3201.320  205 .161 .581  220 .161 .581
205.18461.3821.382  206 .121 .581  221 .121 .581
206.18461.3821.382  207 .161 .581  222 .121 .581
207 .1991.3201.320  208 .161 .433  223 .161 .581
208.21861.241.6597  224.2855 .581
209.21861.241.6597  210 .161 .581  225.2855 .433
210 .1991.3201.320  211 .161 .581  226 .161 .581
211.18461.3821.382  212 .121 .581  227 .161 .581
212.18461.3821.382  213 .161 .581  228 .161 .581
213.19901.3201.320  214 .161 .581  229 .161 .581
214.19901.3201.320  215 .161 .581  230 .161 .581
215.19901.3201.320  216 .161 .581  231 .161 .581
216.19901.3201.320  217 .161 .581  232 .161 .581
217.19901.3201.320  218 .161 .581  233 .161 .581
218.19901.3201.320  219 .161 .581  234 .161 .581
219.19901.3201.320  220 .161 .581  235 .161 .581
220.19901.3201.320  221 .161 .581  236 .161 .581
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  221.18461.3821.382  222 .121 .581  237 .161 .581
  222.18461.3821.382  223 .161 .581  238 .161 .581
  223 .1991.3201.320  224 .161 .433  239 .161 .581
  224.21861.241.6597  240.2855 .581
  225.21861.241.6597  226 .161 .581  241.2855 .538
  226.19901.3201.320  227 .161 .581  242 .161 .433
  227.19901.3201.320  228 .161 .581  243 .161 .433
  228.19901.3201.320  229 .161 .581  244 .161 .433
  229.19901.3201.320  230 .161 .581  245 .161 .433
  230.19901.3201.320  231 .161 .581  246 .161 .433
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2   38.1564.688   0.    41.500 5.44   116.188 2.03
2   48.1564.688   0.    52.121 5.44   126.188 2.03
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2   68.1564.688   0.    72.121 5.44   146.188 2.03
2   78.1564.688   0.    81.500 5.44   156.188 2.03
2   88.1564.688   0.   166.188 2.03
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2  1010.926.872   0.
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   2                    989.
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   4    1  .95              1    5    1
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   6    1  .95              1    7    1
   7    1  .95              1    8    1
   8    1  .95
   9    2 1.74              2   10    2   16    2
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  12    2 1.74              1   13    2
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  16    2 1.74
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   2   12.145      4.614      989.
   3    .0130      6.684
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             2    1    2
   2    9    1    9    1    1   10    1    1   11    1    1   12    1
             1   13    1    1   14    1    1   15    1    1   16    1
             2    2    2
   3    9    1   16    1    1   32    1    1   48    1    1   64    1
             1   80    1    1   96    1    1  112    1    1  128    1
             2    3    2
   4    9    1  144    1    1  160    1    1  176    1    1  192    1
             1  208    1    1  224    1    1  240    1    1  256    1
             2    4    2
   5    9    1  249    1    1  250    1    1  251    1    1  249    1
             1  253    1    1  254    1    1  255    1    1  256    1
             2    5    2
   6    9    1  241    1    1  242    1    1  243    1    1  244    1
             1  245    1    1  246    1    1  247    1    1  248    1
             2    6    2
   7    9    1  129    1    1  145    1    1  161    1    1  177    1
             1  193    1    1  209    1    1  225    1    1  241    1
             2    7    2
   8    9    1    1    1    1   17    1    1   33    1    1   49    1
             1   65    1    1   81    1    1   97    1    1  113    1
             2    8    2
   9    1    2   09    3
  10    1    2   10    3
  11    1    2   11    3
  12    1    2   12    3
  13    1    2   13    3
  14    1    2   14    3
  15    1    2   15    3
  16    1    2   16    3

radg    2    1    1
   1   16
   14.614  .25   1.0016    2.0       3.0       4.0       5.0       6.0
                 7.0       8.0       9.6808   10.2656   11.0085   12.0
                13.0      14.0      15.0      16.0435
   24.614  .25   1.0       2.0016    3.0       4.0       5.0       6.0
                 7.0       8.0       9.2656   10.6808   11.0435   12.0
                13.0      14.0      15.0      16.0085
   34.614  .25   1.0       2.0       3.0016    4.0       5.0       6.0
                 7.0       8.0       9.0      10.0435   11.6808   12.2656
                13.0085   14.0      15.0      16.0
   44.614  .25   1.0       2.0       3.0       4.0016    5.0       6.0
                 7.0       8.0       9.0      10.0085   11.2656   12.6808
                13.0435   14.0      15.0      16.0
   54.614  .25   1.0       2.0       3.0       4.0       5.0016    6.0
                 7.0       8.0       9.0      10.0      11.0      12.0435
                13.6808   14.2656   15.0085   16.0
   64.614  .25   1.0       2.0       3.0       4.0       5.0       6.0016
                 7.0       8.0       9.0      10.0      11.0      12.0085
                13.2656   14.6808   15.0435   16.0
   74.614  .25   1.0       2.0       3.0       4.0       5.0       6.0
```

```
                7.0016    8.0      9.0085   10.0      11.0      12.0
                13.0      14.0435  15.6808  16.2656
  84.614  .25   1.0       2.0      3.0       4.0      5.0       6.0
                7.0       8.0016   9.0435   10.0      11.0      12.0
                13.0      14.0085  15.2656  16.6808
  96.684  .6    1.4700    2.1833   3.0       4.0      5.0       6.0
                7.0059    8.03     9.0271   10.0734   11.0637   12.0
                13.0      14.0134  15.0637  16.0695
 106.684  .6    1.1833    2.4700   3.0300    4.0059   5.0       6.0
                7.0       8.0      9.0734   10.0271   11.0695   12.0637
                13.0134   14.0     15.0     16.0637
 116.684  .6    1.0059    2.03     3.47      4.1833   5.0       6.0
                7.0       8.0      9.0637   10.0695   11.0271   12.0734
                13.0637   14.0     15.0     16.0134
 126.684  .6    1.0       2.0      3.1833    4.47     5.03      6.0059
                7.0       8.0      9.0000   10.0637   11.0734   12.0271
                13.0695   14.0637  15.0134  16.0
 136.684  .6    1.0       2.0      3.0059    4.0300   5.47      6.1833
                7.0       8.0      9.0      10.0134   11.0637   12.0695
                13.0271   14.0734  15.0637  16.0
 146.684  .6    1.0       2.0      3.0       4.0      5.1833    6.4700
                7.0300    8.0059   9.0134   10.0      11.0      12.0637
                13.0734   14.0271  15.0695  16.0637
 156.684  .6    1.0       2.0      3.0       4.0      5.0059    6.03
                7.47      8.1833   9.0637   10.0      11.0      12.0134
                13.0637   14.0695  15.0271  16.0734
 166.684  .6    1.03      2.0059   3.0       4.0      5.0       6.0
                7.1833    8.4700   9.0695   10.0637   11.0134   12.0
                13.0      14.0637  15.0734  16.0271
   1    1    8  1    2    3    4    5    6    7    8
   2   -1   16  1    2    3    4    5    6    7    8    9   10   11   12
                13   14   15   16
heat    1    0  1
              3.66               3.66
  1.0  1.0
drag    2    2
 100. -1.0                100. -1.0  .05
 100. -1.0                100. -1.0  1.0
   1   16    0
   7   16  240 .066   2. .155   2. .276   8. .393   2. .454   8. .699   8.
               .979   8.
   7    1   17 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
               .979   4.
   7   32   33 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
               .979   4.
   7   48   49 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
               .979   4.
   7   64   65 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
               .979   4.
   7   80   81 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
               .979   4.
   7   96   97 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
               .979   4.
   7  112  113 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
               .979   4.
   7  128  129 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
               .979   4.
   7  144  145 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
               .979   4.
   7  160  161 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
```

```
                .979   4.
   7  176  177 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
                .979   4.
   7  192  193 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
                .979   4.
   7  208  209 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
                .979   4.
   7  224  225 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
                .979   4.
   7  240  256 .066   1. .155   1. .276   4. .393   1. .454   4. .699   4.
                .979   4.
   2    1    0
   1    1   16 0.01 36.0
bdry    5    4    8    2
   1    .001
   2  9.98e-6
   3  3.22e-6
   4  1.98e-6
   5  1.00e-4
   1  23-.015 189.-.008 260..0055 283..0219 299..0459 313..0980 334.
        .1567 350..2112 360..2829 370..3548 377..4529 381..6854 381.
        .7942 376..8383 371..8804 363..9483 347.1.030 316.1.071 296.
        1.120 274.1.134 253.1.153 231.1.171 205.1.184 166.
   2  23-.015 186.-.012 247.-.002 267..0112 281..0424 300..0767 316.
        .1238 331..1741 344..2526 357..3349 366..3670 367..7386 367.
        .7877 365..8542 360..8948 353..9413 342.1.009 323.1.061 303.
        1.091 287.1.129 262.1.151 239.1.170 210.1.185 167.
   3  23-.014 188.-.005 234..0087 258..0258 271..0460 284..0922 302.
        .1487 317..2176 333..2840 343..3349 348..3873 351..7521 353.
        .8034 351..8818 342..9464 329.1.015 310.1.076 284.1.110 265.
        1.134 249.1.153 230.1.169 209.1.178 189.1.185 166.
   4  23-.012 186.-.002 210..0153 225..0427 244..0736 261..1099 276.
        .1673 293..2172 305..3166 324..3579 329..4184 334..4931 338.
        .7748 337..8240 335..8710 330..9062 322..9629 300.1.024 288.
        1.069 270.1.114 245.1.151 220.1.171 196.1.188 166.
   9    1 7.07    1
   1  1.    1   1.    1
  10    1 7.07    1
   1  1.    1   1.    1
  11    1 7.07    2
   1  1.    1   1.    1
  12    1 7.07    3
   1  1.    1   1.    1
  13    1 7.07    4
   1  1.    1   1.    1
  14    1 7.07    4
   1  1.    1   1.    1
  15    1 7.07    3
   1  1.    1   1.    1
  16    1 7.07    2
   1  1.    1   1.    1
   1 379. 254.    2    2188.7188.7
   1  1.    3
   2  1.    1
   1  1.    2
   2  1.    1    8    1    2  .95   2.    2    2  .95   2.    3    2  .95   2.
                     4    2  .95   2.    5    2  .95   2.    6    2  .95   2.
                     7    2  .95   2.    8    2  .95   2.
  21340. 240.    2    2255.7162.8
   1  1.    3
```

```
  2  1.    1
  1  1.    4
  2 2.56   5
calc    1    0    0
                                         0.1
     25
oper    1    2    3    1                                        1
 20.          282.    .0001 .001997821    250.    .000000        0.0
  1. -.33
1.000
   6
  0.   0..1043   0..1044   1..9758   1..9759   0.  1.0  0.0
outp 11011
endd
```

```
 data from iterative solution using the recirculation module
 time =    0.0000    dt = ******     implicit dt = 0.0000    explicit dt = ******     mode =  0


 iteration  sweep            peak clad            total flow    pressure                   error
    no.      no.   ----------------------------   (lbm/s)      drop(psi)    ------------------------------------
                     temp(f)  fluid  rod  ass.                                total    flow    fluid     rod
                                                                              energy           energy    energy

     1        1      522.3     24    98    1      0.397e-10    0.0000057    17.7506  9.6068  0.0220   0.0100
              2      524.1     24    98    1                                 0.0362  9.6068  0.0449   0.0024

     2        1      533.1     23    98    1      0.191e-10    0.0000001    -0.0300  1.1146  0.0325   0.0098
              2      544.3     21    98    1                                 0.0644  1.1146  0.0077   0.0059

     3        1      549.1     20    98    1      0.462e-11    0.0000000     0.0565  0.3786  0.0043   0.0029
              2      553.1     19    98    1                                 0.0299  0.3786  0.0042   0.0010

     4        1      554.9     18    98    1     -0.374e-11    0.0000000    -0.0329  0.1873  0.0027   0.0019
              2      556.1     18    98    1                                 0.0125  0.1873  0.0033   0.0004

     5        1      556.7     17    98    1     -0.556e-11    0.0000000     0.0104  0.0648  0.0019   0.0011
              2      557.0     17    98    1                                 0.0056  0.0648  0.0026   0.0005

     6        1      557.2     17    98    1     -0.547e-11    0.0000000     0.0042  0.0417  0.0020   0.0006
              2      557.3     16    98    1                                 0.0025  0.0417  0.0024   0.0005

     7        1      557.3     16    98    1     -0.438e-11    0.0000000    -0.0022  0.0268  0.0020   0.0006
              2      557.3     16    98    1                                 0.0012  0.0268  0.0023   0.0005

     8        1      557.3     16    98    1      0.365e-11    0.0000000     0.0011  0.0173  0.0020   0.0006
              2      557.3     16    98    1                                 0.0008  0.0173  0.0022   0.0005

     9        1      557.3     16    98    1      0.938e-11    0.0000000     0.0006  0.0112  0.0020   0.0006
              2      557.3     16    98    1                                 0.0005  0.0112  0.0022   0.0005

    10        1      557.3     16    98    1      0.747e-11    0.0000000    -0.0003  0.0072  0.0020   0.0005
              2      557.3     16    98    1                                 0.0003  0.0072  0.0021   0.0005



  axial zone    ( 1)      ( 2)      ( 3)      ( 4)      ( 5)      ( 6)      ( 7)      ( 8)      ( 9)      ( 10)
```

```
 (inches)

  0.0 -  6.9    230.94    230.94    236.36    232.94    229.00    229.00    232.93    236.36    298.02    298.02
  6.9 - 13.8    291.88    291.89    288.54    283.93    279.03    279.02    283.92    288.53    319.46    319.46
 13.8 - 20.7    334.93    334.95    331.48    326.84    322.04    322.03    326.80    331.44    335.47    335.47
 20.7 - 27.5    399.39    399.43    395.99    391.73    387.27    387.27    391.47    395.77    346.92    346.92
 27.5 - 34.4    423.78    423.83    420.55    416.50    412.24    412.23    416.23    420.32    355.58    355.58
 34.4 - 41.3    434.92    434.96    431.81    427.95    423.84    423.83    427.68    431.58    362.45    362.45
 41.3 - 48.2    441.21    441.25    438.16    434.44    430.52    430.52    434.18    437.94    368.26    368.26
 48.2 - 55.1    445.44    445.48    442.44    438.87    435.23    435.22    438.61    442.23    372.84    372.84
 55.1 - 62.0    448.34    448.38    445.29    441.76    438.23    438.23    441.51    445.07    376.86    376.86
 62.0 - 68.9    449.95    450.00    446.88    443.48    440.16    440.15    443.23    446.66    378.61    378.61
 68.9 - 75.8    450.95    450.99    447.78    444.46    441.37    441.36    444.21    447.57    380.27    380.27
 75.8 - 82.6    451.47    451.51    448.29    445.05    442.13    442.12    444.80    448.07    380.90    380.90
 82.6 - 89.5    451.68    451.70    448.50    445.31    442.46    442.45    445.06    448.29    380.91    380.91
 89.5 - 96.4    451.74    451.78    448.59    445.41    442.54    442.53    445.15    448.37    380.91    380.91
 96.4 -103.3    451.76    451.80    448.62    445.44    442.54    442.54    445.19    448.40    380.91    380.91
103.3 -110.2    451.73    451.77    448.60    445.42    442.51    442.50    445.17    448.39    380.90    380.90
110.2 -117.1    451.55    451.59    448.45    445.30    442.38    442.37    445.05    448.24    380.79    380.79
117.1 -124.0    450.83    450.88    447.93    444.89    442.00    441.99    444.64    447.72    378.92    378.92
124.0 -130.9    449.52    449.56    446.75    443.85    441.06    441.05    443.59    446.54    377.00    377.00
130.9 -137.7    446.98    447.02    444.35    441.57    438.90    438.89    441.31    444.14    373.84    373.84
137.7 -144.6    442.21    442.25    439.81    437.13    434.56    434.55    436.87    439.59    367.94    367.94
144.6 -151.5    433.15    433.19    430.96    428.43    425.89    425.88    428.17    430.74    359.35    359.35
151.5 -158.4    413.97    414.00    411.87    409.40    406.81    406.80    409.16    411.67    349.48    349.48
158.4 -165.3    365.41    365.42    363.66    361.15    358.47    358.46    361.11    363.62    335.43    335.43




 side boundary temperature summary     time =    0.0000 seconds
 boundary slab node no.     9


axial zone      (  1)      (  2)      (
 (inches)

  0.0 -  6.9    298.02     297.96
  6.9 - 13.8    319.46     319.69
 13.8 - 20.7    335.47     335.68
 20.7 - 27.5    346.92     347.04
 27.5 - 34.4    355.58     355.65
 34.4 - 41.3    362.45     362.51
 41.3 - 48.2    368.26     368.32
 48.2 - 55.1    372.84     372.88
 55.1 - 62.0    376.86     376.94
 62.0 - 68.9    378.61     378.67
 68.9 - 75.8    380.27     380.37
 75.8 - 82.6    380.90     381.00
 82.6 - 89.5    380.91     381.00
 89.5 - 96.4    380.91     381.00
 96.4 -103.3    380.91     381.00
103.3 -110.2    380.90     381.00
110.2 -117.1    380.79     380.90
117.1 -124.0    378.92     378.99
124.0 -130.9    377.00     377.07
```

```
130.9 -137.7      373.84      373.93
137.7 -144.6      367.94      367.98
144.6 -151.5      359.35      359.36
151.5 -158.4      349.48      349.54
158.4 -165.3      335.43      335.29
```

```
 calculated rod temperatures at time =    0.0000 seconds
 rod no.    1
 assembly   1                  (fuel type  1 - cylinder)
0rod o.d. - 0.420 (in.)     zone-(fuel dia.(in.)) -  1-(0.350)

                                                 *   fuel temperatures(f.)
                                                 *
   axial zone  heat flux   type           hsurf  *   fluid    clad
      (in.)   (mbtu/hr-ft2)             (b/h-f-ft2) *
     0.0 -   6.9    0.0000    1              1.2      237.2    237.0
     6.9 -  13.8    0.0000    1              1.3      289.6    289.4
    13.8 -  20.7    0.0000    1              1.3      332.7    332.4
    20.7 -  27.5    0.0000    1              1.4      423.3    436.3
    27.5 -  34.4    0.0000    1              1.5      446.9    459.5
    34.4 -  41.3    0.0000    1              1.5      457.6    470.0
    41.3 -  48.2    0.0000    1              1.5      463.7    475.9
    48.2 -  55.1    0.0000    1              1.5      467.7    479.9
    55.1 -  62.0    0.0000    1              1.5      470.5    482.5
    62.0 -  68.9    0.0000    1              1.5      472.0    484.1
    68.9 -  75.8    0.0000    1              1.5      472.9    485.0
    75.8 -  82.6    0.0000    1              1.5      473.4    485.5
    82.6 -  89.5    0.0000    1              1.5      473.6    485.7
    89.5 -  96.4    0.0000    1              1.5      473.7    485.7
    96.4 - 103.3    0.0000    1              1.5      473.7    485.8
   103.3 - 110.2    0.0000    1              1.5      473.7    485.7
   110.2 - 117.1    0.0000    1              1.5      473.6    485.6
   117.1 - 124.0    0.0000    1              1.5      473.0    485.0
   124.0 - 130.9    0.0000    1              1.5      471.9    483.9
   130.9 - 137.7    0.0000    1              1.5      469.6    481.7
   137.7 - 144.6    0.0000    1              1.5      465.2    477.4
   144.6 - 151.5    0.0000    1              1.5      456.9    469.3
   151.5 - 158.4    0.0000    1              1.4      439.6    452.5
   158.4 - 165.3    0.0000    1              1.4      364.5    364.5
```

```
 calculated rod temperatures at time =    0.0000 seconds
 rod no.  128
 assembly   1                  (fuel type  1 - cylinder)
0rod o.d. - 0.420 (in.)     zone-(fuel dia.(in.)) -  1-(0.350)

                                                 *   fuel temperatures(f.)
                                                 *
   axial zone  heat flux   type           hsurf  *   fluid    clad
      (in.)   (mbtu/hr-ft2)             (b/h-f-ft2) *
     0.0 -   6.9    0.0000    1              1.4      233.1    233.1
     6.9 -  13.8    0.0000    1              1.5      284.4    284.5
    13.8 -  20.7    0.0000    1              1.5      327.6    327.6
    20.7 -  27.5    0.0000    1              1.8      514.1    515.6
    27.5 -  34.4    0.0000    1              1.8      533.5    534.8
    34.4 -  41.3    0.0000    1              1.8      542.1    543.4
    41.3 -  48.2    0.0000    1              1.8      547.0    548.3
```

```
 48.2 -  55.1   0.0000   1          1.9    550.4   551.7
 55.1 -  62.0   0.0000   1          1.9    552.6   553.9
 62.0 -  68.9   0.0000   1          1.9    554.0   555.2
 68.9 -  75.8   0.0000   1          1.9    554.8   556.0
 75.8 -  82.6   0.0000   1          1.9    555.2   556.5
 82.6 -  89.5   0.0000   1          1.9    555.4   556.7
 89.5 -  96.4   0.0000   1          1.9    555.5   556.7
 96.4 - 103.3   0.0000   1          1.9    555.5   556.7
103.3 - 110.2   0.0000   1          1.9    555.5   556.7
110.2 - 117.1   0.0000   1          1.9    555.4   556.6
117.1 - 124.0   0.0000   1          1.9    555.0   556.2
124.0 - 130.9   0.0000   1          1.9    554.2   555.4
130.9 - 137.7   0.0000   1          1.9    552.4   553.7
137.7 - 144.6   0.0000   1          1.8    549.1   550.3
144.6 - 151.5   0.0000   1          1.8    542.5   543.6
151.5 - 158.4   0.0000   1          1.8    528.6   530.1
158.4 - 165.3   0.0000   1          1.6    363.6   363.5


iterations =   10
```

APPENDIX C

REA SINGLE ASSEMBLY CONSOLIDATED ROD TEST SIMULATIONS INPUT, OUTPUT, AND CONVERGENCE LISTS

APPENDIX C

REA SINGLE ASSEMBLY CONSOLIDATED ROD TEST SIMULATIONS INPUT, OUTPUT, AND CONVERGENCE LISTS

	Page Number		
Test Case	Input	Convergence List	Output
Horizontal, air	C.2	C.12	C.14
Horizontal, helium	C.16	C.26	C.28

```
+1000
    1     1 CONS. ZeRO-GAP, SYMM., air; CASe 4 (800 WATTS) validation run.
prop     11     1
          1.        00.0      109.9      .0133       .239      11.63      .040
          2.        200.      157.9      .0174       .241      16.67      .0518
          3.        300.      182.1      .0193       .243      19.23      .0580
          4.        400.      206.5      .0212       .245      21.74      .0630
          5.        500.      231.1      .0231       .247      24.27      .0680
          6.        600.      256.0      .0250       .250      26.81      .0720
          7.        700.      281.1      .0268       .253      29.33      .0770
          8.        800.      306.7      .0286       .256      31.85      .0810
         10.        900.      332.5      .0303       .259      34.36      .0850
         15.       1000.      358.6      .0319       .262      36.90      .0889
         20.       2000.      617.2      .0471       .286      62.11      .1242
    1  SST                                9.8
chan       2     2
         24.         90.0
    1     1  242     0      0
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     2.04211.1420.393
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     4.02681.2950.785    16.0001.3000
     5.02681.2950.785    18.0001.3000
     6.02681.2950.785    20.0001.3000
     7.02681.2950.785    22.0001.3000
     8.02681.2950.785    24.0001.3000
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    10.02681.2950.785    28.0001.3000
    11.02681.2950.785    30.0001.3000
    12.02681.2950.785    32.0001.3000
    13.12642.1921.309    14.0001.3000    34.0001.3000
    14.01010.7850.785    15.0001.3000
    15.01010.7850.785    16.0001.3000    35.0001.3000
    16.01010.7850.785    17.0001.3000
    17.01010.7850.785    18.0001.3000    37.0001.3000
    18.01010.7850.785    19.0001.3000
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    20.01010.7850.785    21.0001.3000
    21.01010.7850.785    22.0001.3000    41.0001.3000
    22.01010.7850.785    23.0001.3000
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    29.01010.7850.785    30.0001.3000    49.0001.3000
    30.01010.7850.785    31.0001.3000
    31.01010.7850.785    32.0001.3000    51.0001.3000
    32.01010.7850.785    33.0001.3000
    33.12642.1921.309    52.0001.3000
    34.01010.7850.785    35.0001.3000    54.0001.3000
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    41.01010.7850.785    42.0001.3000
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 72.01010.7850.785   73.0001.3000
 73.12842.1921.309   92.0001.3000
 74.01010.7850.785   75.0001.3000   94.0001.3000
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      1    2    0    0    1
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      2.292011.6611.66    3 .098 5.66
      3.642416.8016.80    4 .098 5.66
      4.292011.6611.66

rods     2    1    1              1  126   31
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      60.5001.000    7.2500    8.2500   22.1667   23.1667   24.1667    0.0000
      70.5001.000    8.2500    9.2500   24.1667   25.1667   26.1667    0.0000
      80.5001.000    9.2500   10.2500   26.1667   27.1667   28.1667    0.0000
      90.5001.000   10.2500   11.2500   28.1667   29.1667   30.1667    0.0000
     100.5001.000   11.2500   12.2500   30.1667   31.1667   32.1667    0.0000
     110.5001.000   12.2500    2.2500   32.1667   33.3333    0.0000    0.0000
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     150.5001.000   19.1667   20.1667   21.1667   39.1667   40.1667   41.1667
     160.5001.000   21.1667   22.1667   23.1667   41.1667   42.1667   43.1667
     170.5001.000   23.1667   24.1667   25.1667   43.1667   44.1667   45.1667
     180.5001.000   25.1667   26.1667   27.1667   45.1667   46.1667   47.1667
     190.5001.000   27.1667   28.1667   29.1667   47.1667   48.1667   49.1667
     200.5001.000   29.1667   30.1667   31.1667   49.1667   50.1667   51.1667
     210.5001.000   31.1667   32.1667   33.3333   51.1667   52.1667    0.0000
     220.5001.000   13.3333   34.1667   54.1667   53.3333    0.0000    0.0000
     230.5001.000   34.1667   35.1667   36.1667   54.1667   55.1667   56.1667
     240.5001.000   36.1667   37.1667   38.1667   56.1667   57.1667   58.1667
     250.5001.000   38.1667   39.1667   40.1667   58.1667   59.1667   60.1667
     260.5001.000   40.1667   41.1667   42.1667   60.1667   61.1667   62.1667
     270.5001.000   42.1667   43.1667   44.1667   62.1667   63.1667   64.1667
     280.5001.000   44.1667   45.1667   46.1667   64.1667   65.1667   66.1667
     290.5001.000   46.1667   47.1667   48.1667   66.1667   67.1667   68.1667
     300.5001.000   48.1667   49.1667   50.1667   68.1667   69.1667   70.1667
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360.5001.000   59.1667   60.1667   61.1667   79.1667   80.1667   81.1667
370.5001.000   61.1667   62.1667   63.1667   81.1667   82.1667   83.1667
380.5001.000   63.1667   64.1667   65.1667   83.1667   84.1667   85.1667
390.5001.000   65.1667   66.1667   67.1667   85.1667   86.1667   87.1667
400.5001.000   67.1667   68.1667   69.1667   87.1667   88.1667   89.1667
410.5001.000   69.1667   70.1667   71.1667   89.1667   90.1667   91.1667
420.5001.000   71.1667   72.1667   73.3333   91.1667   92.1667    0.0000
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440.5001.000   74.1667   75.1667   76.1667   94.1667   95.1667   96.1667
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480.5001.000   82.1667   83.1667   84.1667  102.1667  103.1667  104.1667
490.5001.000   84.1667   85.1667   86.1667  104.1667  105.1667  106.1667
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610.5001.000  107.1667  108.1667  109.1667  127.1667  128.1667  129.1667
620.5001.000  109.1667  110.1667  111.1667  129.1667  130.1667  131.1667
630.5001.000  111.1667  112.1667  113.3333  131.1667  132.1667    0.0000
640.5001.000   93.3333  114.1667  134.1667  133.3333    0.0000    0.0000
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700.5001.000  124.1667  125.1667  126.1667  144.1667  145.1667  146.1667
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780.5001.000  139.1667  140.1667  141.1667  159.1667  160.1667  161.1667
790.5001.000  141.1667  142.1667  143.1667  161.1667  162.1667  163.1667
800.5001.000  143.1667  144.1667  145.1667  163.1667  164.1667  165.1667
810.5001.000  145.1667  146.1667  147.1667  165.1667  166.1667  167.1667
820.5001.000  147.1667  148.1667  149.1667  167.1667  168.1667  169.1667
830.5001.000  149.1667  150.1667  151.1667  169.1667  170.1667  171.1667
840.5001.000  151.1667  152.1667  153.3333  171.1667  172.1667    0.0000
850.5001.000  133.3333  154.1667  174.1667  173.3333    0.0000    0.0000
860.5001.000  154.1667  155.1667  156.1667  174.1667  175.1667  176.1667
870.5001.000  156.1667  157.1667  158.1667  176.1667  177.1667  178.1667
880.5001.000  158.1667  159.1667  160.1667  178.1667  179.1667  180.1667
890.5001.000  160.1667  161.1667  162.1667  180.1667  181.1667  182.1667
900.5001.000  162.1667  163.1667  164.1667  182.1667  183.1667  184.1667
```

```
  910.5001.000  164.1667  165.1667  166.1667  184.1667  185.1667  186.1667
  920.5001.000  166.1667  167.1667  168.1667  186.1667  187.1667  188.1667
  930.5001.000  168.1667  169.1667  170.1667  188.1667  189.1667  190.1667
  940.5001.000  170.1667  171.1667  172.1667  190.1667  191.1667  192.1667
  950.5001.000  153.3333  172.1667  192.1667  193.3333    0.0000    0.0000
  960.5001.000  173.3333  174.1667  175.1667  194.1667  195.1667    0.0000
  970.5001.000  175.1667  176.1667  177.1667  195.1667  196.1667  197.1667
  980.5001.000  177.1667  178.1667  179.1667  197.1667  198.1667  199.1667
  990.5001.000  179.1667  180.1667  181.1667  199.1667  200.1667  201.1667
 1000.5001.000  181.1667  182.1667  183.1667  201.1667  202.1667  203.1667
 1010.5001.000  183.1667  184.1667  185.1667  203.1667  204.1667  205.1667
 1020.5001.000  185.1667  186.1667  187.1667  205.1667  206.1667  207.1667
 1030.5001.000  187.1667  188.1667  189.1667  207.1667  208.1667  209.1667
 1040.5001.000  189.1667  190.1667  191.1667  209.1667  210.1667  211.1667
 1050.5001.000  191.1667  192.1667  193.3333  211.1667  212.1667    0.0000
 1060.5001.000  173.3333  194.1667  214.1667  213.3333    0.0000    0.0000
 1070.5001.000  194.1667  195.1667  196.1667  214.1667  215.1667  216.1667
 1080.5001.000  196.1667  197.1667  198.1667  216.1667  217.1667  218.1667
 1090.5001.000  198.1667  199.1667  200.1667  218.1667  219.1667  220.1667
 1100.5001.000  200.1667  201.1667  202.1667  220.1667  221.1667  222.1667
 1110.5001.000  202.1667  203.1667  204.1667  222.1667  223.1667  224.1667
 1120.5001.000  204.1667  205.1667  206.1667  224.1667  225.1667  226.1667
 1130.5001.000  206.1667  207.1667  208.1667  226.1667  227.1667  228.1667
 1140.5001.000  208.1667  209.1667  210.1667  228.1667  229.1667  230.1667
 1150.5001.000  210.1667  211.1667  212.1667  230.1667  231.1667  232.1667
 1160.5001.000  193.3333  212.1667  232.1667  233.3333    0.0000    0.0000
 1170.5001.000  213.4167  214.1667  215.1667  234.2500    0.0000    0.0000
 1180.5001.000  215.1667  216.1667  217.1667  234.2500  235.2500    0.0000
 1190.5001.000  217.1667  218.1667  219.1667  235.2500  236.2500    0.0000
 1200.5001.000  219.1667  220.1667  221.1667  236.2500  237.2500    0.0000
 1210.5001.000  221.1667  222.1667  223.1667  237.2500  238.2500    0.0000
 1220.5001.000  223.1667  224.1667  225.1667  238.2500  239.2500    0.0000
 1230.5001.000  225.1667  226.1667  227.1667  239.2500  240.2500    0.0000
 1240.5001.000  227.1667  228.1667  229.1667  240.2500  241.2500    0.0000
 1250.5001.000  229.1667  230.1667  231.1667  241.2420  242.2420    0.0000
 1260.5001.000  231.1667  232.1667  233.4167  242.2420    0.0000    0.0000
    2    0    0
2.903 .200184.1  .33  11.  .11 400. .050 100.   .5
    0.5e-4
    1    2    2   12    0    0    0    0
    2    4    3   12   13    1    0    0
    3    4    4   13   14    2    0    0
    4    4    5   14   15    3    0    0
    5    4    6   15   16    4    0    0
    6    4    7   16   17    5    0    0
    7    4    8   17   18    6    0    0
    8    4    9   18   19    7    0    0
    9    4   10   19   20    8    0    0
   10    4   11   20   21    9    0    0
   11    2   21   10    0    0    0    0
   12    5    1    2   13   23   22    0
   13    6    2    3   14   24   23   12
   14    6    3    4   15   25   24   13
   15    6    4    5   16   26   25   14
   16    6    5    6   17   27   26   15
   17    6    6    7   18   28   27   16
   18    6    7    8   19   29   28   17
   19    6    8    9   20   30   29   18
   20    6    9   10   21   31   30   19
   21    5   10   11   20   32   31    0
```

22	3	12	23	33	0	0	0
23	6	12	13	24	34	33	22
24	6	13	14	25	35	34	23
25	6	14	15	26	36	35	24
26	6	15	16	27	37	36	25
27	6	16	17	28	38	37	26
28	6	17	18	29	39	38	27
29	6	18	19	30	40	39	28
30	6	19	20	31	41	40	29
31	6	20	21	32	42	41	30
32	3	21	31	42	0	0	0
33	5	22	23	34	44	43	0
34	6	23	24	35	45	44	33
35	6	24	25	36	46	45	34
36	6	25	26	37	47	46	35
37	6	26	27	38	48	47	36
38	6	27	28	39	49	48	37
39	6	28	29	40	50	49	38
40	6	29	30	41	51	50	39
41	6	30	31	42	52	51	40
42	5	31	32	41	53	52	0
43	3	33	44	54	0	0	0
44	6	33	34	45	55	54	43
45	6	34	35	46	56	55	44
46	6	35	36	47	57	56	45
47	6	36	37	48	58	57	46
48	6	37	38	49	59	58	47
49	6	38	39	50	60	59	48
50	6	39	40	51	61	60	49
51	6	40	41	52	62	61	50
52	6	41	42	53	63	62	51
53	3	42	52	63	0	0	0
54	5	43	44	55	65	64	0
55	6	44	45	56	66	65	54
56	6	45	46	57	67	66	55
57	6	46	47	58	68	67	56
58	6	47	48	59	69	68	57
59	6	48	49	60	70	69	58
60	6	49	50	61	71	70	59
61	6	50	51	62	72	71	60
62	6	51	52	63	73	72	61
63	5	52	53	62	74	73	0
64	3	54	65	75	0	0	0
65	6	54	55	66	76	75	64
66	6	55	56	67	77	76	65
67	6	56	57	68	78	77	66
68	6	57	58	69	79	78	67
69	6	58	59	70	80	79	68
70	6	59	60	71	81	80	69
71	6	60	61	72	82	81	70
72	6	61	62	73	83	82	71
73	6	62	63	74	84	83	72
74	3	63	73	84	0	0	0
75	5	64	65	76	86	85	0
76	6	65	66	77	87	86	75
77	6	66	67	78	88	87	76
78	6	67	68	79	89	88	77
79	6	68	69	80	90	89	78
80	6	69	70	81	91	90	79
81	6	70	71	82	92	91	80

```
 82   6   71   72   83   93   92   81
 83   6   72   73   84   94   93   82
 84   5   73   74   83   95   94    0
 85   3   75   86   96    0    0    0
 86   6   75   76   87   97   96   85
 87   6   76   77   88   98   97   86
 88   6   77   78   89   99   98   87
 89   6   78   79   90  100   99   88
 90   6   79   80   91  101  100   89
 91   6   80   81   92  102  101   90
 92   6   81   82   93  103  102   91
 93   6   82   83   94  104  103   92
 94   6   83   84   95  105  104   93
 95   3   84   94  105    0    0    0
 96   5   85   86   97  107  106    0
 97   6   86   87   98  108  107   96
 98   6   87   88   99  109  108   97
 99   6   88   89  100  110  109   98
100   6   89   90  101  111  110   99
101   6   90   91  102  112  111  100
102   6   91   92  103  113  112  101
103   6   92   93  104  114  113  102
104   6   93   94  105  115  114  103
105   5   94   95  104  116  115    0
106   3   96  107  117    0    0    0
107   6   96   97  108  118  117  106
108   6   97   98  109  119  118  107
109   6   98   99  110  120  119  108
110   6   99  100  111  121  120  109
111   6  100  101  112  122  121  110
112   6  101  102  113  123  122  111
113   6  102  103  114  124  123  112
114   6  103  104  115  125  124  113
115   6  104  105  116  126  125  114
116   3  105  115  126    0    0    0
117   3  106  107  118    0    0    0
118   4  107  108  119  117    0    0
119   4  108  109  120  118    0    0
120   4  109  110  121  119    0    0
121   4  110  111  122  120    0    0
122   4  111  112  123  121    0    0
123   4  112  113  124  122    0    0
124   4  113  114  125  123    0    0
125   4  114  115  126  124    0    0
126   3  115  116  125    0    0    0
   0.5e-4
    1    2    1    4
    2    1    1
    3    1    1
    4    1    1
    5    1    1
    6    1    1
    7    1    1
    8    1    1
    9    1    1
   10    1    1
   11    2    1    2
   22    1    4
   32    1    2
   43    1    4
```

```
    53    1    2
    64    1    4
    74    1    2
    85    1    4
    95    1    2
   106    1    4
   116    1    2
   117    1    3
   118    1    3
   119    1    3
   120    1    3
   121    1    3
   122    1    3
   123    1    3
   124    1    3
   125    1    3
   126    1    3
slab           8    8
     1    1 5.68
     2    15.263
     3    1 5.68
     4    15.263
     5    1   6.
     6    1   6.
     7    1   6.
     8    1   6.
     1      39.32      .3745
     2      29.45         .5
     3      17.30     .86603
     4      21.50     .68301
     5      29.45         .5
     6    2.5925       5.68
     7    2.7053      5.443
     8   1.70430      6.000
     1   13    1    1    1    1    2    1    1    3    2    1    4    2
               1    5    2    1    6    2    1    7    2    1    8    2
               1    9    2    1   10    2    1   11    2    1   12    2
               2    1    6
     2    8    1    2    1    1   33    3    1   73    3    1  113    3
               1  153    3    1  193    3    1  233    4    2    2    7
     3   12    1  213    5    1  234    2    1  235    2    1  236    2
               1  237    2    1  238    2    1  239    2    1  240    2
               1  241    2    1  242    2    1  233    5    2    3    6
     4    8    1  213    4    1  173    3    1  133    3    1   93    3
               1   53    3    1   13    3    1    1    1    2    4    7
     5    1    2    1    8
     6    1    2    2    8
     7    1    2    3    8
     8    1    2    4    8

radg      2    1    1
    1     8
    1 5.68   .2    1   0.    2   0.    3   0.    4   0.    5.9788    6.0106
                   7   0.    8.0106
    25.443   .2    1   0.    2   0.    3   0.    4   0.    5.0000    6.9989
                   7.0000    8   0.
    3 5.68   .2    1   0.    2   0.    3   0.    4   0.    5   0.    6.0106
                   7.9788    8.0106
    45.443   .2    1   0.    2   0.    3   0.    4   0.    5.0000    6   0.
                   7.0000    8.9989
```

```
    5   6.   .2    1.9633    2.0005    3   0.    4.0005    5   0.    6.0178
                   7   0.    8.0178
    6   6.   .2    1.0104    2.9428    3.0104    4   0.    5.0178    6   0.
                   7.0178    8.0008
    7   6.   .2    1   0.    2.0005    3.9633    4.0005    5   0.    6.0178
                   7   0.    8.0178
    8   6.   .2    1.0104    2   0.    3.0104    4.9428    5.0178    6.0008
                   7.0178    8   0.
    1    1    4    1    2    3    4
    2   -1    8    1    2    3    4    5    6    7    8
heat     2         1
              1.326                1.326
                     2.                   2.
  1.0  1.0
drag     2
98.53  -1.   0.   0.   .05
100.0  -1.   0.   0.   .05
bdry     1    1    4    0
    1    1.0e-3
    1    2   0. 392.   1. 392.
    1    1  6.0    1
    5   1.    1   1.    1
    2    1  6.0    1
    6   1.    1   1.    1
    3    1  6.0    1
    7   1.    1   1.    1
    4    1  6.0    1
    8   1.    1   1.    1
calc    1

        30
oper     1         3    0                                              1
      20.0     392.5   1.0e-06 .00304030     392.5        0.        0.
    2
   0.   1.   1.   1.
outp     1
endd
```

```
 data from iterative solution using the recirculation module
 time =     0.0000    dt = ******    implicit dt = 0.0000    explicit dt = ******    mode =  0


 iteration  sweep            peak clad              total flow    pressure                  error
    no.      no.   ----------------------------     (lbm/s)      drop(psi)    -----------------------------------
                   temp(f)  fluid  rod  ass.                                    total     flow    fluid     rod
                                                                                energy            energy   energy

    1         1     398.3      3    55    1       -0.144e-08    0.0000000     -0.2150   0.1183   0.0033   0.0009
              2     401.9      3    70    1                                    0.7888   0.1183   0.0033   0.0005

    2         1     405.4      3    69    1        0.472e-08    0.0000000      0.6881   0.0001   0.0029   0.0003

    3         1     408.7      3    69    1       -0.187e-08    0.0000000      0.6094   0.0000   0.0026   0.0005
              2     411.7      3    69    1                                    0.5427   0.0000   0.0023   0.0004

    4         1     414.5      3    69    1        0.532e-09    0.0000000     -0.1238   0.0000   0.0019   0.0004
```

5	1	417.0	3	69	1	-0.111e-08	0.0000000	0.4326	0.0000	0.0019	0.0003
	2	419.2	3	69	1			0.3881	0.0000	0.0017	0.0003
6	1	421.2	3	69	1	-0.113e-09	0.0000000	0.3479	0.0000	0.0015	0.0003
	2	423.1	3	69	1			0.3122	0.0000	0.0013	0.0002
7	1	424.7	3	69	1	-0.467e-09	0.0000000	-0.0677	0.0000	0.0011	0.0002
	2	426.2	3	69	1			0.2501	0.0000	0.0011	0.0002
8	1	427.5	3	69	1	-0.758e-10	0.0000000	0.2245	0.0000	0.0010	0.0002
	2	428.7	3	69	1			0.2015	0.0000	0.0008	0.0002
9	1	429.7	3	69	1	-0.148e-09	0.0000000	0.1805	0.0000	0.0008	0.0001
	2	430.7	3	69	1			0.1618	0.0000	0.0007	0.0001
10	1	431.5	3	69	1	-0.131e-10	0.0000000	-0.0353	0.0000	0.0006	0.0001
	2	432.3	3	69	1			0.1298	0.0000	0.0005	0.0001
11	1	433.0	3	69	1	-0.331e-10	0.0000000	0.1161	0.0000	0.0006	0.0001
	2	433.6	3	69	1			0.1035	0.0000	0.0004	0.0001
12	1	434.1	3	69	1	0.625e-11	0.0000000	0.0934	0.0000	0.0005	0.0001
	2	434.6	3	69	1			0.0832	0.0000	0.0003	0.0001
13	1	435.1	3	69	1	-0.310e-11	0.0000000	-0.0184	0.0000	0.0004	0.0001
	2	435.5	3	69	1			0.0655	0.0000	0.0003	0.0001
14	1	435.8	3	69	1	0.626e-11	0.0000000	0.0602	0.0000	0.0003	0.0000
	2	436.1	3	69	1			0.0528	0.0000	0.0002	0.0000
15	1	436.4	3	69	1	0.140e-11	0.0000000	0.0482	0.0000	0.0003	0.0000
	2	436.7	3	69	1			0.0417	0.0000	0.0002	0.0000
16	1	436.9	3	69	1	0.306e-11	0.0000000	-0.0094	0.0000	0.0003	0.0000
	2	437.1	3	69	1			0.0332	0.0000	0.0001	0.0000
17	1	437.3	3	69	1	0.863e-12	0.0000000	0.0310	0.0000	0.0002	0.0000
	2	437.5	3	69	1			0.0263	0.0000	0.0001	0.0000
18	1	437.6	3	69	1	0.103e-11	0.0000000	0.0248	0.0000	0.0002	0.0000
	2	437.7	3	69	1			0.0208	0.0000	0.0001	0.0000
19	1	437.9	3	69	1	0.219e-12	0.0000000	-0.0050	0.0000	0.0002	0.0000
	2	438.0	3	69	1			0.0163	0.0000	0.0001	0.0000
20	1	438.1	3	69	1	0.233e-12	0.0000000	0.0158	0.0000	0.0002	0.0000
	2	438.1	3	69	1			0.0127	0.0000	0.0001	0.0000
21	1	438.2	3	69	1	-0.120e-13	0.0000000	0.0126	0.0000	0.0002	0.0000
	2	438.3	3	69	1			0.0099	0.0000	0.0001	0.0000
22	1	438.4	3	69	1	0.120e-13	0.0000000	-0.0026	0.0000	0.0001	0.0000
	2	438.4	3	69	1			0.0075	0.0000	0.0001	0.0000
23	1	438.5	3	69	1	-0.431e-13	0.0000000	0.0080	0.0000	0.0001	0.0000
	2	438.5	3	69	1			0.0057	0.0000	0.0001	0.0000
24	1	438.5	3	69	1	-0.197e-13	0.0000000	0.0063	0.0000	0.0001	0.0000
	2	438.6	3	69	1			0.0042	0.0000	0.0001	0.0000

```
   25        1      438.6      3     69     1      -0.264e-13    0.0000000      -0.0013   0.0000   0.0001   0.0000
             2      438.6      3     69     1                                    0.0030   0.0000   0.0001   0.0000

   26        1      438.7      3     69     1      -0.130e-13    0.0000000       0.0039   0.0000   0.0001   0.0000
             2      438.7      3     69     1                                    0.0021   0.0000   0.0001   0.0000

   27        1      438.7      3     69     1      -0.115e-13    0.0000000       0.0031   0.0000   0.0001   0.0000
             2      438.7      3     69     1                                    0.0013   0.0000   0.0001   0.0000

   28        1      438.7      3     69     1      -0.559e-14    0.0000000      -0.0007   0.0000   0.0001   0.0000
             2      438.7      3     69     1                                    0.0007   0.0000   0.0001   0.0000


 slab temperature summary        time =    0.0000 seconds
 (assembly no. - channel no.)


axial zone      ( 1)       ( 2)       ( 3)       ( 4)       ( 5)       ( 6)       ( 7)       ( 8)       (
 (inches)

 0.0 - 12.0     392.27     392.17     392.27     392.17     392.25     392.17     392.25     392.17
12.0 - 24.0     392.27     392.17     392.27     392.17     392.25     392.17     392.25     392.17



 side boundary temperature summary     time =    0.0000 seconds
 boundary slab node no.     1


axial zone      ( 1)       ( 2)       (
 (inches)

 0.0 - 12.0     392.27     392.00
12.0 - 24.0     392.27     392.00


 calculated rod temperatures at time =    0.0000 seconds
 rod no.    6
 assembly   1                   (fuel type  1 - cylinder)
0rod o.d. - 0.500 (in.)     zone-(fuel dia.(in.)) -  1-(0.330)

                                          *   fuel temperatures(f.)
                                          *
  axial zone  heat flux   type       hsurf *  fluid    clad
     (in.)   (mbtu/hr-ft2)       (b/h-f-ft2) *
   0.0 -  12.0    0.0000    1           5.3     412.9    414.4
  12.0 -  24.0    0.0000    1           5.3     413.0    414.5


 calculated rod temperatures at time =    0.0000 seconds
 rod no.   69
 assembly   1                   (fuel type  1 - cylinder)
0rod o.d. - 0.500 (in.)     zone-(fuel dia.(in.)) -  1-(0.330)

                                          *   fuel temperatures(f.)
                                          *
  axial zone  heat flux   type       hsurf *  fluid    clad
```

```
    (in.)   (mbtu/hr-ft2)          (b/h-f-ft2) *
  0.0 -  12.0    0.0000    1              6.7      438.2    438.7
 12.0 -  24.0    0.0000    1              6.7      438.2    438.0


calculated rod temperatures at time =    0.0000 seconds
rod no.  121
assembly   1                  (fuel type  1 - cylinder)
0rod o.d. - 0.500 (in.)     zone-(fuel dia.(in.)) -  1-(0.330)

                                                *   fuel temperatures(f.)
                                                *
  axial zone  heat flux   type            hsurf *   fluid    clad
    (in.)   (mbtu/hr-ft2)          (b/h-f-ft2) *
  0.0 -  12.0    0.0000    1              5.3      412.0    414.3
 12.0 -  24.0    0.0000    1              5.3      412.0    414.3
```

```
+1000
   1    1 CONS. ZeRO-GAP, SYMM., HeLIUM; CASe 8 (800 WATTS) validation run.
prop     8    1
      0.5      -50.       38.     .0732      1.24     73.80     .0409
       1.        0.     100.0     .0780      1.24     83.33     .0410
       2.      200.     348.0     .0970      1.24    119.78     .0533
       3.      400.     596.0     .1150      1.24    158.25     .0641
       5.      600.     844.0     .1290      1.24    192.31     .0727
      10.      800.    1092.0     .1380      1.24    229.38     .0823
      15.     1000.    1340.0     .1380      1.24    285.25     .0907
      20.     1500.    1588.0     .1380      1.24    357.14     .1138
   1  SST                           9.8
chan     2    2
      24.       90.0
   1    1  242    0    0
   1    1    0    0    1
   1.04211.1420.393
   2.04211.1420.393
   3.02681.2950.785   14.0001.3000
   4.02681.2950.785   16.0001.3000
   5.02681.2950.785   18.0001.3000
   6.02681.2950.785   20.0001.3000
   7.02681.2950.785   22.0001.3000
   8.02681.2950.785   24.0001.3000
   9.02681.2950.785   26.0001.3000
  10.02681.2950.785   28.0001.3000
  11.02681.2950.785   30.0001.3000
  12.02681.2950.785   32.0001.3000
  13.12842.1921.309   14.0001.3000   34.0001.3000
  14.01010.7850.785   15.0001.3000
  15.01010.7850.785   16.0001.3000   35.0001.3000
  16.01010.7850.785   17.0001.3000
  17.01010.7850.785   18.0001.3000   37.0001.3000
  18.01010.7850.785   19.0001.3000
  19.01010.7850.785   20.0001.3000   39.0001.3000
  20.01010.7850.785   21.0001.3000
  21.01010.7850.785   22.0001.3000   41.0001.3000
  22.01010.7850.785   23.0001.3000
  23.01010.7850.785   24.0001.3000   43.0001.3000
  24.01010.7850.785   25.0001.3000
  25.01010.7850.785   26.0001.3000   45.0001.3000
  26.01010.7850.785   27.0001.3000
  27.01010.7850.785   28.0001.3000   47.0001.3000
  28.01010.7850.785   29.0001.3000
  29.01010.7850.785   30.0001.3000   49.0001.3000
  30.01010.7850.785   31.0001.3000
  31.01010.7850.785   32.0001.3000   51.0001.3000
  32.01010.7850.785   33.0001.3000
  33.12842.1921.309   52.0001.3000
  34.01010.7850.785   35.0001.3000   54.0001.3000
  35.01010.7850.785   36.0001.3000
  36.01010.7850.785   37.0001.3000   56.0001.3000
  37.01010.7850.785   38.0001.3000
  38.01010.7850.785   39.0001.3000   58.0001.3000
  39.01010.7850.785   40.0001.3000
  40.01010.7850.785   41.0001.3000   60.0001.3000
  41.01010.7850.785   42.0001.3000
  42.01010.7850.785   43.0001.3000   62.0001.3000
  43.01010.7850.785   44.0001.3000
  44.01010.7850.785   45.0001.3000   64.0001.3000
```

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 45.01010.7850.785   46.0001.3000
 46.01010.7850.785   47.0001.3000   66.0001.3000
 47.01010.7850.785   48.0001.3000
 48.01010.7850.785   49.0001.3000   68.0001.3000
 49.01010.7850.785   50.0001.3000
 50.01010.7850.785   51.0001.3000   70.0001.3000
 51.01010.7850.785   52.0001.3000
 52.01010.7850.785   72.0001.3000
 53.12842.1921.309   54.0001.3000   74.0001.3000
 54.01010.7850.785   55.0001.3000
 55.01010.7850.785   56.0001.3000   75.0001.3000
 56.01010.7850.785   57.0001.3000
 57.01010.7850.785   58.0001.3000   77.0001.3000
 58.01010.7850.785   59.0001.3000
 59.01010.7850.785   60.0001.3000   79.0001.3000
 60.01010.7850.785   61.0001.3000
 61.01010.7850.785   62.0001.3000   81.0001.3000
 62.01010.7850.785   63.0001.3000
 63.01010.7850.785   64.0001.3000   83.0001.3000
 64.01010.7850.785   65.0001.3000
 65.01010.7850.785   66.0001.3000   85.0001.3000
 66.01010.7850.785   67.0001.3000
 67.01010.7850.785   68.0001.3000   87.0001.3000
 68.01010.7850.785   69.0001.3000
 69.01010.7850.785   70.0001.3000   89.0001.3000
 70.01010.7850.785   71.0001.3000
 71.01010.7850.785   72.0001.3000   91.0001.3000
 72.01010.7850.785   73.0001.3000
 73.12842.1921.309   92.0001.3000
 74.01010.7850.785   75.0001.3000   94.0001.3000
 75.01010.7850.785   76.0001.3000
 76.01010.7850.785   77.0001.3000   96.0001.3000
 77.01010.7850.785   78.0001.3000
 78.01010.7850.785   79.0001.3000   98.0001.3000
 79.01010.7850.785   80.0001.3000
 80.01010.7850.785   81.0001.3000  100.0001.3000
 81.01010.7850.785   82.0001.3000
 82.01010.7850.785   83.0001.3000  102.0001.3000
 83.01010.7850.785   84.0001.3000
 84.01010.7850.785   85.0001.3000  104.0001.3000
 85.01010.7850.785   86.0001.3000
 86.01010.7850.785   87.0001.3000  106.0001.3000
 87.01010.7850.785   88.0001.3000
 88.01010.7850.785   89.0001.3000  108.0001.3000
 89.01010.7850.785   90.0001.3000
 90.01010.7850.785   91.0001.3000  110.0001.3000
 91.01010.7850.785   92.0001.3000
 92.01010.7850.785  112.0001.3000
 93.12842.1921.309   94.0001.3000  114.0001.3000
 94.01010.7850.785   95.0001.3000
 95.01010.7850.785   96.0001.3000  115.0001.3000
 96.01010.7850.785   97.0001.3000
 97.01010.7850.785   98.0001.3000  117.0001.3000
 98.01010.7850.785   99.0001.3000
 99.01010.7850.785  100.0001.3000  119.0001.3000
100.01010.7850.785  101.0001.3000
101.01010.7850.785  102.0001.3000  121.0001.3000
102.01010.7850.785  103.0001.3000
103.01010.7850.785  104.0001.3000  123.0001.3000
104.01010.7850.785  105.0001.3000
```

```
105.01010.7850.785  106.0001.3000  125.0001.3000
106.01010.7850.785  107.0001.3000
107.01010.7850.785  108.0001.3000  127.0001.3000
108.01010.7850.785  109.0001.3000
109.01010.7850.785  110.0001.3000  129.0001.3000
110.01010.7850.785  111.0001.3000
111.01010.7850.785  112.0001.3000  131.0001.3000
112.01010.7850.785  113.0001.3000
113.12842.1921.309  132.0001.3000
114.01010.7850.785  115.0001.3000  134.0001.3000
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116.01010.7850.785  117.0001.3000  136.0001.3000
117.01010.7850.785  118.0001.3000
118.01010.7850.785  119.0001.3000  138.0001.3000
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120.01010.7850.785  121.0001.3000  140.0001.3000
121.01010.7850.785  122.0001.3000
122.01010.7850.785  123.0001.3000  142.0001.3000
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124.01010.7850.785  125.0001.3000  144.0001.3000
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126.01010.7850.785  127.0001.3000  146.0001.3000
127.01010.7850.785  128.0001.3000
128.01010.7850.785  129.0001.3000  148.0001.3000
129.01010.7850.785  130.0001.3000
130.01010.7850.785  131.0001.3000  150.0001.3000
131.01010.7850.785  132.0001.3000
132.01010.7850.785  152.0001.3000
133.12842.1921.309  134.0001.3000  154.0001.3000
134.01010.7850.785  135.0001.3000
135.01010.7850.785  136.0001.3000  156.0001.3000
136.01010.7850.785  137.0001.3000
137.01010.7850.785  138.0001.3000  157.0001.3000
138.01010.7850.785  139.0001.3000
139.01010.7850.785  140.0001.3000  159.0001.3000
140.01010.7850.785  141.0001.3000
141.01010.7850.785  142.0001.3000  161.0001.3000
142.01010.7850.785  143.0001.3000
143.01010.7850.785  144.0001.3000  163.0001.3000
144.01010.7850.785  145.0001.3000
145.01010.7850.785  146.0001.3000  165.0001.3000
146.01010.7850.785  147.0001.3000
147.01010.7850.785  148.0001.3000  167.0001.3000
148.01010.7850.785  149.0001.3000
149.01010.7850.785  150.0001.3000  169.0001.3000
150.01010.7850.785  151.0001.3000
151.01010.7850.785  152.0001.3000  171.0001.3000
152.01010.7850.785  153.0001.3000
153.12842.1921.309  172.0001.3000
154.01010.7850.785  155.0001.3000  174.0001.3000
155.01010.7850.785  156.0001.3000
156.01010.7850.785  157.0001.3000  176.0001.3000
157.01010.7850.785  158.0001.3000
158.01010.7850.785  159.0001.3000  178.0001.3000
159.01010.7850.785  160.0001.3000
160.01010.7850.785  161.0001.3000  180.0001.3000
161.01010.7850.785  162.0001.3000
162.01010.7850.785  163.0001.3000  182.0001.3000
163.01010.7850.785  164.0001.3000
164.01010.7850.785  165.0001.3000  184.0001.3000
```

```
165.01010.7850.785  166.0001.3000
166.01010.7850.785  167.0001.3000  186.0001.3000
167.01010.7850.785  168.0001.3000
168.01010.7850.785  169.0001.3000  188.0001.3000
169.01010.7850.785  170.0001.3000
170.01010.7850.785  171.0001.3000  190.0001.3000
171.01010.7850.785  172.0001.3000
172.01010.7850.785  192.0001.3000
173.12842.1921.309  174.0001.3000  194.0001.3000
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175.01010.7850.785  176.0001.3000  195.0001.3000
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177.01010.7850.785  178.0001.3000  197.0001.3000
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181.01010.7850.785  182.0001.3000  201.0001.3000
182.01010.7850.785  183.0001.3000
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184.01010.7850.785  185.0001.3000
185.01010.7850.785  186.0001.3000  205.0001.3000
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187.01010.7850.785  188.0001.3000  207.0001.3000
188.01010.7850.785  189.0001.3000
189.01010.7850.785  190.0001.3000  209.0001.3000
190.01010.7850.785  191.0001.3000
191.01010.7850.785  192.0001.3000  211.0001.3000
192.01010.7850.785  193.0001.3000
193.12842.1921.309  212.0001.3000
194.01010.7850.785  195.0001.3000  214.0001.3000
195.01010.7850.785  196.0001.3000
196.01010.7850.785  197.0001.3000  216.0001.3000
197.01010.7850.785  198.0001.3000
198.01010.7850.785  199.0001.3000  218.0001.3000
199.01010.7850.785  200.0001.3000
200.01010.7850.785  201.0001.3000  220.0001.3000
201.01010.7850.785  202.0001.3000
202.01010.7850.785  203.0001.3000  222.0001.3000
203.01010.7850.785  204.0001.3000
204.01010.7850.785  205.0001.3000  224.0001.3000
205.01010.7850.785  206.0001.3000
206.01010.7850.785  207.0001.3000  226.0001.3000
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208.01010.7850.785  209.0001.3000  228.0001.3000
209.01010.7850.785  210.0001.3000
210.01010.7850.785  211.0001.3000  230.0001.3000
211.01010.7850.785  212.0001.3000
212.01010.7850.785  232.0001.3000
213.14012.3611.178  214.0001.3000
214.01010.7850.785  215.0001.3000
215.01010.7850.785  216.0001.3000  234.0001.3000
216.01010.7850.785  217.0001.3000
217.01010.7850.785  218.0001.3000  235.0001.3000
218.01010.7850.785  219.0001.3000
219.01010.7850.785  220.0001.3000  236.0001.3000
220.01010.7850.785  221.0001.3000
221.01010.7850.785  222.0001.3000  237.0001.3000
222.01010.7850.785  223.0001.3000
223.01010.7850.785  224.0001.3000  238.0001.3000
224.01010.7850.785  225.0001.3000
```

```
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 229.01010.7850.785  230.0001.3000  241.0001.3000
 230.01010.7850.785  231.0001.3000
 231.01010.7850.785  232.0001.3000  242.0001.3000
 232.01010.7850.785  233.0001.3000
 233.14012.3611.178
 234.02681.2950.785
 235.02681.2950.785
 236.02681.2950.785
 237.02681.2950.785
 238.02681.2950.785
 239.02681.2950.785
 240.02681.2950.785
 241.02681.2950.785
 242.02681.2950.785
   2    2    4    0
   1    2    0    0    1
   1.642416.8016.80    2 .098 5.66    4 .098 5.66
   2.292011.6611.66    3 .098 5.66
   3.642416.8016.80    4 .098 5.66
   4.292011.6611.66

rods     2    1    1              1  126   31
   1    1  126
   10.5001.000    1.2500    3.2500   14.1667   13.3333    0.0000    0.0000
   20.5001.000    3.2500    4.2500   14.1667   15.1667   16.1667    0.0000
   30.5001.000    4.2500    5.2500   16.1667   17.1667   18.1667    0.0000
   40.5001.000    5.2500    6.2500   18.1667   19.1667   20.1667    0.0000
   50.5001.000    6.2500    7.2500   20.1667   21.1667   22.1667    0.0000
   60.5001.000    7.2500    8.2500   22.1667   23.1667   24.1667    0.0000
   70.5001.000    8.2500    9.2500   24.1667   25.1667   26.1667    0.0000
   80.5001.000    9.2500   10.2500   26.1667   27.1667   28.1667    0.0000
   90.5001.000   10.2500   11.2500   28.1667   29.1667   30.1667    0.0000
  100.5001.000   11.2500   12.2500   30.1667   31.1667   32.1667    0.0000
  110.5001.000   12.2500    2.2500   32.1667   33.3333    0.0000    0.0000
  120.5001.000   13.3333   14.1667   15.1667   34.1667   35.1667    0.0000
  130.5001.000   15.1667   16.1667   17.1667   35.1667   36.1667   37.1667
  140.5001.000   17.1667   18.1667   19.1667   37.1667   38.1667   39.1667
  150.5001.000   19.1667   20.1667   21.1667   39.1667   40.1667   41.1667
  160.5001.000   21.1667   22.1667   23.1667   41.1667   42.1667   43.1667
  170.5001.000   23.1667   24.1667   25.1667   43.1667   44.1667   45.1667
  180.5001.000   25.1667   26.1667   27.1667   45.1667   46.1667   47.1667
  190.5001.000   27.1667   28.1667   29.1667   47.1667   48.1667   49.1667
  200.5001.000   29.1667   30.1667   31.1667   49.1667   50.1667   51.1667
  210.5001.000   31.1667   32.1667   33.3333   51.1667   52.1667    0.0000
  220.5001.000   13.3333   34.1667   54.1667   53.3333    0.0000    0.0000
  230.5001.000   34.1667   35.1667   36.1667   54.1667   55.1667   56.1667
  240.5001.000   36.1667   37.1667   38.1667   56.1667   57.1667   58.1667
  250.5001.000   38.1667   39.1667   40.1667   58.1667   59.1667   60.1667
  260.5001.000   40.1667   41.1667   42.1667   60.1667   61.1667   62.1667
  270.5001.000   42.1667   43.1667   44.1667   62.1667   63.1667   64.1667
  280.5001.000   44.1667   45.1667   46.1667   64.1667   65.1667   66.1667
  290.5001.000   46.1667   47.1667   48.1667   66.1667   67.1667   68.1667
  300.5001.000   48.1667   49.1667   50.1667   68.1667   69.1667   70.1667
  310.5001.000   50.1667   51.1667   52.1667   70.1667   71.1667   72.1667
  320.5001.000   33.3333   52.1667   72.1667   73.3333    0.0000    0.0000
  330.5001.000   53.3333   54.1667   55.1667   74.1667   75.1667    0.0000
```

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340.5001.000   55.1667   56.1667   57.1667   75.1667   76.1667   77.1667
350.5001.000   57.1667   58.1667   59.1667   77.1667   78.1667   79.1667
360.5001.000   59.1667   60.1667   61.1667   79.1667   80.1667   81.1667
370.5001.000   61.1667   62.1667   63.1667   81.1667   82.1667   83.1667
380.5001.000   63.1667   64.1667   65.1667   83.1667   84.1667   85.1667
390.5001.000   65.1667   66.1667   67.1667   85.1667   86.1667   87.1667
400.5001.000   67.1667   68.1667   69.1667   87.1667   88.1667   89.1667
410.5001.000   69.1667   70.1667   71.1667   89.1667   90.1667   91.1667
420.5001.000   71.1667   72.1667   73.3333   91.1667   92.1667    0.0000
430.5001.000   53.3333   74.1667   94.1667   93.3333    0.0000    0.0000
440.5001.000   74.1667   75.1667   76.1667   94.1667   95.1667   96.1667
450.5001.000   76.1667   77.1667   78.1667   96.1667   97.1667   98.1667
460.5001.000   78.1667   79.1667   80.1667   98.1667   99.1667  100.1667
470.5001.000   80.1667   81.1667   82.1667  100.1667  101.1667  102.1667
480.5001.000   82.1667   83.1667   84.1667  102.1667  103.1667  104.1667
490.5001.000   84.1667   85.1667   86.1667  104.1667  105.1667  106.1667
500.5001.000   86.1667   87.1667   88.1667  106.1667  107.1667  108.1667
510.5001.000   88.1667   89.1667   90.1667  108.1667  109.1667  110.1667
520.5001.000   90.1667   91.1667   92.1667  110.1667  111.1667  112.1667
530.5001.000   73.3333   92.1667  112.1667  113.3333    0.0000    0.0000
540.5001.000   93.3333   94.1667   95.1667  114.1667  115.1667    0.0000
550.5001.000   95.1667   96.1667   97.1667  115.1667  116.1667  117.1667
560.5001.000   97.1667   98.1667   99.1667  117.1667  118.1667  119.1667
570.5001.000   99.1667  100.1667  101.1667  119.1667  120.1667  121.1667
580.5001.000  101.1667  102.1667  103.1667  121.1667  122.1667  123.1667
590.5001.000  103.1667  104.1667  105.1667  123.1667  124.1667  125.1667
600.5001.000  105.1667  106.1667  107.1667  125.1667  126.1667  127.1667
610.5001.000  107.1667  108.1667  109.1667  127.1667  128.1667  129.1667
620.5001.000  109.1667  110.1667  111.1667  129.1667  130.1667  131.1667
630.5001.000  111.1667  112.1667  113.3333  131.1667  132.1667    0.0000
640.5001.000   93.3333  114.1667  134.1667  133.3333    0.0000    0.0000
650.5001.000  114.1667  115.1667  116.1667  134.1667  135.1667  136.1667
660.5001.000  116.1667  117.1667  118.1667  136.1667  137.1667  138.1667
670.5001.000  118.1667  119.1667  120.1667  138.1667  139.1667  140.1667
680.5001.000  120.1667  121.1667  122.1667  140.1667  141.1667  142.1667
690.5001.000  122.1667  123.1667  124.1667  142.1667  143.1667  144.1667
700.5001.000  124.1667  125.1667  126.1667  144.1667  145.1667  146.1667
710.5001.000  126.1667  127.1667  128.1667  146.1667  147.1667  148.1667
720.5001.000  128.1667  129.1667  130.1667  148.1667  149.1667  150.1667
730.5001.000  130.1667  131.1667  132.1667  150.1667  151.1667  152.1667
740.5001.000  113.3333  132.1667  152.1667  153.3333    0.0000    0.0000
750.5001.000  133.3333  134.1667  135.1667  154.1667  155.1667    0.0000
760.5001.000  135.1667  136.1667  137.1667  155.1667  156.1667  157.1667
770.5001.000  137.1667  138.1667  139.1667  157.1667  158.1667  159.1667
780.5001.000  139.1667  140.1667  141.1667  159.1667  160.1667  161.1667
790.5001.000  141.1667  142.1667  143.1667  161.1667  162.1667  163.1667
800.5001.000  143.1667  144.1667  145.1667  163.1667  164.1667  165.1667
810.5001.000  145.1667  146.1667  147.1667  165.1667  166.1667  167.1667
820.5001.000  147.1667  148.1667  149.1667  167.1667  168.1667  169.1667
830.5001.000  149.1667  150.1667  151.1667  169.1667  170.1667  171.1667
840.5001.000  151.1667  152.1667  153.3333  171.1667  172.1667    0.0000
850.5001.000  133.3333  154.1667  174.1667  173.3333    0.0000    0.0000
860.5001.000  154.1667  155.1667  156.1667  174.1667  175.1667  176.1667
870.5001.000  156.1667  157.1667  158.1667  176.1667  177.1667  178.1667
880.5001.000  158.1667  159.1667  160.1667  178.1667  179.1667  180.1667
890.5001.000  160.1667  161.1667  162.1667  180.1667  181.1667  182.1667
900.5001.000  162.1667  163.1667  164.1667  182.1667  183.1667  184.1667
910.5001.000  164.1667  165.1667  166.1667  184.1667  185.1667  186.1667
920.5001.000  166.1667  167.1667  168.1667  186.1667  187.1667  188.1667
930.5001.000  168.1667  169.1667  170.1667  188.1667  189.1667  190.1667
```

```
 940.5001.000  170.1667  171.1667  172.1667  190.1667  191.1667  192.1667
 950.5001.000  153.3333  172.1667  192.1667  193.3333    0.0000    0.0000
 960.5001.000  173.3333  174.1667  175.1667  194.1667  195.1667    0.0000
 970.5001.000  175.1667  176.1667  177.1667  195.1667  196.1667  197.1667
 980.5001.000  177.1667  178.1667  179.1667  197.1667  198.1667  199.1667
 990.5001.000  179.1667  180.1667  181.1667  199.1667  200.1667  201.1667
1000.5001.000  181.1667  182.1667  183.1667  201.1667  202.1667  203.1667
1010.5001.000  183.1667  184.1667  185.1667  203.1667  204.1667  205.1667
1020.5001.000  185.1667  186.1667  187.1667  205.1667  206.1667  207.1667
1030.5001.000  187.1667  188.1667  189.1667  207.1667- 208.1667  209.1667
1040.5001.000  189.1667  190.1667  191.1667  209.1667  210.1667  211.1667
1050.5001.000  191.1667  192.1667  193.3333  211.1667  212,1667    0.0000
1060.5001.000  173.3333  194.1667  214.1667  213.3333    0.0000    0.0000
1070.5001.000  194.1667  195.1667  196.1667  214.1667  215.1667  216.1667
1080.5001.000  196.1667  197.1667  198.1667  216.1667  217.1667  218.1667
1090.5001.000  198.1667  199.1667  200.1667  218.1667  219.1667  220.1667
1100.5001.000  200.1667  201.1667  202.1667  220.1667  221.1667  222.1667
1110.5001.000  202.1667  203.1667  204.1667  222.1667  223.1667  224.1667
1120.5001.000  204.1667  205.1667  206.1667  224.1667  225.1667  226.1667
1130.5001.000  206.1667  207.1667  208.1667  226.1667  227.1667  228.1667
1140.5001.000  208.1667  209.1667  210.1667  228.1667  229.1667  230.1667
1150.5001.000  210.1667  211.1667  212.1667  230.1667  231.1667  232.1667
1160.5001.000  193.3333  212.1667  232.1667  233.3333    0.0000    0.0000
1170.5001.000  213.4167  214.1667  215.1667  234.2500    0.0000    0.0000
1180.5001.000  215.1667  216.1667  217.1667  234.2500  235.2500    0.0000
1190.5001.000  217.1667  218.1667  219.1667  235.2500  236.2500    0.0000
1200.5001.000  219.1667  220.1667  221.1667  236.2500  237.2500    0.0000
1210.5001.000  221.1667  222.1667  223.1667  237.2500  238.2500    0.0000
1220.5001.000  223.1667  224.1667  225.1667  238.2500  239.2500    0.0000
1230.5001.000  225.1667  226.1667  227.1667  239.2500  240.2500    0.0000
1240.5001.000  227.1667  228.1667  229.1667  240.2500  241.2500    0.0000
1250.5001.000  229.1667  230.1667  231.1667  241.2420  242.2420    0.0000
1260.5001.000  231.1667  232.1667  233.4167  242.2420    0.0000    0.0000
   2    0    0
2.903 .208184.1  .33  11.  .11 488. .050 100.   .5
   0.5e-4
   1    2    2   12    0    0    0    0
   2    4    3   12   13    1    0    0
   3    4    4   13   14    2    0    0
   4    4    5   14   15    3    0    0
   5    4    6   15   16    4    0    0
   6    4    7   16   17    5    0    0
   7    4    8   17   18    6    0    0
   8    4    9   18   19    7    0    0
   9    4   10   19   20    8    0    0
  10    4   11   20   21    9    0    0
  11    2   21   10    0    0    0    0
  12    5    1    2   13   23   22    0
  13    6    2    3   14   24   23   12
  14    6    3    4   15   25   24   13
  15    6    4    5   16   26   25   14
  16    6    5    6   17   27   26   15
  17    6    6    7   18   28   27   16
  18    6    7    8   19   29   28   17
  19    6    8    9   20   30   29   18
  20    6    9   10   21   31   30   19
  21    5   10   11   20   32   31    0
  22    3   12   23   33    0    0    0
  23    6   12   13   24   34   33   22
  24    6   13   14   25   35   34   23
```

25	6	14	15	26	36	35	24
26	6	15	16	27	37	36	25
27	6	16	17	28	38	37	26
28	6	17	18	29	39	38	27
29	6	18	19	30	40	39	28
30	6	19	20	31	41	40	29
31	6	20	21	32	42	41	30
32	3	21	31	42	0	0	0
33	5	22	23	34	44	43	0
34	6	23	24	35	45	44	33
35	6	24	25	36	46	45	34
36	6	25	26	37	47	46	35
37	6	26	27	38	48	47	36
38	6	27	28	39	49	48	37
39	6	28	29	40	50	49	38
40	6	29	30	41	51	50	39
41	6	30	31	42	52	51	40
42	5	31	32	41	53	52	0
43	3	33	44	54	0	0	0
44	6	33	34	45	55	54	43
45	6	34	35	46	56	55	44
46	6	35	36	47	57	56	45
47	6	36	37	48	58	57	46
48	6	37	38	49	59	58	47
49	6	38	39	50	60	59	48
50	6	39	40	51	61	60	49
51	6	40	41	52	62	61	50
52	6	41	42	53	63	62	51
53	3	42	52	63	0	0	0
54	5	43	44	55	65	64	0
55	6	44	45	56	66	65	54
56	6	45	46	57	67	66	55
57	6	46	47	58	68	67	56
58	6	47	48	59	69	68	57
59	6	48	49	60	70	69	58
60	6	49	50	61	71	70	59
61	6	50	51	62	72	71	60
62	6	51	52	63	73	72	61
63	5	52	53	62	74	73	0
64	3	54	65	75	0	0	0
65	6	54	55	66	76	75	64
66	6	55	56	67	77	76	65
67	6	56	57	68	78	77	66
68	6	57	58	69	79	78	67
69	6	58	59	70	80	79	68
70	6	59	60	71	81	80	69
71	6	60	61	72	82	81	70
72	6	61	62	73	83	82	71
73	6	62	63	74	84	83	72
74	3	63	73	84	0	0	0
75	5	64	65	76	86	85	0
76	6	65	66	77	87	86	75
77	6	66	67	78	88	87	76
78	6	67	68	79	89	88	77
79	6	68	69	80	90	89	78
80	6	69	70	81	91	90	79
81	6	70	71	82	92	91	80
82	6	71	72	83	93	92	81
83	6	72	73	84	94	93	82
84	5	73	74	83	95	94	0

```
 85    3   75   86   96    0    0    0
 86    6   75   76   87   97   96   85
 87    6   76   77   88   98   97   86
 88    6   77   78   89   99   98   87
 89.   6   78   79   90  100   99   88
 90    6   79   80   91  101  100   89
 91    6   80   81   92  102  101   90
 92    6   81   82   93  103  102   91
 93    6   82   83   94  104  103   92
 94    6   83   84   95  105  104   93
 95    3   84   94  105    0    0    0
 96    5   85   86   97  107  106    0
 97    6   86   87   98  108  107   96
 98    6   87   88   99  109  108   97
 99    6   88   89  100  110  109   98
100    6   89   90  101  111  110   99
101    6   90   91  102  112  111  100
102    6   91   92  103  113  112  101
103    6   92   93  104  114  113  102
104    6   93   94  105  115  114  103
105    5   94   95  104  116  115    0
106    3   96  107  117    0    0    0
107    6   96   97  108  118  117  106
108    6   97   98  109  119  118  107
109    6   98   99  110  120  119  108
110    6   99  100  111  121  120  109
111    6  100  101  112  122  121  110
112    6  101  102  113  123  122  111
113    6  102  103  114  124  123  112
114    6  103  104  115  125  124  113
115    6  104  105  116  126  125  114
116    3  105  115  126    0    0    0
117    3  106  107  118    0    0    0
118    4  107  108  119  117    0    0
119    4  108  109  120  118    0    0
120    4  109  110  121  119    0    0
121    4  110  111  122  120    0    0
122    4  111  112  123  121    0    0
123    4  112  113  124  122    0    0
124    4  113  114  125  123    0    0
125    4  114  115  126  124    0    0
126    3  115  116  125    0    0    0
  0.5e-4
  1    2    1    4
  2    1    1
  3    1    1
  4    1    1
  5    1    1
  6    1    1
  7    1    1
  8    1    1
  9    1    1
 10    1    1
 11    2    1    2
 22    1    4
 32    1    2
 43    1    4
 53    1    2
 64    1    4
 74    1    2
```

```
   85    1    4
   95    1    2
  106    1    4
  116    1    2
  117    1    3
  118    1    3
  119    1    3
  120    1    3
  121    1    3
  122    1    3
  123    1    3
  124    1    3
  125    1    3
  126    1    3
slab          8    8
    1    1 5.68
    2    15.263
    3    1 5.68
    4    15.263
    5    1   6.
    6    1   6.
    7    1   6.
    8    1 . 6.
    1      39.32     .3745
    2      29.45        .5
    3      17.30    .86603
    4      21.56    .68301
    5      29.45        .5
    6     2.5925      5.68
    7     2.7053     5.443
    8    1.70436     6.000
    1   13    1    1    1    1    2    1    1    3    2    1    4    2
              1    5    2    1    6    2    1    7    2    1    8    2
              1    9    2    1   10    2    1   11    2    1   12    2
              2    1    6
    2    8    1    2    1    1   33    3    1   73    3    1  113    3
              1  153    3    1  193    3    1  233    4    2    2    7
    3   12    1  213    5    1  234    2    1  235    2    1  236    2
              1  237    2    1  238    2    1  239    2    1  240    2
              1  241    2    1  242    2    1  233    5    2    3    6
    4    8    1  213    4    1  173    3    1  133    3    1   93    3
              1   53    3    1   13    3    1    1    1    2    4    7
    5    1    2    1    8
    6    1    2    2    8
    7    1    2    3    8
    8    1    2    4    8

radg      2    1    1
    1    8
    1 5.68   .2    1   0.    2   0.    3   0.    4   0.    5.9788    6.0166
                   7   0.    8.0166
    25.443   .2    1   0.    2   0.    3   0.    4   0.    5.0006    6.9989
                   7.0006    8   0.
    3 5.68   .2    1   0.    2   0.    3   0.    4   0.    5   0.    6.0166
                   7.9788    8.0166
    45.443   .2    1   0.    2   0.    3   0.    4   0.    5.0006    6   0.
                   7.0006    6.9989
    5   6.   .2    1.9833    2.0005    3   0.    4.0005    5   0.    6.0178
                   7   0.    6.0178
    6   6.   .2    1.0104    2.9428    3.0104    4   0.    5.0178    6   0.
```

```
                 7.0178    8.0008
    7   6.    .2    1   0.    2.0005    3.9633    4.0005    5   0.    6.0178
                    7   0.    8.0178
    8   6.    .2    1.0104    2   0.    3.0104    4.9428    5.0178    6.0008
                    7.0178    8   0.
    1    1    4    1    2    3    4
    2   -1    8    1    2    3    4    5    6    7    8
heat      2         1
              1.326               1.326
                     2.                2.
  1.0  1.0
drag      2
98.53  -1.   0.   0.  .05
100.0  -1.   0.   0.  .05
bdry      1    1    4    0
    1    1.0e-3
    1    2   0. 392.   1. 392.
    1    1  6.0    1
    5   1.    1   1.    1
    2    1  6.0    1
    6   1.    1   1.    1
    3    1  6.0    1
    7   1.    1   1.    1
    4    1  6.0    1
    8   1.    1   1.    1
calc     1

        30
oper     1         3    0                                              1
       20.0      392.5   1.0e-06 .00304630     392.5        0.        0.
    2
  0.   1.   1.   1.
outp     1
endd
```

```
 data from iterative solution using the recirculation module
 time =     0.0000     dt = ******     implicit dt = 0.0000     explicit dt = ******     mode =  0


 iteration  sweep          peak clad            total flow     pressure                  error
    no.      no.    ---------------------------   (lbm/s)     drop(psi)    -----------------------------------
                    temp(f)  fluid  rod  ass.                                 total     flow    fluid     rod
                                                                             energy            energy   energy

     1        1      394.9     3     58    1     -0.128e-08    0.0000000    -0.2333   0.8502   0.0028   0.0001
              2      396.8     3     59    1                                0.7529   0.8502   0.0025   0.0000

     2        1      398.6     3     59    1      0.291e-07    0.0000000     0.6485   0.0076   0.0022   0.0001

     3        1      400.3     3     59    1     -0.129e-07    0.0000000     0.5649   0.0009   0.0019   0.0000
              2      401.8     3     59    1                                0.4943   0.0009   0.0017   0.0000

     4        1      403.2     3     59    1      0.110e-08    0.0000000    -0.1307   0.0022   0.0013   0.0000

     5        1      404.4     3     59    1     -0.845e-08    0.0000000     0.3792   0.0000   0.0013   0.0000
              2      405.4     3     59    1                                0.3343   0.0000   0.0011   0.0000
```

6	1	406.4	3	59	1	-0.190e-08	0.0000000	0.2941	0.0005	0.0010	0.0000
	2	407.2	3	59	1			0.2589	0.0005	0.0009	0.0000
7	1	407.9	3	59	1	-0.355e-08	0.0000000	-0.0660	0.0002	0.0007	0.0000
	2	408.6	3	59	1			0.1995	0.0002	0.0007	0.0000
8	1	409.1	3	59	1	-0.867e-09	0.0000000	0.1758	0.0000	0.0006	0.0000
	2	409.6	3	59	1			0.1549	0.0000	0.0005	0.0000
9	1	410.1	3	59	1	-0.108e-08	0.0000000	0.1361	0.0001	0.0005	0.0000
	2	410.5	3	59	1			0.1198	0.0001	0.0004	0.0000
10	1	410.8	3	59	1	-0.158e-09	0.0000000	-0.0368	0.0000	0.0003	0.0000
	2	411.1	3	59	1			0.0921	0.0000	0.0003	0.0000
11	1	411.4	3	59	1	-0.218e-09	0.0000000	0.0809	0.0001	0.0003	0.0000
	2	411.6	3	59	1			0.0712	0.0001	0.0002	0.0000
12	1	411.8	3	59	1	0.435e-10	0.0000000	0.0624	0.0000	0.0002	0.0000
13	1	412.0	3	59	1	-0.542e-11	0.0000000	-0.0074	0.0000	0.0002	0.0000
	2	412.1	3	59	1			0.0479	0.0000	0.0002	0.0000
14	1	412.3	3	59	1	0.582e-10	0.0000000	0.0420	0.0000	0.0002	0.0000
15	1	412.4	3	59	1	0.179e-10	0.0000000	0.0368	0.0000	0.0001	0.0000
16	1	412.5	3	59	1	0.245e-10	0.0000000	-0.0045	0.0000	0.0001	0.0000
17	1	412.6	3	59	1	0.683e-11	0.0000000	0.0281	0.0000	0.0001	0.0000
18	1	412.7	3	59	1	0.815e-11	0.0000000	0.0246	0.0000	0.0001	0.0000
19	1	412.8	3	59	1	0.222e-11	0.0000000	-0.0031	0.0000	0.0001	0.0000
	2	412.8	3	59	1			0.0187	0.0000	0.0001	0.0000
20	1	412.9	3	59	1	0.177e-11	0.0000000	0.0163	0.0000	0.0001	0.0000
	2	412.9	3	59	1			0.0127	0.0000	0.0000	0.0000
21	1	413.0	3	59	1	0.298e-13	0.0000000	0.0128	0.0000	0.0001	0.0000
	2	413.0	3	59	1			0.0094	0.0000	0.0000	0.0000
22	1	413.0	3	59	1	0.746e-13	0.0000000	-0.0029	0.0000	0.0001	0.0000
	2	413.1	3	59	1			0.0074	0.0000	0.0000	0.0000
23	1	413.1	3	59	1	-0.287e-12	0.0000000	0.0073	0.0000	0.0001	0.0000
	2	413.1	3	59	1			0.0052	0.0000	0.0000	0.0000
24	1	413.1	3	59	1	-0.143e-12	0.0000000	0.0055	0.0000	0.0000	0.0000
	2	413.2	3	59	1			0.0038	0.0000	0.0000	0.0000
25	1	413.2	3	59	1	-0.171e-12	0.0000000	-0.0015	0.0000	0.0000	0.0000
	2	413.2	3	59	1			0.0024	0.0000	0.0000	0.0000
26	1	413.2	3	59	1	-0.787e-13	0.0000000	0.0029	0.0000	0.0000	0.0000
	2	413.2	3	59	1			0.0015	0.0000	0.0000	0.0000
27	1	413.2	3	59	1	-0.628e-13	0.0000000	0.0021	0.0000	0.0000	0.0000
	2	413.2	3	59	1			0.0007	0.0000	0.0000	0.0000

```
  slab temperature summary        time =    0.0000 seconds
  (assembly no. - channel no.)


 axial zone      ( 1)       ( 2)       ( 3)       ( 4)       ( 5)       ( 6)       ( 7)       ( 8)       (
  (inches)

  0.0 - 12.0     392.28     392.18     392.28     392.15     392.26     392.18     392.25     392.15
 12.0 - 24.0     392.28     392.18     392.28     392.15     392.26     392.18     392.25     392.15



  side boundary temperature summary     time =    0.0000 seconds
  boundary slab node no.     1


 axial zone      ( 1)       ( 2)       (
  (inches)

  0.0 - 12.0     392.28     392.00
 12.0 - 24.0     392.28     392.00



 calculated rod temperatures at time =    0.0000 seconds
 rod no.    6
 assembly   1                  (fuel type  1 - cylinder)
0rod o.d. - 0.500 (in.)     zone-(fuel dia.(in.)) -  1-(0.330)

                                            *  fuel temperatures(f.)
                                            *
   axial zone  heat flux  type         hsurf  *  fluid    clad
      (in.)   (mbtu/hr-ft2)         (b/h-f-ft2) *
   0.0 -  12.0   0.0000    1           28.7      401.4    401.8
  12.0 -  24.0   0.0000    1           28.7      401.4    401.9


 calculated rod temperatures at time =    0.0000 seconds
 rod no.   69
 assembly   1                  (fuel type  1 - cylinder)
0rod o.d. - 0.500 (in.)     zone-(fuel dia.(in.)) -  1-(0.330)

                                            *  fuel temperatures(f.)
                                            *
   axial zone  heat flux  type         hsurf  *  fluid    clad
      (in.)   (mbtu/hr-ft2)         (b/h-f-ft2) *
   0.0 -  12.0   0.0000    1           35.6      412.9    413.2
  12.0 -  24.0   0.0000    1           35.6      413.0    413.2


 calculated rod temperatures at time =    0.0000 seconds
 rod no.  121
 assembly   1                  (fuel type  1 - cylinder)
0rod o.d. - 0.500 (in.)     zone-(fuel dia.(in.)) -  1-(0.330)
```

```
                                                *   fuel temperatures(f.)
                                                *
 axial zone  heat flux   type           hsurf  *   fluid    clad
    (in.)   (mbtu/hr-ft2)           (b/h-f-ft2) *
  0.0 -  12.0    0.0000    1             28.0      401.0    401.4
 12.0 -  24.0    0.0000    1             28.0      401.0    401.4
```

APPENDIX D

CASTOR-1C BWR SPENT FUEL STORAGE CASK PERFORMANCE TEST SIMULATIONS INPUT, OUTPUT, AND CONVERGENCE LISTS

APPENDIX D

CASTOR-1C BWR SPENT FUEL STORAGE CASK PERFORMANCE TEST SIMULATIONS INPUT, OUTPUT, AND CONVERGENCE LISTS

Test Case	Page Number Input	 Convergence List	 Output
Vertical, helium	D.2	D.22	D.23

```
+5300
   1     castor 1c  vertical helium full-load validation cask simulation
prop     7    3
        1.         0.      100.0     .0780       1.24     83.33      .0410
        2.       200.      348.0     .0970       1.24    119.76      .0533
        3.       400.      596.0     .1150       1.24    156.25      .0641
        5.       600.      844.0     .1290       1.24    192.31      .0727
       10.       800.     1092.0     .1380       1.24    229.36      .0823
       15.      1000.     1340.0     .1380       1.24    265.25      .0907
       20.      1500.     1588.0     .1380       1.24    357.14      .1138
   1  can                            10.2
   2   fe                            24.3
   3  mix                            13.5
chan      8   18
     176.0         .0
   1    1   60    0    0
   1    1    0    0    1
   1.66202.5811.105    2.4569.7382    7.7629         8.1756.7382
   2.42071.622.8837    3.4569.7382    9.1756.7382
   3.42071.622.8837    4.4569.7382   10.1756.7382
   4.42071.622.8837    5.4569.7382   11.1756.7382
   5.42071.622.8837    6.4569.7382   12.1756.7382
   6.66202.5811.105   13.1756.7382   14.7629
2  71.4472.5811.105    8.17561.004   15.9884.7382
   8.29641.7671.767    9.1756.7382   16.1756.7382
   9.29641.7671.767   10.1756.7382   17.1756.7382
  10.29641.7671.767   11.1756.7382   18.1756.7382
  11.29641.7671.767   12.1756.7382   19.1756.7382
  12.29641.7671.767   13.1756.7382   20.1756.7382
  13.29641.7671.767   14.1756.7382   21.1756.7382
  14.66202.5811.105   22.4569.7382
2 15.81301.622.8837   16.17561.004   23.9884.7382
  16.29641.7671.767   17.1756.7382   24.1756.7382
  17.29641.7671.767   18.1756.7382   25.1756.7382
  18.29641.7671.767   19.1756.7382   26.1756.7382
  19.29641.7671.767   20.1756.7382   27.1756.7382
  20.29641.7671.767   21.1756.7382   28.1756.7382
  21.29641.7671.767   22.1756.7382   29.1756.7382
  22.42071.622.8837   30.4569.7382
2 23.81301.622.8837   24.17561.004   31.9884.7382
  24.29641.7671.767   25.1756.7382   32.1756.7382
  25.29641.7671.767   26.1756.7382   33.1756.7382
  26.29641.7671.767   27.1756.7382   34.1756.7382
  27.29641.7671.767   28.1756.7382   35.1756.7382
  28.29641.7671.767   29.1756.7382   36.1756.7382
  29.29641.7671.767   30.1756.7382   37.1756.7382
  30.42071.622.8837   38.4569.7382
2 31.81301.622.8837   32.17561.004   39.9884.7382
  32.29641.7671.767   33.1756.7382   40.1756.7382
  33.29641.7671.767   34.1756.7382   41.1756.7382
  34.29641.7671.767   35.1756.7382   42.1756.7382
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  36.29641.7671.767   37.1756.7382   44.1756.7382
  37.29641.7671.767   38.1756.7382   45.1756.7382
  38.42071.622.8837   46.4569.7382
2 39.81301.622.8837   40.17561.004   47.9884.7382
  40.29641.7671.767   41.1756.7382   48.1756.7382
  41.29641.7671.767   42.1756.7382   49.1756.7382
  42.29641.7671.767   43.1756.7382   50.1756.7382
  43.29641.7671.767   44.1756.7382   51.1756.7382
```

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  46.42071.622.8837   54.4569.7382
2 471.4472.5811.105   48.17561.004   55.7629
  48.29641.7671.767   49.1756.7382   55.1756.7382
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  50.29641.7671.767   51.1756.7382   57.1756.7382
  51.29641.7671.767   52.1756.7382   58.1756.7382
  52.29641.7671.767   53.1756.7382   59.1756.7382
  53.29641.7671.767   54.1756.7382   60.1756.7382
  54.66202.5811.105   60.7629
  55.66202.5811.105   56.4569.7382
  56.42071.622.8837   57.4569.7382
  57.42071.622.8837   58.4569.7382
  58.42071.622.8837   59.4569.7382
  59.42071.622.8837   60.4569.7382
  60.66202.5811.105
   2    2   60    0    0
   1    1    0    0    1
   1.66202.5811.105   2.4569.7382    7.7629         8.1756.7382
   2.42071.622.8837   3.4569.7382    9.1756.7382
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   4.42071.622.8837   5.4569.7382   11.1756.7382
   5.42071.622.8837   6.4569.7382   12.1756.7382
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   7.66202.5811.105   8.1756.7382   15.4569.7382
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   9.29641.7671.767  10.1756.7382   17.1756.7382
  10.29641.7671.767  11.1756.7382   18.1756.7382
  11.29641.7671.767  12.1756.7382   19.1756.7382
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  13.29641.7671.767  14.1756.7382   21.1756.7382
  14.66202.5811.105  22.4569.7382
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  20.29641.7671.767  21.1756.7382   28.1756.7382
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53.29641.7671.767   54.1756.7382   60.1756.7382
54.66202.5811.105   60.7629
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57.42071.622.8837   58.4569.7382
58.42071.622.8837   59.4569.7382
59.42071.622.8837   60.4569.7382
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 1    1    0    0    1
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 8.59232.320.9661    9.1476.6398   17.4675.6398
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15.21901.5461.546   16.1476.6398   24.1476.6398
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23.21901.5461.546   24.1476.6398   32.1476.6398
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39.21901.5461.546   40.1476.6398   48.1476.6398
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    43.36151.413.7730   52.4675.6398
    44.36151.413.7730   45.1476.6398   53.4675.6398
    45.21901.5461.546   46.1476.6398   54.1476.6398
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    47.21901.5461.546   48.1476.6398   56.1476.6398
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    53.36151.413.7730   54.1476.6398   62.4675.6398
    54.21901.5461.546   55.1476.6398   63.1476.6398
    55.21901.5461.546   56.1476.6398   64.1476.6398
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    61.36151.413.7730   70.4675.6398
    62.59232.320.9661   63.1476.6398   71.7629
    63.21901.5461.546   64.1476.6398   71.1476.6398
    64.21901.5461.546   65.1476.6398   72.1476.6398
    65.21901.5461.546   66.1476.6398   73.1476.6398
    66.21901.5461.546   67.1476.6398   74.1476.6398
    67.21901.5461.546   68.1476.6398   75.1476.6398
    68.21901.5461.546   69.1476.6398   76.1476.6398
    69.21901.5461.546   70.1476.6398   77.7629
    70.59232.320.9661   77.7629
    71.59232.320.9661   72.4675.6398
    72.36151.413.7730   73.4675.6398
    73.36151.413.7730   74.4675.6398
    74.36151.413.7730   75.4675.6398
    75.36151.413.7730   76.4675.6398
    76.36151.413.7730   77.4675.6398
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     1    1    0    0    1
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     3.36151.413.7730    4.1476.6398   11.1476.6398
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     5.36151.413.7730    6.1476.6398   13.1476.6398
     6.36151.413.7730    7.1476.6398   14.1476.6398
     7.59232.320.9661   15.1476.6398   16.7629
     8.59232.320.9661    9.1476.6398   17.4675.6398
     9.21901.5461.546   10.1476.6398   18.1476.6398
    10.21901.5461.546   11.1476.6398   19.1476.6398
    11.21901.5461.546   12.1476.6398   20.1476.6398
    12.21901.5461.546   13.1476.6398   21.1476.6398
    13.21901.5461.546   14.1476.6398   22.1476.6398
    14.21901.5461.546   15.1476.6398   23.1476.6398
    15.21901.5461.546   16.14761.065   24.14761.065
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    20.21901.5461.546   21.1476.6398   29.1476.6398
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   23.21901.5461.546   24.1476.6398   32.1476.6398
   24.21901.5461.546   25.14761.065   33.14761.065
2  25.70151.413.7730   34.9990.6398
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   27.21901.5461.546   28.1476.6398   36.1476.6398
   28.21901.5461.546   29.1476.6398   37.1476.6398
   29.21901.5461.546   30.1476.6398   38.1476.6398
   30.21901.5461.546   31.1476.6398   39.1476.6398
   31.21901.5461.546   32.1476.6398   40.1476.6398
   32.21901.5461.546   33.1476.6398   41.1476.6398
   33.21901.5461.546   34.14761.065   42.14761.065
2  34.70151.413.7730   43.9990.6398
   35.36151.413.7730   36.1476.6398   44.4675.6398
   36.21901.5461.546   37.1476.6398   45.1476.6398
   37.21901.5461.546   38.1476.6398   46.1476.6398
   38.21901.5461.546   39.1476.6398   47.1476.6398
   39.21901.5461.546   40.1476.6398   48.1476.6398
   40.21901.5461.546   41.1476.6398   49.1476.6398
   41.21901.5461.546   42.1476.6398   50.1476.6398
   42.21901.5461.546   43.14761.065   51.1476.6398
2  43.70151.413.7730   52.9990.6398
   44.36151.413.7730   45.1476.6398   53.4675.6398
   45.21901.5461.546   46.1476.6398   54.1476.6398
   46.21901.5461.546   47.1476.6398   55.1476.6398
   47.21901.5461.546   48.1476.6398   56.1476.6398
   48.21901.5461.546   49.1476.6398   57.1476.6398
   49.21901.5461.546   50.1476.6398   58.1476.6398
   50.21901.5461.546   51.1476.6398   59.1476.6398
   51.21901.5461.546   52.14761.065   60.1476.6398
2  52.70151.413.7730   61.9990.6398
   53.36151.413.7730   54.1476.6398   62.4675.6398
   54.21901.5461.546   55.1476.6398   63.1476.6398
   55.21901.5461.546   56.1476.6398   64.1476.6398
   56.21901.5461.546   57.1476.6398   65.1476.6398
   57.21901.5461.546   58.1476.6398   66.1476.6398
   58.21901.5461.546   59.1476.6398   67.1476.6398
   59.21901.5461.546   60.1476.6398   68.1476.6398
   60.21901.5461.546   61.14761.065   69.1476.6398
2  61.70151.413.7730   70.9990.6398
   62.59232.320.9661   63.1476.6398   71.7629
   63.21901.5461.546   64.1476.6398   71.1476.6398
   64.21901.5461.546   65.1476.6398   72.1476.6398
   65.21901.5461.546   66.1476.6398   73.1476.6398
   66.21901.5461.546   67.1476.6398   74.1476.6398
   67.21901.5461.546   68.1476.6398   75.1476.6398
   68.21901.5461.546   69.1476.6398   76.1476.6398
   69.21901.5461.546   70.1476.6398   77.7629
2  701.3122.320.9661   77.7629
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   72.36151.413.7730   73.4675.6398
   73.36151.413.7730   74.4675.6398
   74.36151.413.7730   75.4675.6398
   75.36151.413.7730   76.4675.6398
   76.36151.413.7730   77.4675.6398
   77.59232.320.9661
    5    5   60    0    0
    1    1    0    0    1
    1.66202.5811.105   2.4569.7382   7.7629         8.1756.7382
```

```
      2.42071.622.8837    3.4569.7382     9.1756.7382
      3.42071.622.8837    4.4569.7382    10.1756.7382
      4.42071.622.8837    5.4569.7382    11.1756.7382
      5.42071.622.8837    6.4569.7382    12.1756.7382
      6.66202.5811.105   13.1756.7382    14.7629
2     71.4472.5811.105    8.17561.004    15.9884.7382
      8.29641.7671.767    9.1756.7382    16.1756.7382
      9.29641.7671.767   10.1756.7382    17.1756.7382
     10.29641.7671.767   11.1756.7382    18.1756.7382
     11.29641.7671.767   12.1756.7382    19.1756.7382
     12.29641.7671.767   13.1756.7382    20.1756.7382
     13.29641.7671.767   14.1756.7382    21.1756.7382
     14.66202.5811.105   22.4569.7382
2    15.81301.622.8837   16.17561.004    23.9884.7382
     16.29641.7671.767   17.1756.7382    24.1756.7382
     17.29641.7671.767   18.1756.7382    25.1756.7382
     18.29641.7671.767   19.1756.7382    26.1756.7382
     19.29641.7671.767   20.1756.7382    27.1756.7382
     20.29641.7671.767   21.1756.7382    28.1756.7382
     21.29641.7671.767   22.1756.7382    29.1756.7382
     22.42071.622.8837   30.4569.7382
2    23.81301.622.8837   24.17561.004    31.9884.7382
     24.29641.7671.767   25.1756.7382    32.1756.7382
     25.29641.7671.767   26.1756.7382    33.1756.7382
     26.29641.7671.767   27.1756.7382    34.1756.7382
     27.29641.7671.767   28.1756.7382    35.1756.7382
     28.29641.7671.767   29.1756.7382    36.1756.7382
     29.29641.7671.767   30.1756.7382    37.1756.7382
     30.42071.622.8837   38.4569.7382
2    31.81301.622.8837   32.17561.004    39.9884.7382
     32.29641.7671.767   33.1756.7382    40.1756.7382
     33.29641.7671.767   34.1756.7382    41.1756.7382
     34.29641.7671.767   35.1756.7382    42.1756.7382
     35.29641.7671.767   36.1756.7382    43.1756.7382
     36.29641.7671.767   37.1756.7382    44.1756.7382
     37.29641.7671.767   38.1756.7382    45.1756.7382
     38.42071.622.8837   46.4569.7382
2    39.81301.622.8837   40.17561.004    47.9884.7382
     40.29641.7671.767   41.1756.7382    48.1756.7382
     41.29641.7671.767   42.1756.7382    49.1756.7382
     42.29641.7671.767   43.1756.7382    50.1756.7382
     43.29641.7671.767   44.1756.7382    51.1756.7382
     44.29641.7671.767   45.1756.7382    52.1756.7382
     45.29641.7671.767   46.1756.7382    53.1756.7382
     46.42071.622.8837   54.4569.7382
2    471.5873.1131.105   48.17561.004    55.7629
     48.29641.7671.767   49.1756.7382    55.1756.7382
     49.29641.7671.767   50.1756.7382    56.1756.7382
     50.29641.7671.767   51.1756.7382    57.1756.7382
     51.29641.7671.767   52.1756.7382    58.1756.7382
     52.29641.7671.767   53.1756.7382    59.1756.7382
     53.29641.7671.767   54.1756.7382    60.1756.7382
     54.66202.5811.105   60.7629
2    551.5873.1131.105   56.9884.7382
2    56.81301.7671.767   57.9884.7382
2    57.81301.7671.767   58.9884.7382
2    58.81301.7671.767   59.9884.7382
2    59.81301.7671.767   60.9884.7382
2    601.4472.5811.105
      6    1   60    0    0
```

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  7   4  77   0   0
  1   1   0   0   1
  8   5  77   0   0
  1   1   0   0   1
  1.59232.320.9661   2.4675.6398   8.7629         9.1476.6398
  2.36151.413.7730   3.1476.6398  10.1476.6398
  3.36151.413.7730   4.1476.6398  11.1476.6398
  4.36151.413.7730   5.1476.6398  12.1476.6398
  5.36151.413.7730   6.1476.6398  13.1476.6398
  6.36151.413.7730   7.1476.6398  14.1476.6398
  7.59232.320.9661  15.1476.6398  16.7629
  8.59232.320.9661   9.1476.6398  17.4675.6398
  9.21901.5461.546  10.1476.6398  18.1476.6398
 10.21901.5461.546  11.1476.6398  19.1476.6398
 11.21901.5461.546  12.1476.6398  20.1476.6398
 12.21901.5461.546  13.1476.6398  21.1476.6398
 13.21901.5461.546  14.1476.6398  22.1476.6398
 14.21901.5461.546  15.1476.6398  23.1476.6398
 15.21901.5461.546  16.14761.665  24.1476.6398
2 161.3122.320.9661  25.9990.6398
 17.36151.413.7730  18.1476.6398  26.1476.6398
 18.21901.5461.546  19.1476.6398  27.1476.6398
 19.21901.5461.546  20.1476.6398  28.1476.6398
 20.21901.5461.546  21.1476.6398  29.1476.6398
 21.21901.5461.546  22.1476.6398  30.1476.6398
 22.21901.5461.546  23.1476.6398  31.1476.6398
 23.21901.5461.546  24.1476.6398  32.1476.6398
 24.21901.5461.546  25.14761.665  33.1476.6398
2 25.70151.413.7730  34.9990.6398
 26.36151.413.7730  27.1476.6398  35.4675.6398
 27.21901.5461.546  28.1476.6398  36.1476.6398
 28.21901.5461.546  29.1476.6398  37.1476.6398
 29.21901.5461.546  30.1476.6398  38.1476.6398
 30.21901.5461.546  31.1476.6398  39.1476.6398
 31.21901.5461.546  32.1476.6398  40.1476.6398
 32.21901.5461.546  33.1476.6398  41.1476.6398
 33.21901.5461.546  34.14761.665  42.1476.6398
2 34.70151.413.7730  43.9990.6398
 35.36151.413.7730  36.1476.6398  44.4675.6398
 36.21901.5461.546  37.1476.6398  45.1476.6398
 37.21901.5461.546  38.1476.6398  46.1476.6398
 38.21901.5461.546  39.1476.6398  47.1476.6398
 39.21901.5461.546  40.1476.6398  48.1476.6398
 40.21901.5461.546  41.1476.6398  49.1476.6398
 41.21901.5461.546  42.1476.6398  50.1476.6398
 42.21901.5461.546  43.14761.665  51.1476.6398
2 43.70151.413.7730  52.9990.6398
 44.36151.413.7730  45.1476.6398  53.4675.6398
 45.21901.5461.546  46.1476.6398  54.1476.6398
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 47.21901.5461.546  48.1476.6398  56.1476.6398
 48.21901.5461.546  49.1476.6398  57.1476.6398
 49.21901.5461.546  50.1476.6398  58.1476.6398
 50.21901.5461.546  51.1476.6398  59.1476.6398
 51.21901.5461.546  52.14761.665  60.1476.6398
2 52.70151.413.7730  61.9990.6398
 53.36151.413.7730  54.1476.6398  62.4675.6398
 54.21901.5461.546  55.1476.6398  63.1476.6398
 55.21901.5461.546  56.1476.6398  64.1476.6398
```

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   57.21901.5461.546   58.1476.6398   66.1476.6398
   58.21901.5461.546   59.1476.6398   67.1476.6398
   59.21901.5461.546   60.1476.6398   68.1476.6398
   60.21901.5461.546   61.14761.065   69.1476.6398
2  61.70151.413.7730   70.9990.6398
   62.59232.320.9661   63.1476.6398   71.7629
   63.21901.5461.546   64.1476.6398   71.1476.6398
   64.21901.5461.546   65.1476.6398   72.1476.6398
   65.21901.5461.546   66.1476.6398   73.1476.6398
   66.21901.5461.546   67.1476.6398   74.1476.6398
   67.21901.5461.546   68.1476.6398   75.1476.6398
   68.21901.5461.546   69.1476.6398   76.1476.6398
   69.21901.5461.546   70.1476.6398   77.7629
2  701.4532.851.9661   77.7629
2  711.3122.320.9661   72.9990.6398
2  72.70151.413.7730   73.9990.6398
2  73.70151.413.7730   74.9990.6398
2  74.70151.413.7730   75.9990.6398
2  75.70151.413.7730   76.9990.6398
2  76.70151.413.7730   77.9990.6398
2  771.4532.851.9661

rods     8    1    2    0    0    1
    1    1   49    0
    1 .563  1.0   1 .375   2 .375   8 .250
    2 .563  1.0   1 .250   2 .250   8 .250   9 .250
    3 .563  1.0   2 .250   3 .250   9 .250  10 .250
    4 .563  1.0   3 .250   4 .250  10 .250  11 .250
    5 .563  1.0   4 .250   5 .250  11 .250  12 .250
    6 .563  1.0   5 .250   6 .250  12 .250  13 .250
    7 .563  1.0   6 .375  13 .250  14 .375
    8 .563  1.0   7 .250   8 .250  15 .250  16 .250
    9 .563  1.0   8 .250   9 .250  16 .250  17 .250
   10 .563  1.0   9 .250  10 .250  17 .250  18 .250
   11 .563  1.0  10 .250  11 .250  18 .250  19 .250
   12 .563  1.0  11 .250  12 .250  19 .250  20 .250
   13 .563  1.0  12 .250  13 .250  20 .250  21 .250
   14 .563  1.0  13 .250  14 .250  21 .250  22 .250
   15 .563  1.0  15 .250  16 .250  23 .250  24 .250
   16 .563  1.0  16 .250  17 .250  24 .250  25 .250
   17 .563  1.0  17 .250  18 .250  25 .250  26 .250
   18 .563  1.0  18 .250  19 .250  26 .250  27 .250
   19 .563  1.0  19 .250  20 .250  27 .250  28 .250
   20 .563  1.0  20 .250  21 .250  28 .250  29 .250
   21 .563  1.0  21 .250  22 .250  29 .250  30 .250
   22 .563  1.0  23 .250  24 .250  31 .250  32 .250
   23 .563  1.0  24 .250  25 .250  32 .250  33 .250
   24 .563  1.0  25 .250  26 .250  33 .250  34 .250
   25 .563  1.0  26 .250  27 .250  34 .250  35 .250
   26 .563  1.0  27 .250  28 .250  35 .250  36 .250
   27 .563  1.0  28 .250  29 .250  36 .250  37 .250
   28 .563  1.0  29 .250  30 .250  37 .250  38 .250
   29 .563  1.0  31 .250  32 .250  39 .250  40 .250
   30 .563  1.0  32 .250  33 .250  40 .250  41 .250
   31 .563  1.0  33 .250  34 .250  41 .250  42 .250
   32 .563  1.0  34 .250  35 .250  42 .250  43 .250
   33 .563  1.0  35 .250  36 .250  43 .250  44 .250
   34 .563  1.0  36 .250  37 .250  44 .250  45 .250
   35 .563  1.0  37 .250  38 .250  45 .250  46 .250
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36 .563  1.0   39 .250   40 .250   47 .250   48 .250
37 .563  1.0   40 .250   41 .250   48 .250   49 .250
38 .563  1.0   41 .250   42 .250   49 .250   50 .250
39 .563  1.0   42 .250   43 .250   50 .250   51 .250
40 .563  1.0   43 .250   44 .250   51 .250   52 .250
41 .563  1.0   44 .250   45 .250   52 .250   53 .250
42 .563  1.0   45 .250   46 .250   53 .250   54 .250
43 .563  1.0   47 .375   48 .250   55 .375
44 .563  1.0   48 .250   49 .250   55 .250   56 .250
45 .563  1.0   49 .250   50 .250   56 .250   57 .250
46 .563  1.0   50 .250   51 .250   57 .250   58 .250
47 .563  1.0   51 .250   52 .250   58 .250   59 .250
48 .563  1.0   52 .250   53 .250   59 .250   60 .250
49 .563  1.0   53 .250   54 .375   60 .375
 2    2   49    0
 1 .563  1.0    1 .375    2 .375    8 .250
 2 .563  1.0    1 .250    2 .250    8 .250    9 .250
 3 .563  1.0    2 .250    3 .250    9 .250   10 .250
 4 .563  1.0    3 .250    4 .250   10 .250   11 .250
 5 .563  1.0    4 .250    5 .250   11 .250   12 .250
 6 .563  1.0    5 .250    6 .250   12 .250   13 .250
 7 .563  1.0    6 .375   13 .250   14 .375
 8 .563  1.0    7 .250    8 .250   15 .250   16 .250
 9 .563  1.0    8 .250    9 .250   16 .250   17 .250
10 .563  1.0    9 .250   10 .250   17 .250   18 .250
11 .563  1.0   10 .250   11 .250   18 .250   19 .250
12 .563  1.0   11 .250   12 .250   19 .250   20 .250
13 .563  1.0   12 .250   13 .250   20 .250   21 .250
14 .563  1.0   13 .250   14 .250   21 .250   22 .250
15 .563  1.0   15 .250   16 .250   23 .250   24 .250
16 .563  1.0   16 .250   17 .250   24 .250   25 .250
17 .563  1.0   17 .250   18 .250   25 .250   26 .250
18 .563  1.0   18 .250   19 .250   26 .250   27 .250
19 .563  1.0   19 .250   20 .250   27 .250   28 .250
20 .563  1.0   20 .250   21 .250   28 .250   29 .250
21 .563  1.0   21 .250   22 .250   29 .250   30 .250
22 .563  1.0   23 .250   24 .250   31 .250   32 .250
23 .563  1.0   24 .250   25 .250   32 .250   33 .250
24 .563  1.0   25 .250   26 .250   33 .250   34 .250
25 .563  1.0   26 .250   27 .250   34 .250   35 .250
26 .563  1.0   27 .250   28 .250   35 .250   36 .250
27 .563  1.0   28 .250   29 .250   36 .250   37 .250
28 .563  1.0   29 .250   30 .250   37 .250   38 .250
29 .563  1.0   31 .250   32 .250   39 .250   40 .250
30 .563  1.0   32 .250   33 .250   40 .250   41 .250
31 .563  1.0   33 .250   34 .250   41 .250   42 .250
32 .563  1.0   34 .250   35 .250   42 .250   43 .250
33 .563  1.0   35 .250   36 .250   43 .250   44 .250
34 .563  1.0   36 .250   37 .250   44 .250   45 .250
35 .563  1.0   37 .250   38 .250   45 .250   46 .250
36 .563  1.0   39 .250   40 .250   47 .250   48 .250
37 .563  1.0   40 .250   41 .250   48 .250   49 .250
38 .563  1.0   41 .250   42 .250   49 .250   50 .250
39 .563  1.0   42 .250   43 .250   50 .250   51 .250
40 .563  1.0   43 .250   44 .250   51 .250   52 .250
41 .563  1.0   44 .250   45 .250   52 .250   53 .250
42 .563  1.0   45 .250   46 .250   53 .250   54 .250
43 .563  1.0   47 .375   48 .250   55 .375
44 .563  1.0   48 .250   49 .250   55 .250   56 .250
45 .563  1.0   49 .250   50 .250   56 .250   57 .250
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   46 .563  1.0   50 .250   51 .250   57 .250   58 .250
   47 .563  1.0   51 .250   52 .250   58 .250   59 .250
   48 .563  1.0   52 .250   53 .250   59 .250   60 .250
   49 .563  1.0   53 .250   54 .375   60 .375
    3    3   64    0
 2  1 .492  1.0    1 .375    8 .375    9 .250
 2  2 .492  1.0    1 .250    2 .250    9 .250   10 .250
 2  3 .492  1.0    2 .250    3 .250   10 .250   11 .250
 2  4 .492  1.0    3 .250    4 .250   11 .250   12 .250
 2  5 .492  1.0    4 .250    5 .250   12 .250   13 .250
 2  6 .492  1.0    5 .250    6 .250   13 .250   14 .250
 2  7 .492  1.0    6 .250    7 .250   14 .250   15 .250
 2  8 .492  1.0    7 .375   15 .250   16 .375
 2  9 .492  1.0    8 .250    9 .250   17 .250   18 .250
 2 10 .492  1.0    9 .250   10 .250   18 .250   19 .250
 2 11 .492  1.0   10 .250   11 .250   19 .250   20 .250
 2 12 .492  1.0   11 .250   12 .250   20 .250   21 .250
 2 13 .492  1.0   12 .250   13 .250   21 .250   22 .250
 2 14 .492  1.0   13 .250   14 .250   22 .250   23 .250
 2 15 .492  1.0   14 .250   15 .250   23 .250   24 .250
 2 16 .492  1.0   15 .250   16 .250   24 .250   25 .250
 2 17 .492  1.0   17 .250   18 .250   26 .250   27 .250
 2 18 .492  1.0   18 .250   19 .250   27 .250   28 .250
 2 19 .492  1.0   19 .250   20 .250   28 .250   29 .250
 2 20 .492  1.0   20 .250   21 .250   29 .250   30 .250
 2 21 .492  1.0   21 .250   22 .250   30 .250   31 .250
 2 22 .492  1.0   22 .250   23 .250   31 .250   32 .250
 2 23 .492  1.0   23 .250   24 .250   32 .250   33 .250
 2 24 .492  1.0   24 .250   25 .250   33 .250   34 .250
 2 25 .492  1.0   26 .250   27 .250   35 .250   36 .250
 2 26 .492  1.0   27 .250   28 .250   36 .250   37 .250
 2 27 .492  1.0   28 .250   29 .250   37 .250   38 .250
 2 28 .492  1.0   29 .250   30 .250   38 .250   39 .250
 2 29 .492  1.0   30 .250   31 .250   39 .250   40 .250
 2 30 .492  1.0   31 .250   32 .250   40 .250   41 .250
 2 31 .492  1.0   32 .250   33 .250   41 .250   42 .250
 2 32 .492  1.0   33 .250   34 .250   42 .250   43 .250
 2 33 .492  1.0   35 .250   36 .250   44 .250   45 .250
 2 34 .492  1.0   36 .250   37 .250   45 .250   46 .250
 2 35 .492  1.0   37 .250   38 .250   46 .250   47 .250
 2 36 .492  1.0   38 .250   39 .250   47 .250   48 .250
 2 37 .492  1.0   39 .250   40 .250   48 .250   49 .250
 2 38 .492  1.0   40 .250   41 .250   49 .250   50 .250
 2 39 .492  1.0   41 .250   42 .250   50 .250   51 .250
 2 40 .492  1.0   42 .250   43 .250   51 .250   52 .250
 2 41 .492  1.0   44 .250   45 .250   53 .250   54 .250
 2 42 .492  1.0   45 .250   46 .250   54 .250   55 .250
 2 43 .492  1.0   46 .250   47 .250   55 .250   56 .250
 2 44 .492  1.0   47 .250   48 .250   56 .250   57 .250
 2 45 .492  1.0   48 .250   49 .250   57 .250   58 .250
 2 46 .492  1.0   49 .250   50 .250   58 .250   59 .250
 2 47 .492  1.0   50 .250   51 .250   59 .250   60 .250
 2 48 .492  1.0   51 .250   52 .250   60 .250   61 .250
 2 49 .492  1.0   53 .250   54 .250   62 .250   63 .250
 2 50 .492  1.0   54 .250   55 .250   63 .250   64 .250
 2 51 .492  1.0   55 .250   56 .250   64 .250   65 .250
 2 52 .492  1.0   56 .250   57 .250   65 .250   66 .250
 2 53 .492  1.0   57 .250   58 .250   66 .250   67 .250
 2 54 .492  1.0   58 .250   59 .250   67 .250   68 .250
 2 55 .492  1.0   59 .250   60 .250   68 .250   69 .250
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2 56 .492  1.0  60 .250  61 .250  69 .250  70 .250
2 57 .492  1.0  62 .375  63 .250  71 .375
2 58 .492  1.0  63 .250  64 .250  71 .250  72 .250
2 59 .492  1.0  64 .250  65 .250  72 .250  73 .250
2 60 .492  1.0  65 .250  66 .250  73 .250  74 .250
2 61 .492  1.0  66 .250  67 .250  74 .250  75 .250
2 62 .492  1.0  67 .250  68 .250  75 .250  76 .250
2 63 .492  1.0  68 .250  69 .250  76 .250  77 .250
2 64 .492  1.0  69 .250  70 .375  77 .375
   4    4   64   0
2  1 .492  1.0   1 .375   8 .375   9 .250
2  2 .492  1.0   1 .250   2 .250   9 .250  10 .250
2  3 .492  1.0   2 .250   3 .250  10 .250  11 .250
2  4 .492  1.0   3 .250   4 .250  11 .250  12 .250
2  5 .492  1.0   4 .250   5 .250  12 .250  13 .250
2  6 .492  1.0   5 .250   6 .250  13 .250  14 .250
2  7 .492  1.0   6 .250   7 .250  14 .250  15 .250
2  8 .492  1.0   7 .375  15 .250  16 .375
2  9 .492  1.0   8 .250   9 .250  17 .250  18 .250
2 10 .492  1.0   9 .250  10 .250  18 .250  19 .250
2 11 .492  1.0  10 .250  11 .250  19 .250  20 .250
2 12 .492  1.0  11 .250  12 .250  20 .250  21 .250
2 13 .492  1.0  12 .250  13 .250  21 .250  22 .250
2 14 .492  1.0  13 .250  14 .250  22 .250  23 .250
2 15 .492  1.0  14 .250  15 .250  23 .250  24 .250
2 16 .492  1.0  15 .250  16 .250  24 .250  25 .250
2 17 .492  1.0  17 .250  18 .250  26 .250  27 .250
2 18 .492  1.0  18 .250  19 .250  27 .250  28 .250
2 19 .492  1.0  19 .250  20 .250  28 .250  29 .250
2 20 .492  1.0  20 .250  21 .250  29 .250  30 .250
2 21 .492  1.0  21 .250  22 .250  30 .250  31 .250
2 22 .492  1.0  22 .250  23 .250  31 .250  32 .250
2 23 .492  1.0  23 .250  24 .250  32 .250  33 .250
2 24 .492  1.0  24 .250  25 .250  33 .250  34 .250
2 25 .492  1.0  26 .250  27 .250  35 .250  36 .250
2 26 .492  1.0  27 .250  28 .250  36 .250  37 .250
2 27 .492  1.0  28 .250  29 .250  37 .250  38 .250
2 28 .492  1.0  29 .250  30 .250  38 .250  39 .250
2 29 .492  1.0  30 .250  31 .250  39 .250  40 .250
2 30 .492  1.0  31 .250  32 .250  40 .250  41 .250
2 31 .492  1.0  32 .250  33 .250  41 .250  42 .250
2 32 .492  1.0  33 .250  34 .250  42 .250  43 .250
2 33 .492  1.0  35 .250  36 .250  44 .250  45 .250
2 34 .492  1.0  36 .250  37 .250  45 .250  46 .250
2 35 .492  1.0  37 .250  38 .250  46 .250  47 .250
2 36 .492  1.0  38 .250  39 .250  47 .250  48 .250
2 37 .492  1.0  39 .250  40 .250  48 .250  49 .250
2 38 .492  1.0  40 .250  41 .250  49 .250  50 .250
2 39 .492  1.0  41 .250  42 .250  50 .250  51 .250
2 40 .492  1.0  42 .250  43 .250  51 .250  52 .250
2 41 .492  1.0  44 .250  45 .250  53 .250  54 .250
2 42 .492  1.0  45 .250  46 .250  54 .250  55 .250
2 43 .492  1.0  46 .250  47 .250  55 .250  56 .250
2 44 .492  1.0  47 .250  48 .250  56 .250  57 .250
2 45 .492  1.0  48 .250  49 .250  57 .250  58 .250
2 46 .492  1.0  49 .250  50 .250  58 .250  59 .250
2 47 .492  1.0  50 .250  51 .250  59 .250  60 .250
2 48 .492  1.0  51 .250  52 .250  60 .250  61 .250
2 49 .492  1.0  53 .250  54 .250  62 .250  63 .250
2 50 .492  1.0  54 .250  55 .250  63 .250  64 .250
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2 51 .492  1.0   55 .250   56 .250   64 .250   65 .250
2 52 .492  1.0   56 .250   57 .250   65 .250   66 .250
2 53 .492  1.0   57 .250   58 .250   66 .250   67 .250
2 54 .492  1.0   58 .250   59 .250   67 .250   68 .250
2 55 .492  1.0   59 .250   60 .250   68 .250   69 .250
2 56 .492  1.0   60 .250   61 .250   69 .250   70 .250
2 57 .492  1.0   62 .375   63 .250   71 .375
2 58 .492  1.0   63 .250   64 .250   71 .250   72 .250
2 59 .492  1.0   64 .250   65 .250   72 .250   73 .250
2 60 .492  1.0   65 .250   66 .250   73 .250   74 .250
2 61 .492  1.0   66 .250   67 .250   74 .250   75 .250
2 62 .492  1.0   67 .250   68 .250   75 .250   76 .250
2 63 .492  1.0   68 .250   69 .250   76 .250   77 .250
2 64 .492  1.0   69 .250   70 .375   77 .375
   5    5   49    0
   1 .563  1.0    1 .375    2 .375    8 .250
   2 .563  1.0    1 .250    2 .250    8 .250    9 .250
   3 .563  1.0    2 .250    3 .250    9 .250   10 .250
   4 .563  1.0    3 .250    4 .250   10 .250   11 .250
   5 .563  1.0    4 .250    5 .250   11 .250   12 .250
   6 .563  1.0    5 .250    6 .250   12 .250   13 .250
   7 .563  1.0    6 .375   13 .250   14 .375
   8 .563  1.0    7 .250    8 .250   15 .250   16 .250
   9 .563  1.0    8 .250    9 .250   16 .250   17 .250
  10 .563  1.0    9 .250   10 .250   17 .250   18 .250
  11 .563  1.0   10 .250   11 .250   18 .250   19 .250
  12 .563  1.0   11 .250   12 .250   19 .250   20 .250
  13 .563  1.0   12 .250   13 .250   20 .250   21 .250
  14 .563  1.0   13 .250   14 .250   21 .250   22 .250
  15 .563  1.0   15 .250   16 .250   23 .250   24 .250
  16 .563  1.0   16 .250   17 .250   24 .250   25 .250
  17 .563  1.0   17 .250   18 .250   25 .250   26 .250
  18 .563  1.0   18 .250   19 .250   26 .250   27 .250
  19 .563  1.0   19 .250   20 .250   27 .250   28 .250
  20 .563  1.0   20 .250   21 .250   28 .250   29 .250
  21 .563  1.0   21 .250   22 .250   29 .250   30 .250
  22 .563  1.0   23 .250   24 .250   31 .250   32 .250
  23 .563  1.0   24 .250   25 .250   32 .250   33 .250
  24 .563  1.0   25 .250   26 .250   33 .250   34 .250
  25 .563  1.0   26 .250   27 .250   34 .250   35 .250
  26 .563  1.0   27 .250   28 .250   35 .250   36 .250
  27 .563  1.0   28 .250   29 .250   36 .250   37 .250
  28 .563  1.0   29 .250   30 .250   37 .250   38 .250
  29 .563  1.0   31 .250   32 .250   39 .250   40 .250
  30 .563  1.0   32 .250   33 .250   40 .250   41 .250
  31 .563  1.0   33 .250   34 .250   41 .250   42 .250
  32 .563  1.0   34 .250   35 .250   42 .250   43 .250
  33 .563  1.0   35 .250   36 .250   43 .250   44 .250
  34 .563  1.0   36 .250   37 .250   44 .250   45 .250
  35 .563  1.0   37 .250   38 .250   45 .250   46 .250
  36 .563  1.0   39 .250   40 .250   47 .250   48 .250
  37 .563  1.0   40 .250   41 .250   48 .250   49 .250
  38 .563  1.0   41 .250   42 .250   49 .250   50 .250
  39 .563  1.0   42 .250   43 .250   50 .250   51 .250
  40 .563  1.0   43 .250   44 .250   51 .250   52 .250
  41 .563  1.0   44 .250   45 .250   52 .250   53 .250
  42 .563  1.0   45 .250   46 .250   53 .250   54 .250
  43 .563  1.0   47 .375   48 .250   55 .375
  44 .563  1.0   48 .250   49 .250   55 .250   56 .250
  45 .563  1.0   49 .250   50 .250   56 .250   57 .250
```

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   46 .563  1.0   50 .250   51 .250   57 .250   58 .250
   47 .563  1.0   51 .250   52 .250   58 .250   59 .250
   48 .563  1.0   52 .250   53 .250   59 .250   60 .250
   49 .563  1.0   53 .250   54 .375   60 .375
    6    1   49    0
    7    4   64    0
    8    6   64    0
2   1 .492  1.0    1 .375    8 .375    9 .250
2   2 .492  1.0    1 .250    2 .250    9 .250   10 .250
2   3 .492  1.0    2 .250    3 .250   10 .250   11 .250
2   4 .492  1.0    3 .250    4 .250   11 .250   12 .250
2   5 .492  1.0    4 .250    5 .250   12 .250   13 .250
2   6 .492  1.0    5 .250    6 .250   13 .250   14 .250
2   7 .492  1.0    6 .250    7 .250   14 .250   15 .250
2   8 .492  1.0    7 .375   15 .250   16 .375
2   9 .492  1.0    8 .250    9 .250   17 .250   18 .250
2  10 .492  1.0    9 .250   10 .250   18 .250   19 .250
2  11 .492  1.0   10 .250   11 .250   19 .250   20 .250
2  12 .492  1.0   11 .250   12 .250   20 .250   21 .250
2  13 .492  1.0   12 .250   13 .250   21 .250   22 .250
2  14 .492  1.0   13 .250   14 .250   22 .250   23 .250
2  15 .492  1.0   14 .250   15 .250   23 .250   24 .250
2  16 .492  1.0   15 .250   16 .250   24 .250   25 .250
2  17 .492  1.0   17 .250   18 .250   26 .250   27 .250
2  18 .492  1.0   18 .250   19 .250   27 .250   28 .250
2  19 .492  1.0   19 .250   20 .250   28 .250   29 .250
2  20 .492  1.0   20 .250   21 .250   29 .250   30 .250
2  21 .492  1.0   21 .250   22 .250   30 .250   31 .250
2  22 .492  1.0   22 .250   23 .250   31 .250   32 .250
2  23 .492  1.0   23 .250   24 .250   32 .250   33 .250
2  24 .492  1.0   24 .250   25 .250   33 .250   34 .250
2  25 .492  1.0   26 .250   27 .250   35 .250   36 .250
2  26 .492  1.0   27 .250   28 .250   36 .250   37 .250
2  27 .492  1.0   28 .250   29 .250   37 .250   38 .250
2  28 .492  1.0   29 .250   30 .250   38 .250   39 .250
2  29 .492  1.0   30 .250   31 .250   39 .250   40 .250
2  30 .492  1.0   31 .250   32 .250   40 .250   41 .250
2  31 .492  1.0   32 .250   33 .250   41 .250   42 .250
2  32 .492  1.0   33 .250   34 .250   42 .250   43 .250
2  33 .492  1.0   35 .250   36 .250   44 .250   45 .250
2  34 .492  1.0   36 .250   37 .250   45 .250   46 .250
2  35 .492  1.0   37 .250   38 .250   46 .250   47 .250
2  36 .492  1.0   38 .250   39 .250   47 .250   48 .250
2  37 .492  1.0   39 .250   40 .250   48 .250   49 .250
2  38 .492  1.0   40 .250   41 .250   49 .250   50 .250
2  39 .492  1.0   41 .250   42 .250   50 .250   51 .250
2  40 .492  1.0   42 .250   43 .250   51 .250   52 .250
2  41 .492  1.0   44 .250   45 .250   53 .250   54 .250
2  42 .492  1.0   45 .250   46 .250   54 .250   55 .250
2  43 .492  1.0   46 .250   47 .250   55 .250   56 .250
2  44 .492  1.0   47 .250   48 .250   56 .250   57 .250
2  45 .492  1.0   48 .250   49 .250   57 .250   58 .250
2  46 .492  1.0   49 .250   50 .250   58 .250   59 .250
2  47 .492  1.0   50 .250   51 .250   59 .250   60 .250
2  48 .492  1.0   51 .250   52 .250   60 .250   61 .250
2  49 .492  1.0   53 .250   54 .250   62 .250   63 .250
2  50 .492  1.0   54 .250   55 .250   63 .250   64 .250
2  51 .492  1.0   55 .250   56 .250   64 .250   65 .250
2  52 .492  1.0   56 .250   57 .250   65 .250   66 .250
2  53 .492  1.0   57 .250   58 .250   66 .250   67 .250
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 2 54 .492  1.0   58 .250   59 .250   67 .250   68 .250
 2 55 .492  1.0   59 .250   60 .250   68 .250   69 .250
 2 56 .492  1.0   60 .250   61 .250   69 .250   70 .250
 2 57 .492  1.0   62 .375   63 .250   71 .375
 2 58 .492  1.0   63 .250   64 .250   71 .250   72 .250
 2 59 .492  1.0   64 .250   65 .250   72 .250   73 .250
 2 60 .492  1.0   65 .250   66 .250   73 .250   74 .250
 2 61 .492  1.0   66 .250   67 .250   74 .250   75 .250
 2 62 .492  1.0   67 .250   68 .250   75 .250   76 .250
 2 63 .492  1.0   68 .250   69 .250   76 .250   77 .250
 2 64 .492  1.0   69 .250   70 .375   77 .375
  3.0 .059 655. .477  10.  0.1 409. .0321000. .563
  3.0 .059 655. .417  10.  0.1 409. .0321000. .492
slab    34    6  170
    1                       2643.
    2                       1496.
    3                       114.9
    4                       190.4
    5                       95.20
    6                       303.7
    7                       170.7
    8                       307.0
    9                       111.4
   10                       98.77
   11                       114.2
   12                       261.4
   13                       233.1
   14                       122.9
   15                       116.1
   16                       123.5
   17                       172.2
   18                       87.52
   19                       140.1
   20                       220.4
   21                       92.32
   22                       155.8
   23                       216.9
   24                       146.5
   25                       74.60
   26                       208.2
   27                       164.3
   28                       66.69
   29                       199.6
   30                       187.0
   31                       59.05
   32                       5285.
   33                       2993.
   34                      81391.
    1    1 .581            2    2   32   35   34
    2    1 .581            1    3   33
    3    1 .039            2    4   33   12    2
    4    1 .581            1    5   32
    5    1 .581            1    6   33
    6    1 .039            2    7   33   13    2
    7    1 .581            1    8   32
    8    1 .581            1    9   33
    9    1 .039            2   10   33   14    2
   10    1 .581            1   11   32
   11    1 .581            1   74   34
   12    11.162            1   15    1
```

13	11.162	1	16	1				
14	11.162	1	17	1				
15	11.162	1	20	2				
16	11.162	1	23	2				
17	11.162	1	26	2				
18	11.162	3	19	1	36	34	37	34
19	11.162	1	20	2				
20	1 .078	2	21	2	29	2		
21	11.162	1	22	1				
22	11.162	1	23	2				
23	1 .078	2	24	2	30	2		
24	11.162	1	25	1				
25	11.162	1	26	2				
26	1 .078	2	27	2	31	2		
27	11.162	1	28	1				
28	11.162	2	72	34	73	34		
29	11.163	1	32	1				
30	11.163	1	33	1				
31	11.162	1	34	1				
32	11.162	2	60	34	61	34		
33	11.162	2	62	34	63	34		
34	11.162	2	64	34	65	34		
35	2 0.0	1	51	5				
36	2 0.0	1	52	5				
37	2 0.0	1	53	5				
38	2 0.0	3	54	20	55	17	56	14
39	2 0.0	3	57	14	58	17	59	20
40	2 0.0	1	60	5				
41	2 0.0	1	61	5				
42	2 0.0	1	62	5				
43	2 0.0	1	63	5				
44	2 0.0	1	64	5				
45	2 0.0	1	65	5				
46	2 0.0	3	66	20	67	17	68	14
47	2 0.0	3	69	14	70	17	71	20
48	2 0.0	1	72	5				
49	2 0.0	1	73	5				
50	2 0.0	1	74	5				
51	212.77	2	52	3	75	4		
52	212.77	2	53	3	76	4		
53	212.77	2	54	21	77	4		
54	2 6.99	2	55	18	78	22		
55	2 5.46	2	56	15	79	19		
56	2 3.93	2	57	15	80	16		
57	2 3.93	2	58	15	81	16		
58	2 5.46	2	59	18	82	19		
59	2 6.99	2	60	21	83	22		
60	212.77	2	61	3	84	4		
61	212.77	2	62	3	85	4		
62	212.77	2	63	3	86	4		
63	212.77	2	64	3	87	4		
64	212.77	2	65	3	88	4		
65	212.77	2	66	21	89	4		
66	2 6.99	2	67	18	90	22		
67	2 5.46	2	68	15	91	19		
68	2 3.93	2	69	15	92	16		
69	2 3.93	2	70	15	93	16		
70	2 5.46	2	71	18	94	19		
71	2 6.99	2	72	21	95	22		
72	212.77	2	73	3	96	4		

73	212.77	2	74	3	97	4
74	212.77	2	98	4		
75	212.77	2	76	3	99	6
76	212.77	2	77	3	100	6
77	212.77	2	78	11	101	6
78	212.69	2	79	11	102	12
79	212.69	2	80	11	103	12
80	212.69	2	81	11	104	12
81	212.69	2	82	11	105	12
82	212.69	2	83	11	106	12
83	212.69	2	84	11	107	12
84	212.77	2	85	3	108	6
85	212.77	2	86	3	109	6
86	212.77	2	87	3	110	6
87	212.77	2	88	3	111	6
88	212.77	2	89	3	112	6
89	212.77	2	90	11	113	6
90	212.69	2	91	11	114	12
91	212.69	2	92	11	115	12
92	212.69	2	93	11	116	12
93	212.69	2	94	11	117	12
94	212.69	2	95	11	118	12
95	212.69	2	96	11	119	12
96	212.77	2	97	3	120	6
97	212.77	2	98	3	121	6
98	212.77	2	122	6		
99	315.50	2	100	7	123	8
100	315.50	2	101	7	124	8
101	315.50	2	102	13	125	8
102	321.18	2	103	13	126	29
103	321.18	2	104	13	127	26
104	321.18	2	105	13	128	23
105	321.18	2	106	13	129	23
106	321.18	2	107	13	130	26
107	321.18	2	108	13	131	29
108	315.50	2	109	7	132	8
109	315.50	2	110	7	133	8
110	315.50	2	111	7	134	8
111	315.50	2	112	7	135	8
112	315.50	2	113	7	136	8
113	315.50	2	114	13	137	8
114	321.18	2	115	13	138	29
115	321.18	2	116	13	139	26
116	321.18	2	117	13	140	23
117	321.18	2	118	13	141	23
118	321.18	2	119	13	142	26
119	321.18	2	120	13	143	29
120	315.50	2	121	7	144	8
121	315.50	2	122	7	145	8
122	315.50	2	146	8		
123	213.21	2	124	9	147	10
124	213.21	2	125	9	148	10
125	213.21	2	126	30	149	10
126	223.69	2	127	27	150	31
127	226.77	2	128	24	151	28
128	229.83	2	129	24	152	25
129	229.83	2	130	24	153	25
130	226.77	2	131	27	154	28
131	223.69	2	132	30	155	31
132	213.21	2	133	9	156	10

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133    213.21            2  134    9  157   10
134    213.21            2  135    9  158   10
135    213.21            2  136    9  159   10
136    213.21            2  137    9  160   10
137    213.21            2  138   30  161   10
138    223.69            2  139   27  162   31
139    226.77            2  140   24  163   28
140    229.83            2  141   24  164   25
141    229.83            2  142   24  165   25
142    226.77            2  143   27  166   28
143    223.69            2  144   30  167   31
144    213.21            2  145    9  168   10
145    213.21            2  146    9  169   10
146    213.21            1  170   10
147    2  0.0
148    2  0.0
149    2  0.0
150    2  0.0
151    2  0.0
152    2  0.0
153    2  0.0
154    2  0.0
155    2  0.0
156    2  0.0
157    2  0.0
158    2  0.0
159    2  0.0
160    2  0.0
161    2  0.0
162    2  0.0
163    2  0.0
164    2  0.0
165    2  0.0
166    2  0.0
167    2  0.0
168    2  0.0
169    2  0.0
170    2  0.0
  1     .0144      1.4
  2     .0288      0.7
  3     .0157      1.3
  4     .0333      0.6
  5     .0665      0.3
  6     .1660      0.1
  1    4    1    1    1    1    2    2    1    3    2    1    7    6
  2    3    1    4    2    1    5    2    1    6    1
  4    3    2    1    1    2    2    2    2    3    2
  5    3    2    4    2    2    5    2    2    6    1
  7    4    3    1    3    3    2    4    3    3    4    3    4    5
  8    4    3    4    5    3    5    4    3    6    4    3    7    3
 10    4    4    1    3    4    2    4    4    3    4    4    4    5
 11    4    4    4    5    4    5    4    4    6    4    4    7    3
 12    6    1   14    1    1   22    2    1   30    2    2    7    1
            2   15    2    2   23    2
 13    7    2   14    1    2   22    2    2   30    2    3    8    3
            3   17    4    3   28    4    3   35    5
 14    8    3   16    3    3   25    4    3   34    4    3   43    5
            4    8    3    4   17    4    4   26    4    4   35    5
 15    6    1   38    2    1   46    2    1   54    1    2   31    2
            2   39    2    2   47    1
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16    7    2   38    2    2   46    2    2   54    1    3   35    5
           3   44    4    3   53    4    3   62    3
17    8    3   43    5    3   52    4    3   61    4    3   70    3
           4   35    5    4   44    4    4   53    4    4   62    3
18    8    1   55    1    1   56    2    1   57    2    5    1    1
           5    2    2    5    3    2    1   47    6    5    7    6
19    6    1   58    2    1   59    2    1   60    1    5    4    2
           5    5    2    5    6    1
21    6    2   55    1    2   56    2    2   57    2    6   14    1
           6   22    2    6   30    2
22    6    2   58    2    2   59    2    2   60    1    6   38    2
           6   46    2    6   54    1
24    8    3   71    3    3   72    4    3   73    4    3   74    5
           7   62    3    7   53    4    7   44    4    7   35    5
25    8    3   74    5    3   75    4    3   76    4    3   77    3
           7   35    5    7   26    4    7   17    4    7    8    3
27    8    4   71    3    4   72    4    4   73    4    4   74    5
           8    4    5    8    3    4    8    2    4    8    1    3
28   10    4   74    5    4   75    4    4   76    4    4   77    3
           8    4    5    8    5    4    8    6    4    8    7    3
           4   70    6    8   16    6
29    6    5   14    1    5   22    2    5   30    2    6    4    1
           6    5    2    6    6    2
30    7    6   60    1    6   59    2    6   58    2    7   71    3
           7   72    4    7   73    4    7   74    5
31    8    7    1    3    7    2    4    7    3    4    7    4    5
           8    8    3    8   17    4    8   26    4    8   35    5
32    8    5   38    2    5   46    2    5   54    1    6    1    1
           6    2    2    6    3    2    5   60    6    6    7    6
33    9    6   57    2    6   56    2    6   55    1    7   74    5
           7   75    4    7   76    4    7   77    3    6   47    6
           7   70    6
34   10    7    4    5    7    5    4    7    6    4    7    7    3
           8   35    5    8   44    4    8   53    4    8   62    3
           7   16    6    8   71    6
35    3    1    7    1    1   15    2    1   23    2
36    3    1   31    2    1   39    2    1   47    1
37    3    5    7    1    5   15    2    5   23    1
38    3    5   31    2    5   39    2    5   47    1
39    3    5   55    1    5   56    2    5   57    2
40    3    5   58    2    5   59    2    5   60    1
41    3    6    7    1    6   15    2    6   23    2
42    3    6   31    2    6   39    2    6   47    1
43    4    7   70    3    7   61    4    7   52    4    7   43    5
44    4    7   43    5    7   34    4    7   25    4    7   16    3
45    4    8   71    3    8   72    4    8   73    4    8   74    5
46    4    8   74    5    8   75    4    8   76    4    8   77    3
47    4    8   43    5    8   52    4    8   61    4    8   70    3
48    4    8   16    3    8   25    4    8   34    4    8   43    5
49    4    4   43    5    4   52    4    4   61    4    4   70    3
50    4    4   16    3    4   25    4    4   34    4    4   43    5

radg    8    6    0
   1    1    8    1    2   12   15   19   18   36   35
   2    2    8    4    5   13   16   22   21   15   12
   3    4    8    7    8   14   17   25   24   16   13
   4    5    8   10   11   50   49   28   27   17   14
   5    3    8   18   19   29   32   40   39   38   37
   6    1    8   32   29   21   22   30   33   42   41
   7    5    8   31   34   44   43   33   30   24   25
```

```
    8    6    8   27   28   48   47   46   45   34   31
heat      1    0    1
               3.66                3.66
   1.   1.   1.   1.   1.   1.   1.   1.
drag      2    0
 100. -1.0                100. -1.0
  64. -1.0                 64. -1.0
bdry      9    1   24    2
     1 4.500e-06                    .93
     2 8.070e-05
     3 3.287e-06                  0.25 0.25
     4 7.664e-05
     5 3.816e-07             0.33 0.25
     6 1.385e-04
     7 1.143e-04
     8 1.342e-04
     9 3.442e-07             0.33 0.25
     1    2    0. 78.8    1. 78.8
   147      1 3.52    1
     1   1.     1   1.    1
   148      1 3.52    1
     1   1.     1   1.    1
   149      1 3.52    1
     1   1.     1   1.    1
   150      1 4.95    1
     1   1.     1   1.    1
   151      1 4.95    1
     1   1.     1   1.    1
   152      1 4.95    1
     1   1.     1   1.    1
   153      1 4.95    1
     1   1.     1   1.    1
   154      1 4.95    1
     1   1.     1   1.    1
   155      1 4.95    1
     1   1.     1   1.    1
   156      1 3.52    1
     1   1.     1   1.    1
   157      1 3.52    1
     1   1.     1   1.    1
   158      1 3.52    1
     1   1.     1   1.    1
   159      1 3.52    1
     1   1.     1   1.    1
   160      1 3.52    1
     1   1.     1   1.    1
   161      1 3.52    1
     1   1.     1   1.    1
   162      1 4.95    1
     1   1.     1   1.    1
   163      1 4.95    1
     1   1.     1   1.    1
   164      1 4.95    1
     1   1.     1   1.    1
   165      1 4.95    1
     1   1.     1   1.    1
   166      1 4.95    1
     1   1.     1   1.    1
   167      1 4.95    1
     1   1.     1   1.    1
```

```
168     1 3.52    1
  1   1.    1   1.    1
169     1 3.52    1
  1   1.    1   1.    1
170     1 3.52    1
  1   1.    1   1.    1
  1343.8   0.    6    0 78.8   0.
  1  1.0    6   14    1    210.00  9.0    2    210.00  9.0   10    210.00  9.0
                     11    210.00  9.0   18    210.00  9.0   19    210.00  9.0
                     27    210.00  9.0   28    210.00  9.0   29    210.00  9.0
                     30    210.00  9.0   31    210.00  9.0   32    210.00  9.0
                     33    210.00  9.0   34    210.00  9.0
  2 3.19    6   24   51    212.77  9.0   52    212.77  9.0   53    212.77  9.0
                     54    2 6.99  9.0   55    2 5.46  9.0   56    2 3.93  9.0
                     57    2 3.93  9.0   58    2 5.46  9.0   59    2 6.99  9.0
                     60    212.77  9.0   61    212.77  9.0   62    212.77  9.0
                     63    212.77  9.0   64    212.77  9.0   65    212.77  9.0
                     66    2 6.99  9.0   67    2 5.46  9.0   68    2 3.93  9.0
                     69    2 3.93  9.0   70    2 5.46  9.0   71    2 6.99  9.0
                     72    212.77  9.0   73    212.77  9.0   74    212.77  9.0
  3 3.95    6   24   75    212.77  9.0   76    212.77  9.0   77    212.77  9.0
                     78    212.69  9.0   79    212.69  9.0   80    212.69  9.0
                     81    212.69  9.0   82    212.69  9.0   83    212.69  9.0
                     84    212.77  9.0   85    212.77  9.0   86    212.77  9.0
                     87    212.77  9.0   88    212.77  9.0   89    212.77  9.0
                     90    212.69  9.0   91    212.69  9.0   92    212.69  9.0
                     93    212.69  9.0   94    212.69  9.0   95    212.69  9.0
                     96    212.77  9.0   97    212.77  9.0   98    212.77  9.0
  4 4.60    7   24   99    215.50  9.0  100    215.50  9.0  101    215.50  9.0
                    102    221.18  9.0  103    221.18  9.0  104    221.18  9.0
                    105    221.18  9.0  106    221.18  9.0  107    221.18  9.0
                    108    215.50  9.0  109    215.50  9.0  110    215.50  9.0
                    111    215.50  9.0  112    215.50  9.0  113    215.50  9.0
                    114    221.18  9.0  115    221.18  9.0  116    221.18  9.0
                    117    221.18  9.0  118    221.18  9.0  119    221.18  9.0
                    120    215.50  9.0  121    215.50  9.0  122    215.50  9.0
  5 5.09    8   24  123    213.21  9.0  124    213.21  9.0  125    213.21  9.0
                    126    223.69  9.0  127    226.77  9.0  128    229.83  9.0
                    129    229.83  9.0  130    226.77  9.0  131    223.69  9.0
                    132    213.21  9.0  133    213.21  9.0  134    213.21  9.0
                    135    213.21  9.0  136    213.21  9.0  137    213.21  9.0
                    138    223.69  9.0  139    226.77  9.0  140    229.83  9.0
                    141    229.83  9.0  142    226.77  9.0  143    223.69  9.0
                    144    213.21  9.0  145    213.21  9.0  146    213.21  9.0
  6 5.77    9    0
  2   0. 549.    0    4   0. 78.8
  1   1.    2
  21.595    3
  32.218    4
  42.493    5
calc     1

       20
oper     1        3    1                                              1
     20.0       250.     .00003   .004000      500.     .00000        0.0
.0483.0523.0375.0771.0436.0483.0771.7147
   17
   0.   0..0460   0..0469 0.01.0760 0.01.1345 0.01.1929 0.93
.3098 1.15.3682 1.18.4267 1.27.5436 1.22.6020 1.16.6604 1.14
.7773 0.01.0358 0.45.0652 0.45.0653   0.  1.0   0.
```

```
outp 1101
endd




data from iterative solution using the recirculation module
time =    0.0000    dt = ******    implicit dt = 0.0000    explicit dt = 0.6230    mode =  0

iteration  sweep          peak clad            total flow    pressure                  error
   no.      no.   --------------------------    (lbm/s)     drop(psi)     -----------------------------------
                  temp(f)  fluid  rod  ass.                                total     flow    fluid     rod
                                                                           energy            energy    energy

    1        1     530.0    10    19    2     0.770e-11    0.0007559     0.0337   4.9984   0.0783   0.0023
             2     539.9    15    19    2                                0.1763   4.9984   0.2045   0.0023

    2        1     557.9    14    19    2     0.319e-11    0.0007792     0.1384   4.4702   0.0437   0.0110
             2     591.9    13    19    2                                0.1308   4.4702   0.1276   0.0043

    3        1     607.2    13    19    2     0.151e-11    0.0007769     0.1361   3.4860   0.0139   0.0023
             2     630.5    12    19    2                                0.1365   3.4860   0.0454   0.0020

    4        1     642.5    12    19    2     0.431e-12    0.0007684     0.0089   3.3572   0.0124   0.0010
             2     666.6    11    19    2                                0.0093   3.3572   0.0237   0.0020

    5        1     674.6    11    19    2    -0.155e-11    0.0007665     0.0147   1.3074   0.0104   0.0005
             2     683.1    11    19    2                                0.0151   1.3074   0.0441   0.0006

    6        1     687.4    11    19    2     0.957e-12    0.0007662     0.0169   4.9814   0.0105   0.0006
             2     692.2    11    13    2                                0.0166   4.9814   0.0126   0.0004

    7        1     694.6    11    13    2     0.667e-12    0.0007650     0.0042   1.0386   0.0102   0.0003
             2     697.4    11    13    2                                0.0055   1.0386   0.0111   0.0004

    8        1     698.5    11    13    2     0.244e-12    0.0007646     0.0059   0.9529   0.0105   0.0002
             2     699.8    11    13    2                                0.0060   0.9529   0.0107   0.0003

    9        1     700.4    11    13    2    -0.132e-11    0.0007643     0.0060   0.9960   0.0105   0.0002
             2     701.1    11    13    2                                0.0059   0.9960   0.0128   0.0003

   10        1     701.4    11    13    2     0.121e-11    0.0007640     0.0009   0.4374   0.0101   0.0002
             2     701.9    11    13    2                                0.0013   0.4374   0.0099   0.0003

   11        1     702.0    11    13    2     0.788e-12    0.0007639     0.0014   0.1101   0.0103   0.0002
             2     702.2    11    13    2                                0.0014   0.1101   0.0098   0.0002

   12        1     702.3    11    13    2     0.386e-12    0.0007639     0.0014   0.0631   0.0103   0.0002
             2     702.4    11    13    2                                0.0014   0.0631   0.0099   0.0002

   13        1     702.4    11    13    2     0.119e-12    0.0007638     0.0005   0.0393   0.0103   0.0002
             2     702.5    11    13    2                                0.0005   0.0393   0.0100   0.0002

   14        1     702.5    11    13    2    -0.230e-13    0.0007638     0.0005   0.0205   0.0103   0.0002
             2     702.6    11    13    2                                0.0005   0.0205   0.0101   0.0002

   15        1     702.6    11    13    2    -0.668e-13    0.0007637     0.0005   0.0129   0.0103   0.0002
             2     702.6    11    13    2                                0.0005   0.0129   0.0101   0.0002
```

```
  16        1      702.6      11     13     2       -0.609e-13    0.0007637       0.0003   0.0142   0.0103   0.0002
            2      702.6      11     13     2                                     0.0003   0.0142   0.0101   0.0002

  17        1      702.6      11     13     2       -0.389e-13    0.0007637       0.0003   0.0038   0.0103   0.0002
            2      702.6      11     13     2                                     0.0003   0.0038   0.0101   0.0002

  side boundary temperature summary     time =    0.0000 seconds
  boundary slab node no.   147


 axial zone     ( 1)      ( 2)      (
  (inches)

  0.0 -  9.8    114.36     70.00
  9.8 - 19.6    116.74     70.00
 19.6 - 29.3    120.48     70.00
 29.3 - 39.1    124.81     70.00
 39.1 - 48.9    129.22     70.00
 48.9 - 58.7    133.30     70.00
 58.7 - 68.4    136.73     70.00
 68.4 - 78.2    139.31     70.00
 78.2 - 88.0    140.87     70.00
 88.0 - 97.8    141.33     70.00
 97.8 -107.6    140.71     70.00
107.6 -117.3    139.06     70.00
117.3 -127.1    136.46     70.00
127.1 -136.9    133.12     70.00
136.9 -146.7    129.38     70.00
146.7 -156.4    125.75     70.00
156.4 -166.2    122.81     70.00
166.2 -176.0    121.20     70.00

  slab temperature summary          time =    0.0000 seconds
  (assembly no. - channel no.)

 axial zone     ( 61)      ( 62)      ( 63)      ( 64)      ( 65)      ( 66)      ( 67)      ( 68)      ( 69)      ( 70)
  (inches)

  0.0 -  9.8    120.36     120.34     120.31     120.25     120.16     119.77     119.61     119.54     119.54     119.60
  9.8 - 19.6    125.25     125.42     125.40     125.16     124.60     123.67     123.28     123.14     123.13     123.26
 19.6 - 29.3    131.43     131.85     131.82     131.34     130.28     128.82     128.20     127.96     127.95     128.17
 29.3 - 39.1    138.10     138.74     138.71     137.99     136.46     134.51     133.68     133.35     133.33     133.64
 39.1 - 48.9    144.66     145.53     145.49     144.54     142.58     140.18     139.16     138.75     138.72     139.10
 48.9 - 58.7    150.66     151.72     151.68     150.52     148.17     145.37     144.18     143.70     143.66     144.11
 58.7 - 68.4    155.62     156.85     156.79     155.47     152.80     149.70     148.37     147.82     147.78     148.20
 68.4 - 78.2    159.41     160.77     160.71     159.25     156.31     152.95     151.61     150.91     150.87     151.42
 78.2 - 88.0    161.66     163.11     163.05     161.49     158.38     154.87     153.36     152.73     152.68     153.26
 88.0 - 97.8    162.33     163.85     163.79     162.18     158.98     155.41     153.87     153.22     153.17     153.76
 97.8 -107.6    161.49     163.02     162.97     161.35     158.14     154.59     153.05     152.40     152.35     152.95
107.6 -117.3    159.23     160.76     160.71     159.11     155.94     152.48     150.98     150.34     150.29     150.87
117.3 -127.1    155.56     156.98     156.94     155.41     152.38     149.12     147.70     147.09     147.04     147.60
127.1 -136.9    150.47     151.85     151.82     150.42     147.66     144.72     143.44     142.88     142.84     143.35
136.9 -146.7    144.60     145.80     145.78     144.57     142.21     139.73     138.63     138.16     138.12     138.56
146.7 -156.4    138.70     139.68     139.67     138.69     136.79     134.82     133.95     133.56     133.53     133.88
156.4 -166.2    133.49     134.17     134.14     133.44     132.14     130.74     130.10     129.82     129.79     130.04
166.2 -176.0    130.77     131.24     131.21     130.69     129.75     128.63     128.13     127.90     127.88     128.07
```

```
 calculated rod temperatures at time =    0.0000 seconds
 rod no.   10
 assembly   3                    (fuel type  2 - cylinder)
0rod o.d. - 0.492 (in.)     zone-(fuel dia.(in.)) -  1-(0.417)

                                                *   fuel temperatures(f.)
                                                *
   axial zone  heat flux   type           hsurf *   fluid     clad
      (in.)   (mbtu/hr-ft2)           (b/h-f-ft2) *
    0.0 -   9.8    0.0000    2                7.1     149.7    149.8
    9.8 -  19.6    0.0000    2                7.9     259.2    261.1
   19.6 -  29.3    0.0000    2                8.6     361.8    363.7
   29.3 -  39.1    0.0000    2                9.1     450.3    452.1
   39.1 -  48.9    0.0000    2                9.5     524.8    526.6
   48.9 -  58.7    0.0000    2                9.9     586.7    588.4
   58.7 -  68.4    0.0000    2               10.1     631.7    633.3
   68.4 -  78.2    0.0000    2               10.2     668.5    670.0
   78.2 -  88.0    0.0000    2               10.3     690.2    691.7
   88.0 -  97.8    0.0000    2               10.3     699.9    701.3
   97.8 - 107.6    0.0000    2               10.3     699.4    700.7
  107.6 - 117.3    0.0000    2               10.3     692.6    693.8
  117.3 - 127.1    0.0000    2               10.2     672.4    673.5
  127.1 - 136.9    0.0000    2               10.1     636.1    637.1
  136.9 - 146.7    0.0000    2                9.8     578.5    579.2
  146.7 - 156.4    0.0000    2                9.5     509.6    510.1
  156.4 - 166.2    0.0000    2                8.9     408.9    408.7
  166.2 - 176.0    0.0000    2                8.5     346.3    346.1


 calculated rod temperatures at time =    0.0000 seconds
 rod no.   20
 assembly   3                    (fuel type  2 - cylinder)
0rod o.d. - 0.492 (in.)     zone-(fuel dia.(in.)) -  1-(0.417)

                                                *   fuel temperatures(f.)
                                                *
   axial zone  heat flux   type           hsurf *   fluid     clad
      (in.)   (mbtu/hr-ft2)           (b/h-f-ft2) *
    0.0 -   9.8    0.0000    2                7.1     148.1    148.2
    9.8 -  19.6    0.0000    2                7.9     269.3    271.0
   19.6 -  29.3    0.0000    2                8.6     371.7    373.5
   29.3 -  39.1    0.0000    2                9.2     457.5    459.3
   39.1 -  48.9    0.0000    2                9.6     529.5    531.2
   48.9 -  58.7    0.0000    2                9.9     589.4    591.1
   58.7 -  68.4    0.0000    2               10.1     632.3    633.9
   68.4 -  78.2    0.0000    2               10.2     668.0    669.6
   78.2 -  88.0    0.0000    2               10.3     688.6    690.1
   88.0 -  97.8    0.0000    2               10.3     697.4    698.8
   97.8 - 107.6    0.0000    2               10.3     696.2    697.6
  107.6 - 117.3    0.0000    2               10.3     689.1    690.4
  117.3 - 127.1    0.0000    2               10.2     668.7    669.9
  127.1 - 136.9    0.0000    2               10.1     631.9    633.0
  136.9 - 146.7    0.0000    2                9.8     573.3    574.1
  146.7 - 156.4    0.0000    2                9.4     504.4    505.0
  156.4 - 166.2    0.0000    2                8.8     399.6    399.5
  166.2 - 176.0    0.0000    2                8.4     338.0    337.9
```

```
 calculated rod temperatures at time =    0.0000 seconds
 rod no.   38
 assembly  3                    (fuel type  2 - cylinder)
0rod o.d. - 0.492 (in.)     zone-(fuel dia.(in.)) -  1-(0.417)

                                                 *   fuel temperatures(f.)
                                                 *
   axial zone  heat flux   type            hsurf *   fluid     clad
      (in.)   (mbtu/hr-ft2)            (b/h-f-ft2) *
    0.0 -   9.8    0.0000    2                7.1      148.3     148.4
    9.8 -  19.6    0.0000    2                7.9      266.6     268.3
   19.6 -  29.3    0.0000    2                8.6      366.5     368.3
   29.3 -  39.1    0.0000    2                9.1      450.0     451.7
   39.1 -  48.9    0.0000    2                9.5      519.8     521.5
   48.9 -  58.7    0.0000    2                9.8      577.9     579.6
   58.7 -  68.4    0.0000    2               10.0      619.5     621.1
   68.4 -  78.2    0.0000    2               10.2      654.2     655.8
   78.2 -  88.0    0.0000    2               10.2      674.0     675.5
   88.0 -  97.8    0.0000    2               10.3      682.4     683.9
   97.8 - 107.6    0.0000    2               10.2      681.0     682.4
  107.6 - 117.3    0.0000    2               10.2      673.9     675.3
  117.3 - 127.1    0.0000    2               10.2      653.6     654.8
  127.1 - 136.9    0.0000    2               10.0      617.4     618.5
  136.9 - 146.7    0.0000    2                9.7      559.7     560.5
  146.7 - 156.4    0.0000    2                9.4      492.0     492.7
  156.4 - 166.2    0.0000    2                8.8      389.5     389.4
  166.2 - 176.0    0.0000    2                8.4      329.6     329.6


 calculated rod temperatures at time =    0.0000 seconds
 rod no.   55
 assembly  3                    (fuel type  2 - cylinder)
0rod o.d. - 0.492 (in.)     zone-(fuel dia.(in.)) -  1-(0.417)

                                                 *   fuel temperatures(f.)
                                                 *
   axial zone  heat flux   type            hsurf *   fluid     clad
      (in.)   (mbtu/hr-ft2)            (b/h-f-ft2) *
    0.0 -   9.8    0.0000    2                7.1      149.5     149.6
    9.8 -  19.6    0.0000    2                7.8      256.4     258.2
   19.6 -  29.3    0.0000    2                8.5      352.3     354.2
   29.3 -  39.1    0.0000    2                9.0      433.0     434.9
   39.1 -  48.9    0.0000    2                9.4      500.6     502.4
   48.9 -  58.7    0.0000    2                9.7      556.8     558.6
   58.7 -  68.4    0.0000    2                9.9      597.4     599.1
   68.4 -  78.2    0.0000    2               10.1      630.9     632.7
   78.2 -  88.0    0.0000    2               10.1      650.3     651.9
   88.0 -  97.8    0.0000    2               10.2      658.5     660.0
   97.8 - 107.6    0.0000    2               10.2      657.2     658.6
  107.6 - 117.3    0.0000    2               10.1      650.1     651.5
  117.3 - 127.1    0.0000    2               10.1      630.4     631.7
  127.1 - 136.9    0.0000    2                9.9      595.3     596.5
  136.9 - 146.7    0.0000    2                9.6      539.7     540.6
  146.7 - 156.4    0.0000    2                9.3      474.3     475.0
  156.4 - 166.2    0.0000    2                8.7      377.8     377.8
  166.2 - 176.0    0.0000    2                8.3      320.5     320.4
```

```
 calculated rod temperatures at time =    0.0000 seconds
 rod no.   20
 assembly   0                  (fuel type  2 - cylinder)
0rod o.d. - 0.492 (in.)     zone-(fuel dia.(in.)) -  1-(0.417)

                                                 *  fuel temperatures(f.)
                                                 *
   axial zone  heat flux   type            hsurf *  fluid    clad
      (in.)    (mbtu/hr-ft2)            (b/h-f-ft2) *
    0.0 -   9.8    0.0000    2                7.1     153.2    153.2
    9.8 -  19.6    0.0000    2                7.7     242.5    243.9
   19.6 -  29.3    0.0000    2                8.2     302.3    303.9
   29.3 -  39.1    0.0000    2                8.5     349.4    351.1
   39.1 -  48.9    0.0000    2                8.8     389.0    390.8
   48.9 -  58.7    0.0000    2                9.0     422.5    424.4
   58.7 -  68.4    0.0000    2                9.1     445.2    447.1
   68.4 -  78.2    0.0000    2                9.2     465.2    467.2
   78.2 -  88.0    0.0000    2                9.3     474.5    476.5
   88.0 -  97.8    0.0000    2                9.3     476.6    478.6
   97.8 - 107.6    0.0000    2                9.3     472.3    474.3
  107.6 - 117.3    0.0000    2                9.2     464.7    466.6
  117.3 - 127.1    0.0000    2                9.1     446.8    448.7
  127.1 - 136.9    0.0000    2                9.0     417.9    419.6
  136.9 - 146.7    0.0000    2                8.7     374.4    375.7
  146.7 - 156.4    0.0000    2                8.3     327.8    328.7
  156.4 - 166.2    0.0000    2                7.8     257.3    257.3
  166.2 - 176.0    0.0000    2                7.7     230.9    230.9
```

APPENDIX E

REA 2023 BWR CASK PERFORMANCE TEST SIMULATIONS INPUT, OUTPUT, AND CONVERGENCE LISTS

APPENDIX E

REA 2023 BWR CASK PERFORMANCE TEST SIMULATIONS INPUT, OUTPUT, AND CONVERGENCE LISTS

Test Case	Page Number Input	Convergence List	Output
Vertical, helium	E.2	E.13	E.15
Vertical, nitrogen	E.22	E.33	E.35
Vertical, vacuum	E.41	E.52	E.53

```
+8000
   1       reaload4n  full load, helium, vertical validation runs.
prop     7    6
        1.        0.     100.0     .0780      1.24     58.30     .0410
        2.      200.     348.0     .0970      1.24     80.90     .0533
        3.      400.     596.0     .1150      1.24    105.60     .0641
        5.      600.     844.0     .1290      1.24    129.90     .0727
       10.      800.    1092.0     .1380      1.24    155.00     .0823
       15.     1000.    1340.0     .1380      1.24    179.20     .0907
       20.     1500.    1588.0     .1380      1.24    241.30     .1138
   1  can                           14.8
   2   cu                           215.
   3   ss                            9.8
   4   pb                           22.7
   5 lpr1                           0.60
   6 lpr2                           16.4
chan    11    24    0
     177.8
   1    1   25    0    0
   1    1    0    0    1
    11.7365.8942.874    2 .175 .772    3 .175 .772    4 .175 .772    8.5245 2.62
    2.1478.8843.8843    3 .175 .738
    3.29571.7691.769    4 .175 .738    9 .175 .738
    4.29571.7691.769    5 .175 .738   10 .175 .738
    5.29571.7691.769    6 .175 .738    8 .175 .772   11 .175 .738
    6.29571.7691.769    7 .175 .738    8 .175 .772   12 .175 .738
    7.29571.7691.769   14 .175 .772    8 .175 .772   13 .175 .738
    81.7365.8942.874   14.8584 2.62
    9.1478.8843.8843   10 .175 .738
   10.29571.7691.769   11 .175 .738   15 .175 .738
   11.29571.7691.769   12 .175 .738   16 .175 .738
   12.29571.7691.769   13 .175 .738   17 .175 .738
   13.29571.7691.769   14 .175 .772   18 .175 .738
   141.7365.8942.874   15 .175 .772   19.5245 2.62
   15.1478.8843.8843   16 .175 .738
   16.29571.7691.769   17 .175 .738   20 .175 .738
   17.29571.7691.769   18 .175 .738   21 .175 .738
   18.29571.7691.769   22 .175 .738
   191.7365.8942.874   22 .175 .772   24 .175 .772   25 .175 .772
   20.1478.8843.8843   21 .175 .738
   21.29571.7691.769   22 .175 .738   23 .175 .738
   22.29571.7691.769   24 .175 .738
   23.1478.8843.8843   24 .175 .738
   24.29571.7691.769   25 .175 .738
   25.1478.8843.8843
   2    2   44    0    0
   1    1    0    0    1
    11.7365.8942.874    2 .175 .772    3 .175 .772    4 .175 .772    8.5245 2.62
    2.29571.7691.769    3 .175 .738    9 .175 .738   15 .175 .772
    3.29571.7691.769    4 .175 .738   10 .175 .738
    4.29571.7691.769    5 .175 .738   11 .175 .738
    5.29571.7691.769    6 .175 .738    8 .175 .772   12 .175 .738
    6.29571.7691.769    7 .175 .738    8 .175 .772   13 .175 .738
    7.29571.7691.769   22 .175 .772    8 .175 .772   14 .175 .738
    81.7365.8942.874   22.8584 2.62
    9.29571.7691.769   10 .175 .738   15 .175 .772   16 .175 .738
   10.29571.7691.769   11 .175 .738   17 .175 .738
   11.29571.7691.769   12 .175 .738   18 .175 .738
   12.29571.7691.769   13 .175 .738   19 .175 .738
   13.29571.7691.769   14 .175 .738   20 .175 .738
```

```
14.29571.7691.769   22 .175 .772   21 .175 .738
151.7365.8942.874    1.6584 2.62   16 .175 .772   23.5245 2.62
16.29571.7691.769   17 .175 .738   24 .175 .738
17.29571.7691.769   18 .175 .738   25 .175 .738
18.29571.7691.769   19 .175 .738   26 .175 .738
19.29571.7691.769   20 .175 .738   27 .175 .738
20.29571.7691.769   21 .175 .738   28 .175 .738
21.29571.7691.769   22 .175 .772   29 .175 .738
221.7365.8942.874   30.5245 2.62
231.7365.8942.874   24 .175 .772   31 .175 .772   37.8584 2.62   38 .175 .772
24.29571.7691.769   25 .175 .738   31 .175 .738
25.29571.7691.769   26 .175 .738   32 .175 .738
26.29571.7691.769   27 .175 .738   33 .175 .738
27.29571.7691.769   28 .175 .738   34 .175 .738
28.29571.7691.769   29 .175 .738   35 .175 .738
29.29571.7691.769   30 .175 .772   36 .175 .738
301.7365.8942.874   36 .175 .772   43 .175 .772   44.8584 2.62
31.29571.7691.769   32 .175 .738   38 .175 .738
32.29571.7691.769   33 .175 .738   39 .175 .738
33.29571.7691.769   34 .175 .738   40 .175 .738
34.29571.7691.769   35 .175 .738   41 .175 .738
35.29571.7691.769   36 .175 .738   42 .175 .738
36.29571.7691.769   43 .175 .738
371.7365.8942.874   38 .175 .772   39 .175 .772   40 .175 .772   44.5245 2.62
38.29571.7691.769   39 .175 .738
39.29571.7691.769   40 .175 .738
40.29571.7691.769   41 .175 .738
41.29571.7691.769   42 .175 .738   44 .175 .772
42.29571.7691.769   43 .175 .738   44 .175 .772
43.29571.7691.769   44 .175 .772
441.7365.8942.874
  3    1   25    0    0
  1    1    0    0    1
  4    2   44    0    0
  1    1    0    0    1
  5    2   44    0    0
  1    1    0    0    1
  6    1   25    0    0
  1    1    0    0    1
  7    2   44    0    0
  1    1    0    0    1
  8    2   44    0    0
  1    1    0    0    1
  9    3    1    0    0
  0    1    0    0    2
  116.0718.11
 10    4    1    0    0
  0    1    0    0    2
  1 5.2413.78
 11    5    1    0
  0    1    0    0    2
  122.1820.18

rods    11    1    1    0    0    1
   1    1   28
   1 .563  1.0    1 .375    2 .125
   2 .563  1.0    1 .500    2 .250    3 .250
   3 .563  1.0    1 .500    3 .250    4 .250
   4 .563  1.0    1 .250    4 .250    5 .250    8 .250
   5 .563  1.0    5 .250    6 .250    8 .500
```

```
 6 .563  1.0   6 .250   7 .250   8 .500
 7 .563  1.0   7 .250   8 .375  14 .375
 8 .563  1.0   2 .125   3 .250   9 .125
 9 .563  1.0   3 .250   4 .250   9 .250  10 .250
10 .563  1.0   4 .250   5 .250  10 .250  11 .250
11 .563  1.0   5 .250   6 .250  11 .250  12 .250
12 .563  1.0   6 .250   7 .250  12 .250  13 .250
13 .563  1.0   7 .250  13 .250  14 .500
14 .563  1.0   9 .125  10 .250  15 .125
15 .563  1.0  10 .250  11 .250  15 .250  16 .250
16 .563  1.0  11 .250  12 .250  16 .250  17 .250
17 .563  1.0  12 .250  13 .250  17 .250  18 .250
18 .563  1.0  13 .250  14 .500  18 .250
19 .563  1.0  15 .125  16 .250  20 .125
20 .563  1.0  16 .250  17 .250  20 .250  21 .250
21 .563  1.0  17 .250  18 .250  21 .250  22 .250
22 .563  1.0  14 .250  18 .250  19 .250  22 .250
23 .563  1.0  20 .125  21 .250  23 .125
24 .563  1.0  21 .250  22 .250  23 .250  24 .250
25 .563  1.0  19 .500  22 .250  24 .250
26 .563  1.0  23 .125  24 .250  25 .125
27 .563  1.0  19 .500  24 .250  25 .250
28 .563  1.0  19 .375  26 .125
 2    2   49
 1 .563  1.0   1 .375   2 .250  15 .375
 2 .563  1.0   1 .500   2 .250   3 .250
 3 .563  1.0   1 .500   3 .250   4 .250
 4 .563  1.0   1 .250   4 .250   5 .250   8 .250
 5 .563  1.0   5 .250   6 .250   8 .500
 6 .563  1.0   6 .250   7 .250   8 .500
 7 .563  1.0   7 .250   8 .375  22 .375
 8 .563  1.0   2 .250   9 .250  15 .500
 9 .563  1.0   2 .250   3 .250   9 .250  10 .250
10 .563  1.0   3 .250   4 .250  10 .250  11 .250
11 .563  1.0   4 .250   5 .250  11 .250  12 .250
12 .563  1.0   5 .250   6 .250  12 .250  13 .250
13 .563  1.0   6 .250   7 .250  13 .250  14 .250
14 .563  1.0   7 .250  14 .250  22 .500
15 .563  1.0   9 .250  15 .500  16 .250
16 .563  1.0   9 .250  10 .250  16 .250  17 .250
17 .563  1.0  10 .250  11 .250  17 .250  18 .250
18 .563  1.0  11 .250  12 .250  18 .250  19 .250
19 .563  1.0  12 .250  13 .250  19 .250  20 .250
20 .563  1.0  13 .250  14 .250  20 .250  21 .250
21 .563  1.0  14 .250  21 .250  22 .500
22 .563  1.0  15 .250  16 .250  23 .250  24 .250
23 .563  1.0  16 .250  17 .250  24 .250  25 .250
24 .563  1.0  17 .250  18 .250  25 .250  26 .250
25 .563  1.0  18 .250  19 .250  26 .250  27 .250
26 .563  1.0  19 .250  20 .250  27 .250  28 .250
27 .563  1.0  20 .250  21 .250  28 .250  29 .250
28 .563  1.0  21 .250  22 .250  29 .250  30 .250
29 .563  1.0  23 .500  24 .250  31 .250
30 .563  1.0  24 .250  25 .250  31 .250  32 .250
31 .563  1.0  25 .250  26 .250  32 .250  33 .250
32 .563  1.0  26 .250  27 .250  33 .250  34 .250
33 .563  1.0  27 .250  28 .250  34 .250  35 .250
34 .563  1.0  28 .250  29 .250  35 .250  36 .250
35 .563  1.0  29 .250  30 .500  36 .250
36 .563  1.0  23 .500  31 .250  36 .250
```

```
  37 .563  1.0   31 .250   32 .250   38 .250   39 .250
  38 .563  1.0   32 .250   33 .250   39 .250   40 .250
  39 .563  1.0   33 .250   34 .250   40 .250   41 .250
  40 .563  1.0   34 .250   35 .250   41 .250   42 .250
  41 .563  1.0   35 .250   36 .250   42 .250   43 .250
  42 .563  1.0   30 .500   36 .250   43 .250
  43 .563  1.0   23 .375   37 .375   38 .250
  44 .563  1.0   37 .500   38 .250   39 .250
  45 .563  1.0   37 .500   39 .250   40 .250
  46 .563  1.0   37 .250   40 .250   41 .250   44 .250
  47 .563  1.0   41 .250   42 .250   44 .500
  48 .563  1.0   42 .250   43 .250   44 .500
  49 .563  1.0   30 .375   43 .250   44 .375
   3    1   28
   4    2   49
   5    2   49
   6    1   28
   7    2   49
   8    2   49
   9    0    0
  10    0    0
  11    0    0
 3.0 .059 655. .477  10.  0.1 409. .0321000. .563
slab    66   29  100
    1                       16.78       520. 0.20 0.50 3.02
    2                       32.09       520. 0.20 0.20 3.02
    3                       38.02       520. 0.20 0.20 3.02
    4                      265.40       0.00
    5                     3476.73       0.00
    6                      195.51       0.00
    7                      173.79       0.00
    8                        1.99      138.3
    9                      164.29       0.00
   10                      145.44       0.00
   11                        1.99      138.3
   12                      169.10       0.00
   13                      130.02       0.00
   14                      150.61       0.00
   15                      215.73       0.00
   16                      211.44       0.00
   17                      237.38       0.00
   18                      220.26       0.00
   19                     6572.72       0.00
   20                     6017.34       0.00
   21                     4102.12       0.00
   22                     4592.99       0.00
   23                     4171.11       0.00
   24                     4400.98       0.00
   25                     5628.79       0.00
   26                     4925.06       0.00
   27                     5619.14       0.00
   28                     6041.59       0.00
   29                     7061.62       0.00
   30                     5680.39       0.00
   31                       32.97       73.2
   32                       51.81       55.5
   33                       50.22       53.4
   34                       52.68       56.3
   35                       69.03       73.2
   36                      136.86      146.4
```

```
37                 69.60     73.2
38                 38.13     520.  0.20 0.20 3.02
39                975.50   13312.  0.20 0.20 .118
40                 51.58     704.  0.20 0.20 1.88
41                 65.25   390.91  0.50 0.20 3.18
42                 95.88   574.40  0.50 0.20 2.16
43                106.71   638.79  0.50 0.20 1.94
44                 73.77   441.61  0.50 0.20 2.81
45                 51.95   310.13  0.50 0.20 4.00
46                 77.59   463.18  0.50 0.20 2.68
47                 43.18   257.20  0.50 0.20 4.83
48                 97.34   579.80  0.50 0.20 2.14
49                102.40     0.00
50                114.96     0.00
51                 81.84     0.00
52                 78.53     0.00
53                146.95   110.15  0.20 0.60 6.23
54                165.02   123.64  0.20 0.60 5.55
55                117.47    87.96  0.20 0.60 7.80
56                112.70    84.37  0.20 0.60 8.13
57                  0.00     0.00
58                  0.00     0.00
59                  0.00     0.00
60                  0.00     0.00
61               3734.31     0.00
62               4241.14     0.00
63               5073.39     0.00
64                217.60     0.00
65                246.53     0.00
66                294.66     0.00
67               1693.87     0.00
68               1921.92     0.00
69               2296.33     0.00
70                 38.21     520.  0.20 0.20 3.02
71                301.27    4101.  0.20 0.20 0.38
72                 43.54     593.  0.20 0.20 2.64
73                 44.87     614.  0.20 0.20 2.56
74                248.74    3400.  0.20 0.20 0.46
75                 48.91     668.  0.20 0.20 2.35
76                 16.79     520.  0.20 0.50 3.02
77                 16.77     520.  0.20 0.50 3.02
78                 16.86     520.  0.20 0.50 3.02
79                 16.84     520.  0.20 0.50 3.02
80                 17.60     520.  0.20 0.50 3.02
81                 16.99     520.  0.20 0.50 3.02
82                 32.19     520.  0.20 0.20 3.02
83                 32.37     520.  0.20 0.20 3.02
84                 32.05     520.  0.20 0.20 3.02
85                 32.11     520.  0.20 0.20 3.02
86                 32.28     520.  0.20 0.20 3.02
 1   2 1.64        2   2   1   3   4
 2   1 .569        1   4   5
 3   2 1.64        2   4   1   9   4
 4   1 .569        1   5   5
 5   1 .569        2   6   2   7   5
 6   1 .569        2   8   5  10   5
 7   1 .569        1   8   2
 8   1 .569        1  13   5
 9   2 1.64        2  10  76  11   4
10   1 .569        1  12   5
```

```
11    2 1.64            2   12   76   27    4
12    1 .569            1   19    5
13    1 .569            2   14   76   16    5
14    2 1.64            2   15   77   17    4
15    1 .569            1   18    5
16    1 .569            2   21    5   17   76
17    2 1.64            2   32    4   18   77
18    1 .569            1   23    5
19    1 .569            2   21    5   20   82
20    1 .569            2   28    5   22    5
21    1 .569            1   22   82
22    1 .569            1   31    5
23    1 .569            2   25    5   24   84
24    1 .569            2   33    5   26    5
25    1 .569            1   26   84
26    1 .569            1   37    5
27    2 1.64            2   29    4   28   78
28    1 .569            1   30    5
29    2 1.64            2   53    4   30   78
30    1 .569            1   41    5
31    1 .569            2   34    5   32   78
32    2 1.64            2   33   79   35    4
33    1 .569            1   36    5
34    1 .569            2   43    5   35   78
35    2 1.64            2   36   79   58    4
36    1 .569            1   45    5
37    1 .569            2   38   85   39    5
38    1 .569            1   40    5
39    1 .569            2   47    5   40   85
40    1 .569            1   49    5
41    1 .569            2   43    5   42   83
42    1 .569            2   54    5   44    5
43    1 .569            1   44   83
44    1 .569            1   57    5
45    1 .569            2   47    5   46   86
46    1 .569            2   59    5   48    5
47    1 .569            1   48   86
48    1 .569            1   63    5
49    1 .569            2   51    5   50    3
50    3 .807            2   64   26   52   29
51    1 .569            1   52    3
52    3 .874            1   92   30
53    2 1.64            2   55    4   54   80
54    1 .569            1   56    5
55    2 1.64            2   75    6   56   80
56    1 .569            1   67    5
57    1 .569            2   60    5   58   80
58    2 1.64            2   59   81   61    4
59    1 .569            1   62    5
60    1 .569            2   69    5   61   80
61    2 1.64            2   62   81   76    9
62    1 .569            1   71    5
63    1 .569            3   65    5   64   73   66   74
64    3 .634            1   66   27
65    1 .569            2   73    5   66   75
66    3 .702            1   91   26
67    1 .569            3   69    5   68   72   70   71
68    3 .711            2   70   19   80   31
69    1 .569            1   70   70
70    3 .846            1   82   20
```

```
 71    1 .569         2   73    5   72   38
 72    3 .779         3   86   24   74   25   73   39
 73    1 .569         1   74   40
 74    3 .588
 75    2 .729         2   79   32   77    7
 76    2 .485         3   86   36   87   10   82   34
 77    2 .634         2   78   33   83    8
 78    3 .477         1   79   22
 79    3 .594         1   80   23
 80    3 .384
 81    3 .367         2   82   21   85   35
 82    3 .576
 83    2 .792         2   84   12   95   41
 84    2 .539         2   85   13   95   42
 85    2 .485         2   86   14   96   43
 86    3 .384
 87    2 .657         1   88   11
 88    2 .701         2   89   15   96   44
 89    2  1.0         2   90   16   97   45
 90    2 .669         3   91   37   93   17   97   46
 91    3 .452
 92    3 .452         1   94   37
 93    2 1.20         2   96   47   94   18
 94    2 .534         1   96   48
 95    3 4.09         2   96   61   99   49
 96    3 3.66         2   97   62  100   50
 97    3 5.09         2   98   63  101   51
 98    3 5.33         1  102   52
 99    4 26.2         2  100   64  103   53
100    4 23.3         2  101   65  104   54
101    4 32.8         2  102   66  105   55
102    4 34.2         1  106   56
103    3 13.9         1  104   67
104    3 12.4         1  105   68
105    3 17.5         1  106   69
106    3 18.2
  1      6.69    2.94
  2     31.59    2.12
  3     28.77    2.31
  4     38.56    1.71
  5     39.98    1.68
  6     32.54    2.04
  7     56.50    1.19
  8     19.75    3.34
  9     24.96    2.64
 10     24.23    2.71
 11     51.55    1.29
 12     20.31    3.21
 13     19.04    3.46
 14     25.67    2.56
 15     24.85    2.64
 16     40.76    1.66
 17     38.53    1.76
 18      3.33    0.60
 19      0.68    2.91
 20      0.80    2.50
 21      0.61    3.26
 22      0.39    5.02
 23      6.69    2.94
 24      6.68    2.94
```

```
25     6.71     2.94
26     6.69     2.94
27     6.71     2.94
28     6.75     2.94
29     6.74     2.94
 2   1   1   1   1
 4   1   1   8   1
 5   1   1  14   1
 6   1   2  15  23
 7   1   1  19   1
 8   1   2  23  23
10   1   2   1  23
12   1   2   8  23
13   1   2  37  23
15   1   3   1  24
16   1   2  44  23
18   1   3   8  24
19   1   2  22  23
20   1   4  15  25
21   1   2  30  25
22   1   4  23  25
23   1   3  14  24
24   1   5  15  26
25   1   3  19  24
26   1   5  23  26
28   1   4   1  25
30   1   4   8  25
31   1   4  37  25
33   1   5   1  26
34   1   4  44  25
36   1   5   8  26
37   1   5  37  26
38   1   6   1  27
39   1   5  44  26
40   1   6   8  27
41   1   4  22  25
42   1   7  15  28
43   1   4  30  25
44   1   7  23  28
45   1   5  22  26
46   1   8  15  29
47   1   5  30  26
48   1   8  23  29
49   1   6  14  27
50   1  11   1  12
51   1   6  19  27
52   1  11   1  13
54   1   7   1  28
56   1   7   8  28
57   1   7  37  28
59   1   8   1  29
60   1   7  44  28
62   1   8   8  29
63   1   8  37  29
64   1  11   1  14
65   1   8  44  29
66   1  11   1  15
67   1   7  22  28
68   1   9   1   7
69   1   7  30  28
```

```
70    1    9    1    8
71    1    8   22   29
72    1   10    1    9
73    1    8   30   29
74    1   10    1   10
77    1    9    1   18
78    1    9    1    2
79    1    9    1    3
80    1    9    1    4
81    1    9    1    5
82    1    9    1    6
84    1    9    1   20
86    1   10    1   11
87    1   10    1   19
89    1   10    1   21
91    1   11    1   16
92    1   11    1   17
93    1   11    1   22

radg     11    2    3
   1    9
   1 .301    .2    1.0098    2.0008    3.0639    4.0956    5.2587    6.1132
                   7.0895    8.0568    9.3137
   2 .846    .2    1.0000    2.0067    3.1962    4.2224    5.1247    6.0876
                   7.0057    8.0442    9.3122
   3.5178    .2    1.0000    2.0000    3.0355    4.1605    5.0764    6.1744
                   7.0590    8.0326    9.1037
   4.4249    .2    1.0000    2.0000    3.0000    4.0160    5.0178    6.1019
                   7.0682    8.0109    9.0749
   5.5358    .2    1.0000    2.0000    3.0000    4.0000    5.0208    6.2649
                   7.2323    8.0364    9.0167
   6.5859    .2    1.0000    2.0000    3.0000    4.0000    5.0000    6.0429
                   7.1878    8.0029    9.1107
   7.4334    .2    1.0000    2.0000    3.0000    4.0000    5.0000    6.0000
                   7.0287    8.0329    9.1873
   8.1514    .2    1.0000    2.0000    3.0000    4.0000    5.0000    6.0000
                   7.0941    8.0493    9.2149
   9.6332    .2    1.0000    2.0000    3.0000    4.0000    5.0000    6.0000
                   7.1282    8.0514    9.0031
   2    5
   1 .384    .2    1.0330    2.2872    3.0637    4.5031    5.1130
   2.7850    .2    1.0000    2.0193    3.0064    4.6029    5.2370
   3.8077    .2    1.0000    2.0000    3.0099    4.1124    5.8470
   4.8658    .2    1.0000    2.0000    3.0000    4.0773    5.0480
   5.9702    .2    1.0000    2.0000    3.0000    4.0000    5.0154
   3    7
   1.3964    .2    1.0568    2.4484    3.1181    4.2547    5.1125    6.0115
                   7.0082
   2.6315    .2    1.0000    2.0329    3.0642    4.1467    5.1500    6.0565
                   7.3333
   3.6188    .2    1.0000    2.0000    3.0187    4.2734    5.1038    6.0993
                   7.4271
   4.7680    .2    1.0000    2.0000    3.0000    4.0184    5.0028    6.0475
                   7.4699
   5.8268    .2    1.0000    2.0000    3.0000    4.0000    5.0326    6.2984
                   7.4292
   6.4266    .2    1.0000    2.0000    3.0000    4.0000    5.0000    6.0825
                   7.0265
   7 1.20    .2    1.0000    2.0000    3.0000    4.0000    5.0000    6.0000
                   7.0000
```

```
     1    1    4    2    4    5    7
     2    2    8   10   12   19   21   16   13    8    6
     3    1    4   15   18   23   25
     4    2    8   28   30   41   43   34   31   22   20
     5    2    8   33   36   46   47   39   37   26   24
     6    1    4   38   40   49   51
     7    2    8   54   56   67   69   60   57   44   42
     8    2    8   59   62   71   73   65   63   48   46
     9   -1    9   68   70   82   81   78   79   80   77   84
    10   -2    5   86   72   74   87   89
    11   -3    7   91   66   64   50   52   92   93
heat      1         1
              3.660               3.660
   1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
drag      2    5
  100. -1.0               100. -1.0
   64. -1.0                64. -1.0
     1    5    0
     9    1   25  .01  2.2  .14  2.2  .25  2.2  .36  2.2  .47  2.2  .58  2.2
                  .69  2.2  .80  2.2  .99  2.2
     9    8    8  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                  .69  1.7  .80  1.7  .99  1.7
     9   14   14  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                  .69  1.7  .80  1.7  .99  1.7
     9   19   19  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                  .69  1.7  .80  1.7  .99  1.7
     9    1    1  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                  .69  1.7  .80  1.7  .99  1.7
     2    8    0
     9    1   44  .01  2.2  .14  2.2  .25  2.2  .36  2.2  .47  2.2  .58  2.2
                  .69  2.2  .80  2.2  .99  2.2
     9    1    1  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                  .69  1.7  .80  1.7  .99  1.7
     9    8    8  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                  .69  1.7  .80  1.7  .99  1.7
     9   15   15  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                  .69  1.7  .80  1.7  .99  1.7
     9   22   23  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                  .69  1.7  .80  1.7  .99  1.7
     9   30   30  .01  2.2  .14  2.2  .25  2.2  .36  2.2  .47  2.2  .58  2.2
                  .69  2.2  .80  2.2  .99  2.2
     9   37   37  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                  .69  1.7  .80  1.7  .99  1.7
     9   44   44  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                  .69  1.7  .80  1.7  .99  1.7
     3    1    0
     2    1    1  .01  7.5  .99  7.5
     4    1    0
     2    1    1  .01  7.5  .99  7.5
     5    1    0
     2    1    1  .01  4.0  .99  4.0
bdry     17    1    4    2
     1 2.054e-04
     2 1.173e-07 2.523e+08        .28
     3 8.729e-04
     4   1.17e-6             0.30  .78
     5   6.75e-7
     6   7.86e-5
     7   2.47e-4             0.30
     8   1.77e-7
```

```
  9  1.877e-4
 10   1.17e-6            0.30  0.3
 11   3.60e-6
 12  5.222e-5
 13  3.723e-6
 14   1.088e-4
 15   8.72e-7            0.30  0.3
 16   1.07e-4
 17   1.17e-6            0.60  0.3
  1    2   0.  6.0   1.  6.0
103     46.485    1
  1  1.     1   1.    1
  21.029    1   1.    2
  31.183    1   1.    3
  41.183    1   1.    4
104     45.777    1
  1  1.     1   1.    1
  21.029    1   1.    2
  31.183    1   1.    3
  41.183    1   1.    4
105     48.121    1
  1  1.     1   1.    1
  21.029    1   1.    2
  31.183    1   1.    3
  41.183    1   1.    4
106     48.289    1
  1  1.     1   1.    1
  21.029    1   1.    2
  31.183    1   1.    3
  41.183    1   1.    4
  1 365.   0.   5     0  6.0  6.0
  1  1.0    5   0
  2  1.0    6  94     1   5      3.63   2   5      3.63   3   5      3.63
                      4   5      3.63   5   5      3.63   6   5      3.63
                      7   5      3.63   8   5      3.63   9   5      3.63
                     10   5      3.63  11   5      3.63  12   5      3.63
                     13   5      3.63  14   5      3.63  15   5      3.63
                     16   5      3.63  17   5      3.63  18   5      3.63
                     19   5      3.63  20   5      3.63  21   5      3.63
                     22   5      3.63  23   5      3.63  24   5      3.63
                     25   5      3.63  26   5      3.63  27   5      3.63
                     28   5      3.63  29   5      3.63  30   5      3.63
                     31   5      3.63  32   5      3.63  33   5      3.63
                     34   5      3.63  35   5      3.63  36   5      3.63
                     37   5      3.63  38   5      3.63  39   5      3.63
                     40   5      3.63  41   5      3.63  42   5      3.63
                     43   5      3.63  44   5      3.63  45   5      3.63
                     46   5      3.63  47   5      3.63  48   5      3.63
                     49   5      3.63  50   5      3.63  51   5      3.63
                     52   5      3.63  53   5      3.63  54   5      3.63
                     55   5      3.63  56   5      3.63  57   5      3.63
                     58   5      3.63  59   5      3.63  60   5      3.63
                     61   5      3.63  62   5      3.63  63   5      3.63
                     64   5      3.63  65   5      3.63  66   5      3.63
                     67   5      3.63  68   5      3.63  69   5      3.63
                     70   5      3.63  71   5      3.63  72   5      3.63
                     73   5      3.63  74   5      3.63  75   5      3.63
                     76   5      3.63  77   5      3.63  78   5      3.63
                     79   5      3.63  80   5      3.63  81   5      3.63
                     82   5      3.63  83   5      3.63  84   5      3.63
```

```
                85    5       3.63   86    5       3.63   87    5       3.63
                88    5       3.63   89    5       3.63   90    5       3.63
                91    5       3.63   92    5       3.63   93    5       3.63
                94    5       3.63
     3 .238    7    0
     4 .475   10   12   95    6       3.63   96    6       3.63   97    6       3.63
                98    6       3.63   99    6       3.63  100    6       3.63
               101    6       3.63  102    6       3.63  103    6       3.63
               104    6       3.63  105    6       3.63  106    6       3.63
     5 .589   17    0
     21.963363.9    3    5  6.8  6.8
     1  1.0    8    0
     285.28    9   12   95    3       3.63   96    3       3.63   97    3       3.63
                98    3       3.63   99    3       3.63  100    3       3.63
               101    3       3.63  102    3       3.63  103    3       3.63
               104    3       3.63  105    3       3.63  106    3       3.63
     3107.7   10    0
     1  1.0   11    0
     2  1.0   12    0
     31.368   13    0
     41.543   14    0
     51.625   15    0
calc      1    0    0

        30
oper      1         3    1                                              1
      20.0      200.     .00001 .00184485      300.   .000000        0.0
.8781.7832.7679.7336.7000.6910.6713.5981
   18
   0.    0..0443  0.0.0444 .476.0786 .476.1470.9951.21541.163
.28391.173.35231.157.42071.145.48911.116.55761.117.62601.096
.69441.042.7629 .911.8313 .611.8655 .611.8656   0.  1.0   0.
outp 11011
endd

 data from iterative solution using the recirculation module
 time =     0.0000    dt = ******    implicit dt = 0.0000    explicit dt = 0.7483    mode =  0


 iteration  sweep         peak clad              total flow    pressure                  error
    no.      no.   ---------------------------    (lbm/s)     drop(psi)    -----------------------------------
                   temp(f)  fluid  rod  ass.                                total     flow    fluid     rod
                                                                           energy            energy   energy

     1        1     231.7     17    19    1     0.130e-10   0.0014122     -0.4747   1.1523   0.0848   0.0006
              2     231.7     16    19    1                               -0.3491   1.1523   0.0157   0.0006

     2        1     231.4     16    19    1     0.669e-11   0.0014410     -0.2082   3.3905   0.0457   0.0008
              2     230.9     16    19    1                               -0.2379   3.3905   0.0085   0.0009

     3        1     230.8     16    19    1     0.387e-11   0.0014425     -0.2294   0.2576   0.0096   0.0002
              2     230.4     16    19    1                               -0.2279   0.2576   0.0063   0.0002

     4        1     230.3     16    19    1     0.298e-11   0.0014697     -0.0086   1.4780   0.0138   0.0002
              2     218.4     16    19    1                               -0.0332   1.4780   0.0091   0.0003

     5        1     218.1     16    19    1     0.150e-11   0.0014628     -0.0417   0.3028   0.0069   0.0000
              2     217.6     16    19    1                               -0.0451   0.3028   0.0039   0.0001

     6        1     217.5     16    19    1     0.470e-12   0.0014640     -0.0492   0.1076   0.0032   0.0000
```

	2	217.0	16	19	1			-0.0518	0.1676	0.0030	0.0000
7	1	216.9	16	19	1	-0.462e-13	0.0014716	-0.0062	0.4479	0.0040	0.0001
	2	214.7	16	19	1			-0.0147	0.4479	0.0064	0.0001
8	1	214.6	16	19	1	-0.292e-12	0.0014711	-0.0188	0.1360	0.0021	0.0000
	2	214.0	16	19	1			-0.0215	0.1360	0.0019	0.0000
9	1	213.9	16	19	1	-0.336e-12	0.0014720	-0.0241	0.0760	0.0016	0.0000
	2	213.6	16	19	1			-0.0262	0.0760	0.0016	0.0000
10	1	213.4	16	19	1	-0.247e-12	0.0014774	0.0065	0.1521	0.0032	0.0000
	2	210.7	16	19	1			0.0065	0.1521	0.0056	0.0001
11	1	210.6	16	19	1	-0.193e-12	0.0014771	-0.0020	0.0580	0.0020	0.0000
	2	210.2	16	19	1			-0.0043	0.0580	0.0018	0.0000
12	1	210.2	16	19	1	-0.148e-12	0.0014778	-0.0061	0.0535	0.0015	0.0000
	2	209.8	16	19	1			-0.0078	0.0535	0.0015	0.0000
13	1	209.7	16	19	1	-0.886e-13	0.0014806	0.0065	0.0076	0.0026	0.0000
	2	208.4	16	19	1			0.0033	0.0076	0.0049	0.0000
14	1	208.3	16	19	1	-0.662e-13	0.0014804	0.0020	0.0441	0.0016	0.0000
	2	208.0	16	19	1			0.0005	0.0441	0.0014	0.0000
15	1	208.0	16	19	1	-0.571e-13	0.0014810	-0.0006	0.0409	0.0012	0.0000
	2	207.7	16	19	1			-0.0018	0.0409	0.0012	0.0000
16	1	207.7	16	19	1	-0.332e-13	0.0014828	0.0068	0.0402	0.0023	0.0000
	2	206.7	16	19	1			0.0049	0.0402	0.0042	0.0000
17	1	206.6	16	19	1	-0.266e-13	0.0014826	0.0042	0.0343	0.0014	0.0000
	2	206.4	16	19	1			0.0033	0.0343	0.0012	0.0000
18	1	206.4	16	19	1	-0.289e-13	0.0014830	0.0026	0.0324	0.0010	0.0000
	2	206.2	16	19	1			0.0019	0.0324	0.0018	0.0000
19	1	206.2	16	19	1	-0.269e-13	0.0014841	0.0060	0.0276	0.0019	0.0000
	2	205.5	16	19	1			0.0050	0.0276	0.0036	0.0000
20	1	205.5	16	19	1	-0.168e-13	0.0014840	0.0048	0.0268	0.0011	0.0000
	2	205.3	16	19	1			0.0042	0.0268	0.0010	0.0000
21	1	205.3	16	19	1	-0.213e-13	0.0014843	0.0038	0.0264	0.0009	0.0000
	2	205.2	16	19	1			0.0034	0.0264	0.0008	0.0000
22	1	205.1	16	19	1	-0.147e-13	0.0014850	0.0054	0.0195	0.0016	0.0000
	2	204.7	16	19	1			0.0049	0.0195	0.0030	0.0000
23	1	204.7	16	19	1	-0.184e-13	0.0014849	0.0048	0.0214	0.0010	0.0000
	2	204.6	16	19	1			0.0045	0.0214	0.0009	0.0000
24	1	204.6	16	19	1	-0.135e-13	0.0014851	0.0043	0.0216	0.0007	0.0000
	2	204.5	16	19	1			0.0040	0.0216	0.0007	0.0000
25	1	204.5	16	19	1	-0.963e-14	0.0014856	0.0046	0.0161	0.0014	0.0000
	2	204.2	16	19	1			0.0045	0.0161	0.0026	0.0000
26	1	204.1	16	19	1	-0.521e-14	0.0014854	0.0046	0.0171	0.0008	0.0000

```
         2     204.1    10    19    1                               0.0044   0.0171   0.0007   0.0000

  27     1     204.1    10    19    1    -0.960e-14   0.0014857     0.0043   0.0176   0.0006   0.0000
         2     204.0    10    19    1                               0.0041   0.0176   0.0006   0.0000

  28     1     204.0    10    19    1    -0.758e-14   0.0014859     0.0040   0.0149   0.0012   0.0000
         2     203.8    10    19    1                               0.0040   0.0149   0.0022   0.0000

  29     1     203.8    10    19    1    -0.388e-14   0.0014858     0.0042   0.0138   0.0007   0.0000
         2     203.7    10    19    1                               0.0040   0.0138   0.0006   0.0000

  30     1     203.7    10    19    1    -0.733e-14   0.0014860     0.0040   0.0144   0.0005   0.0000
         2     203.7    10    19    1                               0.0040   0.0144   0.0005   0.0000



 slab temperature summary        time =    0.0000 seconds
 (assembly no. - channel no.)


axial zone   ( 1)     ( 2)     ( 3)     ( 4)     ( 5)     ( 6)     ( 7)     ( 8)     ( 9)     ( 10)
 (inches)

  0.0 -  7.4   106.18   105.58   105.58   104.77   101.63   101.54   100.47   100.45   104.44   103.55
  7.4 - 14.8   108.71   108.74   108.13   108.17   107.20   107.08   106.49   106.30   106.95   106.87
 14.8 - 22.2   112.74   113.21   112.17   112.90   114.09   113.92   113.98   113.63   110.95   111.52
 22.2 - 29.6   117.77   118.74   117.23   118.74   122.39   122.18   123.01   122.49   115.95   117.28
 29.6 - 37.0   123.17   124.51   122.65   124.78   130.53   130.28   131.65   131.18   121.29   123.24
 37.0 - 44.4   128.54   130.15   128.02   130.64   138.05   137.78   139.96   139.18   126.57   129.00
 44.4 - 51.9   133.55   135.34   133.02   135.96   144.57   144.27   146.94   146.08   131.49   134.24
 51.9 - 59.3   138.07   139.96   137.52   140.69   150.12   149.81   152.84   151.93   135.90   138.87
 59.3 - 66.7   142.00   143.97   141.43   144.76   154.60   154.47   157.77   156.83   139.73   142.86
 66.7 - 74.1   145.34   147.36   144.74   148.20   158.70   158.36   161.87   160.90   142.97   146.22
 74.1 - 81.5   148.05   150.12   147.43   150.99   161.86   161.52   165.19   164.21   145.61   148.96
 81.5 - 88.9   150.14   152.25   149.51   153.15   164.32   163.97   167.78   166.78   147.64   151.06
 88.9 - 96.3   151.60   153.76   150.96   154.68   166.16   165.81   169.75   168.74   149.05   152.57
 96.3 -103.7 . 152.41   154.62   151.76   155:69   167.40   167.05   171.12   170.09   149.84   153.45
103.7 -111.1   152.50   154.76   151.86   155.77   167.92   167.56   171.76   170.72   149.93   153.63
111.1 -118.5   151.81   154.11   151.19   155.18   167.61   167.25   171.58   170.52   149.27   153.05
118.5 -125.9   150.24   152.57   149.65   153.68   166.36   166.01   170.43   169.38   147.77   151.60
125.9 -133.3   147.73   150.04   147.16   151.19   163.93   163.59   168.07   167.02   145.35   149.18
133.3 -140.8   144.12   146.37   143.60   147.55   160.15   159.82   164.30   163.29   141.90   145.66
140.8 -148.2   139.41   141.51   138.98   142.69   154.77   154.47   158.85   157.92   137.45   141.00
148.2 -155.6   133.36   135.35   133.11   136.60   148.14   147.89   152.17   151.35   131.91   135.27
155.6 -163.0   125.81   127.26   125.98   128.63   138.36   138.21   142.14   141.60   125.46   128.04
163.0 -170.4   115.82   117.21   117.51   119.71   129.21   129.22   133.18   132.94   118.55   120.79
170.4 -177.8    99.72   102.53   100.38   110.25   121.86   122.19   126.60   126.64   112.86   115.04



 slab temperature summary        time =    0.0000 seconds
 (assembly no. - channel no.)


axial zone   ( 11)    ( 12)    ( 13)    ( 14)    ( 15)    ( 16)    ( 17)    ( 18)    ( 19)    ( 20)
 (inches)
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0.0 - 7.4	102.81	102.29	100.33	100.62	100.28	99.63	99.79	99.46	99.66	99.49
7.4 - 14.8	105.25	106.48	104.15	103.77	103.82	103.33	102.89	103.11	104.59	104.38
14.8 - 22.2	109.13	109.99	109.72	108.81	109.13	108.77	107.87	108.56	110.78	110.54
22.2 - 29.6	113.99	115.58	116.63	115.09	115.77	115.52	114.07	115.38	118.34	118.06
29.6 - 37.0	119.17	121.35	123.77	121.75	122.71	122.50	120.65	122.50	125.74	125.43
37.0 - 44.4	124.29	126.93	130.60	128.23	129.41	129.19	127.03	129.34	132.59	132.23
44.4 - 51.9	129.05	132.00	136.75	134.14	135.48	135.19	132.84	135.51	138.52	138.12
51.9 - 59.3	133.31	136.48	142.10	139.35	140.80	140.42	137.95	140.89	143.57	143.14
59.3 - 66.7	137.00	140.33	146.66	143.80	145.35	144.87	142.33	145.47	147.83	147.37
66.7 - 74.1	140.13	143.58	150.47	147.53	149.15	148.59	145.98	149.30	151.39	150.90
74.1 - 81.5	142.66	146.21	153.67	150.56	152.24	151.61	148.95	152.41	154.27	153.76
81.5 - 88.9	144.61	148.24	155.98	152.92	154.65	153.96	151.26	154.83	156.49	155.96
88.9 - 96.3	145.96	149.68	157.77	154.66	156.43	155.70	152.95	156.63	158.14	157.59
96.3 -103.7	146.71	150.62	158.93	155.75	157.58	156.82	154.02	157.81	159.22	158.66
103.7 -111.1	146.79	150.68	159.39	156.16	158.03	157.26	154.40	158.30	159.61	159.05
111.1 -118.5	146.14	150.09	159.07	155.80	157.71	156.92	154.04	158.02	159.24	158.67
118.5 -125.9	144.60	148.67	157.88	154.57	156.53	155.73	152.83	156.88	157.98	157.42
125.9 -133.3	142.35	146.32	155.67	152.39	154.34	153.54	150.68	154.74	155.64	155.08
133.3 -140.8	139.04	142.91	152.34	149.17	151.09	150.27	147.50	151.51	152.09	151.54
140.8 -148.2	134.84	138.45	147.89	144.98	146.76	145.89	143.37	147.16	147.14	146.63
148.2 -155.6	129.70	133.06	142.57	139.96	141.62	140.70	138.42	141.96	141.27	140.79
155.6 -163.0	123.94	126.42	136.10	134.47	135.60	134.42	133.00	135.66	132.86	132.45
163.0 -170.4	118.26	120.20	130.61	129.75	130.54	129.18	128.35	130.37	125.87	125.58
170.4 -177.8	114.31	115.85	127.24	127.05	127.58	126.07	125.71	127.21	121.35	121.15

slab temperature summary time = 0.0000 seconds
(assembly no. - channel no.)

axial zone (inches)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)
0.0 - 7.4	98.92	98.78	97.66	97.52	96.96	96.85	100.58	99.97	97.81	97.74
7.4 - 14.8	103.95	103.78	102.75	102.58	102.56	102.42	102.90	102.98	100.60	100.59
14.8 - 22.2	110.41	110.20	109.77	109.56	110.30	110.14	106.61	107.26	103.50	104.67
22.2 - 29.6	118.32	118.00	118.67	118.44	120.20	120.04	111.26	112.59	107.80	109.76
29.6 - 37.0	126.11	125.83	127.74	127.48	130.28	130.12	116.21	118.07	112.53	114.96
37.0 - 44.4	133.31	132.99	136.29	136.00	139.73	139.58	121.09	123.34	117.11	119.94
44.4 - 51.9	139.55	139.18	143.79	143.48	147.97	147.82	125.61	128.12	121.34	124.43
51.9 - 59.3	144.88	144.45	150.19	149.85	154.94	154.79	129.65	132.32	125.12	128.37
59.3 - 66.7	149.32	148.88	155.56	155.20	160.75	160.58	133.15	135.94	128.39	131.76
66.7 - 74.1	153.03	152.57	160.01	159.63	165.54	165.36	136.11	138.98	131.15	134.60
74.1 - 81.5	156.04	155.55	163.62	163.22	169.42	169.22	138.50	141.44	133.38	136.90
81.5 - 88.9	158.36	157.86	166.44	166.03	172.45	172.24	140.34	143.33	135.08	138.65
88.9 - 96.3	160.11	159.59	168.62	168.20	174.83	174.61	141.61	144.66	136.24	139.87
96.3 -103.7	161.29	160.75	170.19	169.76	176.60	176.37	142.30	145.42	136.86	140.56
103.7 -111.1	161.77	161.23	171.06	170.62	177.67	177.43	142.35	145.54	136.88	140.63
111.1 -118.5	161.48	160.93	171.14	170.70	177.94	177.71	141.71	144.95	136.26	140.03
118.5 -125.9	160.29	159.74	170.31	169.87	177.28	177.05	140.30	143.57	134.92	138.70
125.9 -133.3	158.01	157.46	168.31	167.88	175.37	175.16	138.08	141.33	132.83	136.54
133.3 -140.8	154.48	153.94	164.96	164.54	171.99	171.79	134.97	138.12	129.93	133.49
140.8 -148.2	149.56	149.04	160.00	159.60	166.78	166.58	131.05	133.97	126.33	129.59
148.2 -155.6	143.72	143.22	153.87	153.49	160.17	159.97	126.37	129.06	122.10	125.65
155.6 -163.0	135.38	134.92	144.81	144.46	149.87	149.56	121.28	123.14	117.62	119.61
163.0 -170.4	128.60	128.18	137.10	136.76	140.92	140.67	116.57	117.99	113.65	115.08
170.4 -177.8	124.35	123.98	132.02	131.70	134.84	134.58	113.64	114.79	111.35	112.44

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slab temperature summary        time =    0.0000 seconds
(assembly no. - channel no.)

axial zone     ( 31)      ( 32)      ( 33)      ( 34)      ( 35)      ( 36)      ( 37)      ( 38)      ( 39)      ( 40)
 (inches)

  0.0 -  7.4    97.85      98.09      97.67      95.84      95.63      95.69      95.48      95.36      94.39      94.22
  7.4 - 14.8   101.36     101.06     101.14      99.17      98.42      98.96     100.99     100.85      99.63      99.41
 14.8 - 22.2   106.56     105.86     106.38     104.11     102.93     103.93     108.83     108.68     107.10     106.83
 22.2 - 29.6   113.03     111.83     112.97     110.27     108.54     110.19     118.99     118.85     116.78     116.44
 29.6 - 37.0   119.69     118.15     119.82     116.58     114.45     116.65     129.32     129.19     126.52     126.10
 37.0 - 44.4   126.05     124.28     126.39     122.58     120.15     122.80     138.94     138.82     135.50     135.01
 44.4 - 51.9   131.73     129.82     132.29     127.88     125.31     128.29     147.23     147.11     143.16     142.60
 51.9 - 59.3   136.67     134.69     137.42     132.48     129.83     133.05     154.16     154.02     149.51     148.89
 59.3 - 66.7   140.86     138.85     141.77     136.39     133.68     137.08     159.86     159.70     154.70     154.03
 66.7 - 74.1   144.36     142.32     145.40     139.64     136.88     140.42     164.51     164.34     158.93     158.21
 74.1 - 81.5   147.19     145.14     148.34     142.26     139.47     143.13     168.24     168.05     162.29     161.53
 81.5 - 88.9   149.38     147.32     150.63     144.28     141.47     145.21     171.14     170.92     164.88     164.08
 88.9 - 96.3   151.00     148.91     152.31     145.76     142.92     146.74     173.40     173.18     166.89     166.07
 96.3 -103.7   152.02     149.91     153.41     146.68     143.80     147.71     175.11     174.87     168.39     167.54
103.7 -111.1   152.39     150.25     153.85     146.97     144.07     148.05     176.16     175.92     169.27     168.41
111.1 -118.5   152.03     149.86     153.55     146.57     143.65     147.70     176.47     176.22     169.45     168.58
118.5 -125.9   150.84     148.67     152.43     145.39     142.48     146.57     175.88     175.64     168.79     167.93
125.9 -133.3   148.70     146.57     150.34     143.30     140.48     144.53     174.06     173.83     166.96     166.12
133.3 -140.8   145.53     143.50     147.21     140.24     137.53     141.51     170.76     170.53     163.73     162.93
140.8 -148.2   141.31     139.50     143.01     136.20     133.76     137.48     165.55     165.33     158.70     157.96
148.2 -155.6   136.34     134.74     138.00     131.48     129.30     132.72     158.83     158.61     152.29     151.60
155.6 -163.0   130.31     129.52     131.90     125.73     124.41     126.91     148.07     147.82     142.00     141.40
163.0 -170.4   125.37     125.09     126.81     121.14     120.33     122.18     138.66     138.39     133.22     132.69
170.4 -177.8   122.51     122.60     123.80     118.55     118.07     119.44     132.24     131.95     127.37     126.90
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slab temperature summary        time =    0.0000 seconds
(assembly no. - channel no.)

axial zone     ( 51)      ( 52)      ( 53)      ( 54)      ( 55)      ( 56)      ( 57)      ( 58)      ( 59)      ( 60)
 (inches)

  0.0 -  7.4    87.88      86.94      94.34      94.05      90.29      90.76      92.10      92.10      91.92      88.64
  7.4 - 14.8    91.66      90.48      96.36      96.67      92.14      93.17      95.12      94.64      94.87      91.37
 14.8 - 22.2    96.94      95.40      99.60     100.42      95.08      96.58      99.58      98.73      99.37      95.35
 22.2 - 29.6   103.63     101.58     103.64     105.11      98.73     100.60     105.15     103.82     105.01     100.28
 29.6 - 37.0   110.14     107.64     107.93     109.83     102.60     105.04     110.77     109.14     110.75     105.20
 37.0 - 44.4   116.03     113.13     112.13     114.34     106.39     109.08     116.05     114.24     116.17     109.83
 44.4 - 51.9   120.96     117.74     116.01     118.38     109.90     112.71     120.72     118.86     120.97     113.92
 51.9 - 59.3   124.99     121.53     119.48     121.93     113.04     115.91     124.75     122.89     125.11     117.46
 59.3 - 66.7   128.25     124.59     122.48     124.98     115.75     118.65     128.17     126.32     128.61     120.46
 66.7 - 74.1   130.86     127.05     125.00     127.53     118.03     120.95     131.01     129.18     131.51     122.95
 74.1 - 81.5   132.89     128.95     127.04     129.58     119.87     122.79     133.29     131.48     133.84     124.94
 81.5 - 88.9   134.39     130.36     128.58     131.13     121.25     124.17     135.03     133.24     135.62     126.44
 88.9 - 96.3   135.51     131.40     129.63     132.20     122.18     125.10     136.27     134.49     136.90     127.50
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96.3 -103.7	136.26	132.00	130.17	132.78	122.64	125.58	137.02	135.23	137.68	128.10
103.7 -111.1	136.58	132.35	130.16	132.79	122.60	125.54	137.19	135.41	137.89	128.18
111.1 -118.5	136.41	132.15	129.55	132.20	122.02	124.95	136.74	134.96	137.48	127.69
118.5 -125.9	135.87	131.42	128.29	130.93	120.88	123.76	135.58	133.83	136.36	126.58
125.9 -133.3	134.18	129.98	126.36	128.93	119.12	121.92	133.62	131.93	134.43	124.76
133.3 -140.8	131.75	127.71	123.72	126.18	116.77	119.41	130.79	129.23	131.63	122.21
140.8 -148.2	128.21	124.43	120.49	122.65	113.92	116.29	127.12	125.79	127.96	118.94
148.2 -155.6	123.86	120.38	118.75	118.67	110.69	112.82	122.89	121.77	123.70	115.27
155.6 -163.0	117.66	114.25	112.87	113.89	107.40	108.69	117.71	117.40	118.48	110.78
163.0 -170.4	111.72	109.40	109.55	110.18	104.66	105.62	113.78	113.85	114.43	107.54
170.4 -177.8	108.49	106.49	107.72	108.12	103.18	104.01	111.86	111.93	112.21	105.89

slab temperature summary   time =   0.0000 seconds
(assembly no. - channel no.)

axial zone (inches)	(91)	(92)	(93)	(94)	(95)	(96)	(97)	(98)	(99)	(100)
0.0 - 7.4	70.66	68.58	67.94	67.95	69.26	68.28	66.15	64.76	66.63	65.91
7.4 - 14.8	71.17	69.50	68.77	68.80	70.91	69.73	67.14	65.38	68.24	67.28
14.8 - 22.2	72.93	71.07	70.23	70.28	72.75	71.49	68.62	66.60	69.97	68.89
22.2 - 29.6	75.13	73.00	72.11	72.19	74.89	73.58	70.46	68.23	71.94	70.79
29.6 - 37.0	77.49	75.20	74.17	74.29	77.19	75.84	72.49	70.07	74.06	72.85
37.0 - 44.4	79.83	77.46	76.25	76.40	79.49	78.10	74.53	71.94	76.19	74.93
44.4 - 51.9	82.01	79.51	78.22	78.39	81.67	80.24	76.49	73.74	78.22	76.91
51.9 - 59.3	83.97	81.35	79.99	80.18	83.66	82.19	78.26	75.38	80.68	78.72
59.3 - 66.7	85.66	82.94	81.55	81.74	85.40	83.89	79.82	76.82	81.71	80.31
66.7 - 74.1	87.00	84.26	82.85	83.04	86.86	85.32	81.13	78.03	83.09	81.65
74.1 - 81.5	88.21	85.32	83.89	84.00	88.04	86.47	82.18	79.00	84.19	82.73
81.5 - 88.9	89.05	86.10	84.68	84.85	88.91	87.33	82.96	79.72	85.02	83.53
88.9 - 96.3	89.60	86.62	85.18	85.36	89.49	87.90	83.48	80.20	85.56	84.07
96.3 -103.7	89.87	86.86	85.39	85.59	89.76	88.17	83.72	80.42	85.82	84.31
103.7 -111.1	89.83	86.83	85.35	85.56	89.72	88.13	83.68	80.38	85.77	84.28
111.1 -118.5	89.49	86.52	85.03	85.26	89.35	87.78	83.36	80.09	85.43	83.95
118.5 -125.9	88.83	85.93	84.44	84.66	88.65	87.11	82.76	79.54	84.78	83.33
125.9 -133.3	87.87	85.06	83.58	83.81	87.65	86.14	81.89	78.76	83.86	82.43
133.3 -140.8	86.63	83.96	82.50	82.73	86.36	84.91	80.80	77.78	82.68	81.38
140.8 -148.2	85.18	82.65	81.25	81.47	84.89	83.49	79.55	76.87	81.35	80.02
148.2 -155.6	83.62	81.25	79.93	80.13	83.31	81.96	78.23	75.51	79.92	78.66
155.6 -163.0	82.07	79.84	78.68	78.83	81.86	80.58	77.02	74.44	78.62	77.42
163.0 -170.4	80.86	78.69	77.67	77.77	80.61	79.39	. 76.07	73.57	77.51	76.38
170.4 -177.8	80.24	78.04	77.11	77.18	79.63	78.54	75.57	72.97	76.77	75.76

side boundary temperature summary   time =   0.0000 seconds
boundary slab node no.   166

axial zone (inches)	(1)	(2)	(3)	(4)	(5)	(
0.0 - 7.4	59.39	58.12	52.26	52.01	6.80	

```
   7.4 - 14.8        59.23        57.97        52.12        51.87          6.80
  14.8 - 22.2        60.15        58.85        52.91        52.65          6.80
  22.2 - 29.6        61.50        60.16        54.07        53.80          6.80
  29.6 - 37.0        63.03        61.65        55.39        55.11          6.80
  37.0 - 44.4        64.62        63.19        56.76        56.47          6.80
  44.4 - 51.9        66.15        64.67        58.07        57.77          6.80
  51.9 - 59.3        67.56        66.03        59.28        58.97          6.80
  59.3 - 66.7        68.79        67.23        60.34        60.03          6.80
  66.7 - 74.1        69.84        68.24        61.24        60.92          6.80
  74.1 - 81.5        70.67        69.05        61.96        61.63          6.80
  81.5 - 88.9        71.30        69.66        62.49        62.17          6.80
  88.9 - 96.3        71.71        70.05        62.84        62.52          6.80
  96.3 -103.7        71.90        70.24        63.01        62.68          6.80
 103.7 -111.1        71.87        70.21        62.98        62.65          6.80
 111.1 -118.5        71.62        69.96        62.77        62.44          6.80
 118.5 -125.9        71.15        69.51        62.36        62.04          6.80
 125.9 -133.3        70.49        68.87        61.80        61.48          6.80
 133.3 -140.8        69.66        68.07        61.09        60.77          6.80
 140.8 -148.2        68.74        67.18        60.29        59.98 ·        6.80
 148.2 -155.6        67.80        66.26        59.48        59.18          6.80
 155.6 -163.0        66.91        65.41        58.73        58.43          6.80
 163.0 -170.4        66.25        64.77        58.17        57.87          6.80
 170.4 -177.8        65.82        64.35        57.80        57.51          6.80


 calculated rod temperatures at time =    0.0000 seconds
 rod no.   25
 assembly  1                    (fuel type  1 - cylinder)
0rod o.d. - 0.563 (in.)     zone-(fuel dia.(in.)) -  1-(0.477)

                                                *   fuel temperatures(f.)
                                                *
   axial zone  heat flux   type          hsurf  *   fluid    clad
      (in.)   (mbtu/hr-ft2)          (b/h-f-ft2) *
    0.0 -   7.4    0.0000    1              4.4       98.5     98.6
    7.4 -  14.8    0.0000    1              4.5      108.9    110.5
   14.8 -  22.2    0.0000    1              4.6      119.7    121.9
   22.2 -  29.6    0.0000    1              4.6      132.9    136.0
   29.6 -  37.0    0.0000    1              4.7      144.4    147.8
   37.0 -  44.4    0.0000    1              4.7      154.4    158.0
   44.4 -  51.9    0.0000    1              4.8      162.5    165.9
   51.9 -  59.3    0.0000    1              4.8      169.0    172.4
   59.3 -  66.7    0.0000    1              4.8      174.2    177.6
   66.7 -  74.1    0.0000    1              4.8      178.6    181.9
   74.1 -  81.5    0.0000    1              4.9      182.1    185.4
   81.5 -  88.9    0.0000    1              4.9      184.8    188.0
   88.9 -  96.3    0.0000    1              4.9      186.9    190.1
   96.3 - 103.7    0.0000    1              4.9      188.6    191.7
  103.7 - 111.1    0.0000    1              4.9      189.4    192.5
  111.1 - 118.5    0.0000    1              4.9      189.4    192.4
  118.5 - 125.9    0.0000    1              4.9      188.3    191.2
  125.9 - 133.3    0.0000    1              4.9      185.7    188.4
  133.3 - 140.8    0.0000    1              4.9      181.4    183.8
  140.8 - 148.2    0.0000    1              4.8      174.6    176.4
  148.2 - 155.6    0.0000    1              4.8      167.1    168.7
  155.6 - 163.0    0.0000    1              4.7      151.4    151.2
  163.0 - 170.4    0.0000    1              4.6      139.6    139.4
  170.4 - 177.8    0.0000    1              4.6      130.5    130.3
```

```
 calculated rod temperatures at time =   0.0000 seconds
 rod no.   25
 assembly   3                  (fuel type  1 - cylinder)
0rod o.d. - 0.563 (in.)     zone-(fuel dia.(in.)) -  1-(0.477)

                                                  *  fuel temperatures(f.)
                                                  *
   axial zone  heat flux   type            hsurf  *  fluid    clad
      (in.)   (mbtu/hr-ft2)             (b/h-f-ft2) *
    0.0 -   7.4    0.0000    1               4.4      98.5     98.5
    7.4 -  14.8    0.0000    1               4.5     105.0    106.3
   14.8 -  22.2    0.0000    1               4.5     114.8    118.7
   22.2 -  29.6    0.0000    1               4.6     127.5    130.3
   29.6 -  37.0    0.0000    1               4.7     139.4    142.4
   37.0 -  44.4    0.0000    1               4.7     150.2    153.3
   44.4 -  51.9    0.0000    1               4.8     159.2    162.3
   51.9 -  59.3    0.0000    1               4.8     166.7    169.7
   59.3 -  66.7    0.0000    1               4.8     172.9    175.8
   66.7 -  74.1    0.0000    1               4.8     178.0    180.9
   74.1 -  81.5    0.0000    1               4.9     182.2    185.0
   81.5 -  88.9    0.0000    1               4.9     185.4    188.1
   88.9 -  96.3    0.0000    1               4.9     188.0    190.6
   96.3 - 103.7    0.0000    1               4.9     190.0    192.6
  103.7 - 111.1    0.0000    1               4.9     191.2    193.8
  111.1 - 118.5    0.0000    1               4.9     191.7    194.2
  118.5 - 125.9    0.0000    1               4.9     191.1    193.5
  125.9 - 133.3    0.0000    1               4.9     189.0    191.3
  133.3 - 140.8    0.0000    1               4.9     185.3    187.3
  140.8 - 148.2    0.0000    1               4.8     179.1    180.7
  148.2 - 155.6    0.0000    1               4.8     172.2    173.5
  155.6 - 163.0    0.0000    1               4.7     157.7    157.4
  163.0 - 170.4    0.0000    1               4.7     146.9    146.8
  170.4 - 177.8    0.0005    1               4.6     139.1    138.9


 calculated rod temperatures at time =   0.0000 seconds
 rod no.   25
 assembly   6                  (fuel type  1 - cylinder)
0rod o.d. - 0.563 (in.)     zone-(fuel dia.(in.)) -  1-(0.477)

                                                  *  fuel temperatures(f.)
                                                  *
   axial zone  heat flux   type            hsurf  *  fluid    clad
      (in.)   (mbtu/hr-ft2)             (b/h-f-ft2) *
    0.0 -   7.4    0.0000    1               4.4      91.3     91.4
    7.4 -  14.8    0.0000    1               4.5      98.1     99.3
   14.8 -  22.2    0.0000    1               4.5     106.3    108.1
   22.2 -  29.6    0.0000    1               4.5     117.3    119.9
   29.6 -  37.0    0.0000    1               4.6     126.9    129.8
   37.0 -  44.4    0.0000    1               4.6     135.3    138.3
   44.4 -  51.9    0.0000    1               4.7     141.8    144.9
   51.9 -  59.3    0.0000    1               4.7     146.9    150.1
   59.3 -  66.7    0.0000    1               4.7     151.0    154.1
   66.7 -  74.1    0.0000    1               4.7     154.3    157.4
   74.1 -  81.5    0.0000    1               4.7     156.8    160.0
   81.5 -  88.9    0.0000    1               4.8     158.7    161.8
```

```
  88.9 -  96.3   0.0000   1            4.8    160.1   163.2
  96.3 - 103.7   0.0000   1            4.8    161.2   164.3
 103.7 - 111.1   0.0000   1            4.8    161.8   164.9
 111.1 - 118.5   0.0000   1            4.8    161.7   164.7
 118.5 - 125.9   0.0000   1            4.8    160.9   163.8
 125.9 - 133.3   0.0000   1            4.8    158.9   161.7
 133.3 - 140.8   0.0000   1            4.7    155.5   158.1
 140.8 - 148.2   0.0000   1            4.7    150.0   152.1
 148.2 - 155.6   0.0000   1            4.7    144.2   146.1
 155.6 - 163.0   0.0000   1            4.6    130.7   131.1
 163.0 - 170.4   0.0000   1            4.6    122.1   122.4
 170.4 - 177.8   0.0000   1            4.5    116.6   116.9


 calculated rod temperatures at time =    0.0000 seconds
 rod no.   25
 assembly   7                 (fuel type  1 - cylinder)
0rod o.d. - 0.563 (in.)     zone-(fuel dia.(in.)) -  1-(0.477)

                                                 *  fuel temperatures(f.)
                                                 *
   axial zone  heat flux   type           hsurf  *  fluid    clad
      (in.)   (mbtu/hr-ft2)         (b/h-f-ft2)  *
   0.0 -   7.4   0.0000   1            5.6      93.2    93.2
   7.4 -  14.8   0.0000   1            5.7     105.4   106.2
  14.8 -  22.2   0.0000   1            5.8     116.1   117.1
  22.2 -  29.6   0.0000   1            5.9     129.8   131.2
  29.6 -  37.0   0.0000   1            5.9     139.5   140.9
  37.0 -  44.4   0.0000   1            6.0     147.0   148.5
  44.4 -  51.9   0.0000   1            6.0     152.1   153.6
  51.9 -  59.3   0.0000   1            6.0     156.0   157.4
  59.3 -  66.7   0.0000   1            6.1     159.0   160.4
  66.7 -  74.1   0.0000   1            6.1     161.4   162.9
  74.1 -  81.5   0.0000   1            6.1     163.3   164.7
  81.5 -  88.9   0.0000   1            6.1     164.5   165.9
  88.9 -  96.3   0.0000   1            6.1     165.6   167.0
  96.3 - 103.7   0.0000   1            6.1     166.3   167.7
 103.7 - 111.1   0.0000   1            6.1     166.4   167.7
 111.1 - 118.5   0.0000   1            6.1     165.6   166.9
 118.5 - 125.9   0.0000   1            6.1     163.9   165.2
 125.9 - 133.3   0.0000   1            6.1     160.6   161.8
 133.3 - 140.8   0.0000   1            6.0     155.8   156.9
 140.8 - 148.2   0.0000   1            6.0     148.1   148.9
 148.2 - 155.6   0.0000   1            5.9     141.4   142.2
 155.6 - 163.0   0.0000   1            5.8     122.2   122.1
 163.0 - 170.4   0.0000   1            5.8     114.1   114.0
 170.4 - 177.8   0.0000   1            5.7     110.2   110.2
```

```
+6000
   1       reaload2ann  full load, nitrogen, vertical validation run.
prop     5    6
       1.         1.     114.8     .0128       .249    8.4137      .0373
       2.        81.     134.6     .0154       .249     10.09      .0432
       3.       261.     179.6     .0193       .250    13.496      .0532
       4.       441.     225.0     .0230       .252     16.89      .0622
      20.      1500.    1588.0     .1380       1.24    241.30      .1138
    1  can                          14.8
    2   cu                          215.
    3   ss                           9.8
    4   pb                          22.7
    5 lpr1                          0.60
    6 lpr2                          16.4
chan     11   24     0
     177.8
    1    1   25     0     0
    1    1    6     0     1
    11.7365.8942.874    2 .175 .772    3 .175 .772    4 .175 .772     8.5245 2.62
    2.1478.8843.8843    3 .175 .738
    3.29571.7691.769    4 .175 .738    9 .175 .738
    4.29571.7691.769    5 .175 .738   10 .175 .738
    5.29571.7691.769    6 .175 .738    8 .175 .772   11 .175 .738
    6.29571.7691.769    7 .175 .738    8 .175 .772   12 .175 .738
    7.29571.7691.769   14 .175 .772    8 .175 .772   13 .175 .738
    81.7365.8942.874   14.8584 2.62
    9.1478.8843.8843   10 .175 .738
   10.29571.7691.769   11 .175 .738   15 .175 .738
   11.29571.7691.769   12 .175 .738   16 .175 .738
   12.29571.7691.769   13 .175 .738   17 .175 .738
   13.29571.7691.769   14 .175 .772   18 .175 .738
   141.7365.8942.874   18 .175 .772   19.5245 2.62
   15.1478.8843.8843   16 .175 .738
   16.29571.7691.769   17 .175 .738   20 .175 .738
   17.29571.7691.769   18 .175 .738   21 .175 .738
   18.29571.7691.769   22 .175 .738
   191.7365.8942.874   22 .175 .772   24 .175 .772   25 .175 .772
   20.1478.8843.8843   21 .175 .738
   21.29571.7691.769   22 .175 .738   23 .175 .738
   22.29571.7691.769   24 .175 .738
   23.1478.8843.8843   24 .175 .738
   24.29571.7691.769   25 .175 .738
   25.1478.8843.8843
    2    2   44     0     0
    1    1    0     0     1
    11.7365.8942.874    2 .175 .772    3 .175 .772    4 .175 .772     8.5245 2.62
    2.29571.7691.769    3 .175 .738    9 .175 .738   15 .175 .772
    3.29571.7691.769    4 .175 .738   10 .175 .738
    4.29571.7691.769    5 .175 .738   11 .175 .738
    5.29571.7691.769    6 .175 .738    8 .175 .772   12 .175 .738
    6.29571.7691.769    7 .175 .738    8 .175 .772   13 .175 .738
    7.29571.7691.769   22 .175 .772    8 .175 .772   14 .175 .738
    81.7365.8942.874   22.8584 2.62
    9.29571.7691.769   10 .175 .738   15 .175 .772   16 .175 .738
   10.29571.7691.769   11 .175 .738   17 .175 .738
   11.29571.7691.769   12 .175 .738   18 .175 .738
   12.29571.7691.769   13 .175 .738   19 .175 .738
   13.29571.7691.769   14 .175 .738   20 .175 .738
   14.29571.7691.769   22 .175 .772   21 .175 .738
   151.7365.8942.874    1.8584 2.62   16 .175 .772   23.5245 2.62
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  16.29571.7691.769   17 .175 .738   24 .175 .738
  17.29571.7691.769   18 .175 .738   25 .175 .738
  18.29571.7691.769   19 .175 .738   26 .175 .738
  19.29571.7691.769   20 .175 .738   27 .175 .738
  20.29571.7691.769   21 .175 .738   28 .175 .738
  21.29571.7691.769   22 .175 .772   29 .175 .738
  221.7365.8942.874   30.5245 2.62
  231.7365.8942.874   24 .175 .772   31 .175 .772   37.8584 2.62   38 .175 .772
  24.29571.7691.769   25 .175 .738   31 .175 .738
  25.29571.7691.769   26 .175 .738   32 .175 .738
  26.29571.7691.769   27 .175 .738   33 .175 .738
  27.29571.7691.769   28 .175 .738   34 .175 .738
  28.29571.7691.769   29 .175 .738   35 .175 .738
  29.29571.7691.769   30 .175 .772   36 .175 .738
  301.7365.8942.874   36 .175 .772   43 .175 .772   44.8584 2.62
  31.29571.7691.769   32 .175 .738   38 .175 .738
  32.29571.7691.769   33 .175 .738   39 .175 .738
  33.29571.7691.769   34 .175 .738   40 .175 .738
  34.29571.7691.769   35 .175 .738   41 .175 .738
  35.29571.7691.769   36 .175 .738   42 .175 .738
  36.29571.7691.769   43 .175 .738
  371.7365.8942.874   38 .175 .772   39 .175 .772   40 .175 .772   44.5245 2.62
  38.29571.7691.769   39 .175 .738
  39.29571.7691.769   40 .175 .738
  40.29571.7691.769   41 .175 .738
  41.29571.7691.769   42 .175 .738   44 .175 .772
  42.29571.7691.769   43 .175 .738   44 .175 .772
  43.29571.7691.769   44 .175 .772
  441.7365.8942.874
   3   1  25   0   0
   1   1   0   0   1
   4   2  44   0   0
   1   1   0   0   1
   5   2  44   0   0
   1   1   0   0   1
   6   1  25   0   0
   1   1   0   0   1
   7   2  44   0   0
   1   1   0   0   1
   8   2  44   0   0
   1   1   0   0   1
   9   3   1   0   0
   0   1   0   0   2
   116.0718.11
  10   4   1   0   0
   0   1   0   0   2
   1 5.2413.78
  11   5   1   0
   0   1   0   0   2
   122.1820.18

rods    11   1   1   0   0   1
   1   1  28
   1 .563  1.0   1 .375   2 .125
   2 .563  1.0   1 .500   2 .250   3 .250
   3 .563  1.0   1 .500   3 .250   4 .250
   4 .563  1.0   1 .250   4 .250   5 .250   8 .250
   5 .563  1.0   5 .250   6 .250   8 .500
   6 .563  1.0   6 .250   7 .250   8 .500
   7 .563  1.0   7 .250   8 .375  14 .375
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 8 .563  1.0   2 .125   3 .250   9 .125
 9 .563  1.0   3 .250   4 .250   9 .250  10 .250
10 .563  1.0   4 .250   5 .250  10 .250  11 .250
11 .563  1.0   5 .250   6 .250  11 .250  12 .250
12 .563  1.0   6 .250   7 .250  12 .250  13 .250
13 .563  1.0   7 .250  13 .250  14 .500
14 .563  1.0   9 .125  10 .250  15 .125
15 .563  1.0  10 .250  11 .250  15 .250  16 .250
16 .563  1.0  11 .250  12 .250  16 .250  17 .250
17 .563  1.0  12 .250  13 .250  17 .250  18 .250
18 .563  1.0  13 .250  14 .500  18 .250
19 .563  1.0  15 .125  16 .250  20 .125
20 .563  1.0  16 .250  17 .250  20 .250  21 .250
21 .563  1.0  17 .250  18 .250  21 .250  22 .250
22 .563  1.0  14 .250  18 .250  19 .250  22 .250
23 .563  1.0  20 .125  21 .250  23 .125
24 .563  1.0  21 .250  22 .250  23 .250  24 .250
25 .563  1.0  19 .500  22 .250  24 .250
26 .563  1.0  23 .125  24 .250  25 .125
27 .563  1.0  19 .500  24 .250  25 .250
28 .563  1.0  19 .375  25 .125
 2    2   49
 1 .563  1.0   1 .375   2 .250  15 .375
 2 .563  1.0   1 .500   2 .250   3 .250
 3 .563  1.0   1 .500   3 .250   4 .250
 4 .563  1.0   1 .250   4 .250   5 .250   8 .250
 5 .563  1.0   5 .250   6 .250   8 .500
 6 .563  1.0   6 .250   7 .250   8 .500
 7 .563  1.0   7 .250   8 .375  22 .375
 8 .563  1.0   2 .250   9 .250  15 .500
 9 .563  1.0   2 .250   3 .250   9 .250  10 .250
10 .563  1.0   3 .250   4 .250  10 .250  11 .250
11 .563  1.0   4 .250   5 .250  11 .250  12 .250
12 .563  1.0   5 .250   6 .250  12 .250  13 .250
13 .563  1.0   6 .250   7 .250  13 .250  14 .250
14 .563  1.0   7 .250  14 .250  22 .500
15 .563  1.0   9 .250  15 .500  16 .250
16 .563  1.0   9 .250  10 .250  16 .250  17 .250
17 .563  1.0  10 .250  11 .250  17 .250  18 .250
18 .563  1.0  11 .250  12 .250  18 .250  19 .250
19 .563  1.0  12 .250  13 .250  19 .250  20 .250
20 .563  1.0  13 .250  14 .250  20 .250  21 .250
21 .563  1.0  14 .250  21 .250  22 .500
22 .563  1.0  15 .250  16 .250  23 .250  24 .250
23 .563  1.0  16 .250  17 .250  24 .250  25 .250
24 .563  1.0  17 .250  18 .250  25 .250  26 .250
25 .563  1.0  18 .250  19 .250  26 .250  27 .250
26 .563  1.0  19 .250  20 .250  27 .250  28 .250
27 .563  1.0  20 .250  21 .250  28 .250  29 .250
28 .563  1.0  21 .250  22 .250  29 .250  30 .250
29 .563  1.0  23 .500  24 .250  31 .250
30 .563  1.0  24 .250  25 .250  31 .250  32 .250
31 .563  1.0  25 .250  26 .250  32 .250  33 .250
32 .563  1.0  26 .250  27 .250  33 .250  34 .250
33 .563  1.0  27 .250  28 .250  34 .250  35 .250
34 .563  1.0  28 .250  29 .250  35 .250  36 .250
35 .563  1.0  29 .250  30 .500  36 .250
36 .563  1.0  23 .500  31 .250  38 .250
37 .563  1.0  31 .250  32 .250  38 .250  39 .250
38 .563  1.0  32 .250  33 .250  39 .250  40 .250
```

```
   39 .563  1.0   33 .250   34 .250   40 .250   41 .250
   40 .563  1.0   34 .250   35 .250   41 .250   42 .250
   41 .563  1.0   35 .250   36 .250   42 .250   43 .250
   42 .563  1.0   30 .500   36 .250   43 .250
   43 .563  1.0   23 .375   37 .375   38 .250
   44 .563  1.0   37 .500   38 .250   39 .250
   45 .563  1.0   37 .500   39 .250   40 .250
   46 .563  1.0   37 .250   40 .250   41 .250   44 .250
   47 .563  1.0   41 .250   42 .250   44 .500
   48 .563  1.0   42 .250   43 .250   44 .500
   49 .563  1.0   30 .375   43 .250   44 .375
    3    1   28
    4    2   49
    5    2   49
    6    1   28
    7    2   49
    8    2   49
    9    0    0
   10    0    0
   11    0    0
  3.0 .059 655. .477  10.  0.1 409. .0321000. .563
slab    60   29  100
    1                        16.78     2860. 0.20 0.50 3.02
    2                        32.09     2860. 0.20 0.20 3.02
    3                        38.02     2860. 0.20 0.20 3.02
    4                       205.40      0.00
    5                      3470.73      0.00
    6                       195.51      0.00
    7                       173.79      0.00
    8                         1.99      142. 0.50 0.50 1.40
    9                       164.29      0.00
   10                       145.44      0.00
   11                         1.99      142. 0.50 0.50 1.40
   12                       169.10      0.00
   13                       130.02      0.00
   14                       150.61      0.00
   15                       215.73      0.00
   16                       211.44      0.00
   17                       237.38      0.00
   18                       220.26      0.00
   19                      6572.72      0.00
   20                      6017.34      0.00
   21                      4102.12      0.00
   22                      4592.99      0.00
   23                      4171.11      0.00
   24                      4400.98      0.00
   25                      5628.79      0.00
   26                      4925.06      0.00
   27                      5619.14      0.00
   28                      6041.59      0.00
   29                      7061.62      0.00
   30                      5680.39      0.00
   31                        32.97      73.2
   32                        51.81      55.5
   33                        50.22      53.4
   34                        52.68      56.3
   35                        69.03      73.2
   36                       136.86     146.4
   37                        69.60      73.2
   38                        38.13     2860. 0.20 0.20 3.02
```

```
39                       975.50    73220. 0.20 0.20 .118
40                        51.58     3724. 0.20 0.20 1.88
41                        65.25    2126.7 0.50 0.20 3.18
42                        95.88   3124.94 0.50 0.20 2.16
43                       106.71    3475.2 0.50 0.20 1.94
44                        73.77   2402.54 0.50 0.20 2.81
45                        51.95   1687.27 0.50 0.20 4.00
46                        77.59   2519.84 0.50 0.20 2.68
47                        43.18   1399.31 0.50 0.20 4.83
48                        97.34   3154.34 0.50 0.20 2.14
49                       102.40      0.00
50                       114.96      0.00
51                        81.84      0.00
52                        78.53      0.00
53                       146.95    599.25 0.20 0.60 6.23
54                       165.02    672.65 0.20 0.60 5.55
55                       117.47    478.55 0.20 0.60 7.80
56                       112.70    459.00 0.20 0.60 8.13
57                         0.00      0.00
58                         0.00      0.00
59                         0.00      0.00
60                         0.00      0.00
61                      3734.31      0.00
62                      4241.14      0.00
63                      5073.39      0.00
64                       217.80      0.00
65                       246.53      0.00
66                       294.06      0.00
67                      1693.87      0.00
68                      1921.92      0.00
69                      2296.33      0.00
70                        38.21     2860. 0.20 0.20 3.02
71                       301.27    22559. 0.20 0.20 0.38
72                        43.54     3260. 0.20 0.20 2.64
73                        44.87     3375. 0.20 0.20 2.56
74                       248.74    18701. 0.20 0.20 0.46
75                        48.91     3677. 0.20 0.20 2.35
76                        16.79     2860. 0.20 0.50 3.02
77                        16.77     2860. 0.20 0.50 3.02
78                        16.86     2860. 0.20 0.50 3.02
79                        16.84     2860. 0.20 0.50 3.02
80                        17.00     2860. 0.20 0.50 3.02
81                        16.99     2860. 0.20 0.50 3.02
82                        32.19     2860. 0.20 0.20 3.02
83                        32.37     2860. 0.20 0.20 3.02
84                        32.05     2860. 0.20 0.20 3.02
85                        32.11     2860. 0.20 0.20 3.02
86                        32.28     2860. 0.20 0.20 3.02
 1   2 1.64               2    2    1    3    4
 2   1 .569               1    4    5
 3   2 1.64               2    4    1    9    4
 4   1 .569               1    5    5
 5   1 .569               2    6    2    7    5
 6   1 .569               2    8    5   10    5
 7   1 .569               1    8    2
 8   1 .569               1   13    5
 9   2 1.64               2   10   76   11    4
10   1 .569               1   12    5
11   2 1.64               2   12   76   27    4
12   1 .569               1   19    5
```

```
13    1 .569          2   14   76   16    5
14    2 1.64          2   15   77   17    4
15    1 .569          1   18    5
16    1 .569          2   21    5   17   76
17    2 1.64          2   32    4   18   77
18    1 .569          1   23    5
19    1 .569          2   21    5   20   82
20    1 .569          2   28    5   22    5
21    1 .569          1   22   82
22    1 .569          1   31    5
23    1 .569          2   25    5   24   84
24    1 .569          2   33    5   26    5
25    1 .569          1   26   84
26    1 .569          1   37    5
27    2 1.64          2   29    4   28   78
28    1 .569          1   30    5
29    2 1.64          2   53    4   30   78
30    1 .569          1   41    5
31    1 .569          2   34    5   32   78
32    2 1.64          2   33   79   35    4
33    1 .569          1   36    5
34    1 .569          2   43    5   35   78
35    2 1.64          2   36   79   58    4
36    1 .569          1   45    5
37    1 .569          2   38   85   39    5
38    1 .569          1   46    5
39    1 .569          2   47    5   40   85
40    1 .569          1   49    5
41    1 .569          2   43    5   42   63
42    1 .569          2   54    5   44    5
43    1 .569          1   44   63
44    1 .569          1   57    5
45    1 .569          2   47    5   46   86
46    1 .569          2   59    5   48    5
47    1 .569          1   48   86
48    1 .569          1   63    5
49    1 .569          2   51    5   50    3
50    3 .807          2   64   28   52   29
51    1 .569          1   52    3
52    3 .874          1   92   30
53    2 1.64          2   55    4   54   80
54    1 .569          1   56    5
55    2 1.64          2   75    6   56   80
56    1 .569          1   67    5
57    1 .569          2   60    5   58   80
58    2 1.64          2   59   81   61    4
59    1 .569          1   62    5
60    1 .569          2   69    5   61   80
61    2 1.64          2   62   81   76    9
62    1 .569          1   71    5
63    1 .569          3   65    5   64   73   66   74
64    3 .634          1   66   27
65    1 .569          2   73    5   66   75
66    3 .702          1   91   26
67    1 .569          3   69    5   68   72   70   71
68    3 .711          2   70   19   80   31
69    1 .569          1   70   70
70    3 .846          1   82   20
71    1 .569          2   73    5   72   38
72    3 .779          3   86   24   74   25   73   39
```

```
 73    1 .569           1   74   40
 74    3 .588
 75    2 .729           2   79   32   77    7
 76    2 .485           3   86   36   87   10   82   34
 77    2 .634           2   78   33   83    8
 78    3 .477           1   79   22
 79    3 .594           1   80   23
 80    3 .384
 81    3 .367           2   82   21   85   35
 82    3 .576
 83    2 .792           2   84   12   95   41
 84    2 .539           2   85   13   95   42
 85    2 .485           2   86   14   96   43
 86    3 .384
 87    2 .657           1   88   11
 88    2 .701           2   89   15   96   44
 89    2  1.0           2   90   16   97   45
 90    2 .669           3   91   37   93   17   97   46
 91    3 .452
 92    3 .452           1   94   37
 93    2 1.20           2   96   47   94   18
 94    2 .534           1   98   48
 95    3 4.09           2   96   61   99   49
 96    3 3.66           2   97   62  100   50
 97    3 5.09           2   98   63  101   51
 98    3 5.33           1  102   52
 99    4 26.2           2  100   64  103   53
100    4 23.3           2  101   65  104   54
101    4 32.8           2  102   66  105   55
102    4 34.2           1  106   56
103    3 13.9           1  104   57
104    3 12.4           1  105   58
105    3 17.5           1  106   59
106    3 18.2
  1     6.69     2.94
  2    31.59     2.12
  3    28.77     2.31
  4    38.58     1.71
  5    39.98     1.68
  6    32.54     2.04
  7    55.50     1.19
  8    19.75     3.34
  9    24.96     2.64
 10    24.23     2.71
 11    51.55     1.29
 12    20.31     3.21
 13    19.04     3.46
 14    25.67     2.56
 15    24.85     2.64
 16    40.76     1.66
 17    38.53     1.76
 18     3.33     0.60
 19     0.68     2.91
 20     0.80     2.50
 21     0.61     3.26
 22     0.39     5.02
 23     6.69     2.94
 24     6.68     2.94
 25     6.71     2.94
 26     6.69     2.94
```

```
27      6.71       2.94
28      6.75       2.94
29      6.74       2.94
 2   1     1    1     1
 4   1     1    8     1
 5   1     1   14     1
 6   1     2   15    23
 7   1     1   19     1
 8   1     2   23    23
10   1     2    1    23
12   1     2    8    23
13   1     2   37    23
15   1     3    1    24
16   1     2   44    23
18   1     3    8    24
19   1     2   22    23
20   1     4   15    25
21   1     2   30    25
22   1     4   23    25
23   1     3   14    24
24   1     5   15    26
25   1     3   19    24
26   1     5   23    26
28   1     4    1    25
30   1     4    8    25
31   1     4   37    25
33   1     5    1    26
34   1     4   44    25
36   1     5    8    26
37   1     5   37    26
38   1     6    1    27
39   1     5   44    26
40   1     6    8    27
41   1     4   22    25
42   1     7   15    28
43   1     4   30    25
44   1     7   23    28
45   1     5   22    26
46   1     8   15    29
47   1     5   30    26
48   1     8   23    29
49   1     6   14    27
50   1    11    1    12
51   1     6   19    27
52   1    11    1    13
54   1     7    1    28
56   1     7    8    28
57   1     7   37    28
59   1     8    1    29
60   1     7   44    28
62   1     8    8    29
63   1     8   37    29
64   1    11    1    14
65   1     8   44    29
66   1    11    1    15
67   1     7   22    28
68   1     9    1     7
69   1     7   30    28
70   1     9    1     8
71   1     8   22    29
```

```
   72    1   10    1    9
   73    1    8   30   29
   74    1   10    1   10
   77    1    9    1   18
   78    1    9    1    2
   79    1    9    1    3
   80    1    9    1    4
   81    1    9    1    5
   82    1    9    1    6
   84    1    9    1   20
   86    1   10    1   11
   87    1   10    1   19
   89    1   10    1   21
   91    1   11    1   16
   92    1   11    1   17
   93    1   11    1   22

radg    11    2    3
    1    9
    1 .301   .2    1.0098    2.0008    3.0639    4.0956    5.2587    6.1132
                   7.0895    8.0568    9.3137
    2 .846   .2    1.0000    2.0087    3.1962    4.2224    5.1247    6.0876
                   7.0057    8.0442    9.3122
    3.5178   .2    1.0000    2.0000    3.0355    4.1605    5.0764    6.1744
                   7.0590    8.0326    9.1037
    4.4249   .2    1.0000    2.0000    3.0000    4.0160    5.0178    6.1019
                   7.0682    8.0109    9.0749
    5.5358   .2    1.0000    2.0000    3.0000    4.0000    5.0208    6.2649
                   7.2323    8.0364    9.0167
    6.5859   .2    1.0000    2.0000    3.0000    4.0000    5.0000    6.0429
                   7.1878    8.0029    9.1107
    7.4334   .2    1.0000    2.0000    3.0000    4.0000    5.0000    6.0000
                   7.0287    8.0329    9.1873
    8.1514   .2    1.0000    2.0000    3.0000    4.0000    5.0000    6.0000
                   7.0941    8.0493    9.2149
    9.6332   .2    1.0000    2.0000    3.0000    4.0000    5.0000    6.0000
                   7.1282    8.0514    9.0031
    2    5
    1 .384   .2    1.0330    2.2872    3.0637    4.5031    5.1130
    2.7850   .2    1.0000    2.0193    3.0004    4.0029    5.2370
    3.8077   .2    1.0000    2.0000    3.0099    4.1124    5.0470
    4.8658   .2    1.0000    2.0000    3.0000    4.0773    5.0480
    5.9702   .2    1.0000    2.0000    3.0000    4.0000    5.0154
    3    7
    1.3964   .2    1.0568    2.4404    3.1161    4.2547    5.1125    6.0115
                   7.0082
    2.6315   .2    1.0000    2.0329    3.0042    4.1467    5.1500    6.0565
                   7.3333
    3.6108   .2    1.0000    2.0000    3.0167    4.2734    5.1038    6.0993
                   7.4271
    4.7680   .2    1.0000    2.0000    3.0000    4.0104    5.0028    6.0475
                   7.4699
    5.8268   .2    1.0000    2.0000    3.0000    4.0000    5.0326    6.2984
                   7.4292
    6.4286   .2    1.0000    2.0000    3.0000    4.0000    5.0000    6.0825
                   7.0205
    7 1.20   .2    1.0000    2.0000    3.0000    4.0000    5.0000    6.0000
                   7.0009
    1    1    4    2    4    5    7
    2    2    8   10   12   19   21   16   13    8    6
```

```
    3    1    4   15   18   23   25
    4    2    8   28   30   41   43   34   31   22   20
    5    2    8   33   36   46   47   39   37   26   24
    6    1    4   38   40   49   51
    7    2    8   54   56   67   69   60   57   44   42
    8    2    8   59   62   71   73   65   63   48   46
    9   -1    9   68   70   82   81   78   79   80   77   84
   10   -2    5   86   72   74   87   89
   11   -3    7   91   66   64   50   52   92   93
heat      1         1
              3.660                3.660
  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
drag      2    5
 100. -1.0                100. -1.0
  64. -1.0                 64. -1.0
    1    5    0
    9    1   25  .01  2.2  .14  2.2  .25  2.2  .36  2.2  .47  2.2  .58  2.2
                 .69  2.2  .80  2.2  .99  2.2
    9    8    8  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    9   14   14  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    9   19   19  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    9    1    1  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    2    8    0
    9    1   44  .01  2.2  .14  2.2  .25  2.2  .36  2.2  .47  2.2  .58  2.2
                 .69  2.2  .80  2.2  .99  2.2
    9    1    1  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    9    8    8  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    9   15   15  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    9   22   23  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    9   30   30  .01  2.2  .14  2.2  .25  2.2  .36  2.2  .47  2.2  .58  2.2
                 .69  2.2  .80  2.2  .99  2.2
    9   37   37  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    9   44   44  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    3    1    0
    2    1    1  .01  7.5  .99  7.5
    4    1    0
    2    1    1  .01  7.5  .99  7.5
    5    1    0
    2    1    1  .01  4.0  .99  4.0
bdry     17    1    4    2
    1 2.054e-04
    2 1.173e-07 2.523e+08       .28
    3 8.729e-04
    4   3.22e-6               0.20  .78
    5   5.40e-7
    6   7.86e-5
    7   2.47e-4
    8   1.33e-7
    9  1.877e-4
   10   3.22e-6               0.20  .30
```

```
11   2.66e-5
12  5.222e-5
13  3.723e-6
14  1.088e-4
15  2.401e-6                   0.20  .30
16   1.07e-4
17   3.22e-6                   0.20  .30
 1     2   0.  25.   1.  25.
103     46.485    1
 1   1.     1   1.    1
  21.029    1   1.    2
  31.183    1   1.    3
  41.183    1   1.    4
104     45.777    1
 1   1.     1   1.    1
  21.029    1   1.    2
  31.183    1   1.    3
  41.183    1   1.    4
105     48.121    1
 1   1.     1   1.    1
  21.029    1   1.    2
  31.183    1   1.    3
  41.183    1   1.    4
106     48.289    1
 1   1.     1   1.    1
  21.029    1   1.    2
  31.183    1   1.    3
  41.183    1   1.    4
 1 365.   0.    5    0  25.  25.
 1  1.0    5    0
 2  1.0    6   94    1    5      3.63    2    5      3.63    3    5      3.63
                     4    5      3.63    5    5      3.63    6    5      3.63
                     7    5      3.63    8    5      3.63    9    5      3.63
                    10    5      3.63   11    5      3.63   12    5      3.63
                    13    5      3.63   14    5      3.63   15    5      3.63
                    16    5      3.63   17    5      3.63   18    5      3.63
                    19    5      3.63   20    5      3.63   21    5      3.63
                    22    5      3.63   23    5      3.63   24    5      3.63
                    25    5      3.63   26    5      3.63   27    5      3.63
                    28    5      3.63   29    5      3.63   30    5      3.63
                    31    5      3.63   32    5      3.63   33    5      3.63
                    34    5      3.63   35    5      3.63   36    5      3.63
                    37    5      3.63   38    5      3.63   39    5      3.63
                    40    5      3.63   41    5      3.63   42    5      3.63
                    43    5      3.63   44    5      3.63   45    5      3.63
                    46    5      3.63   47    5      3.63   48    5      3.63
                    49    5      3.63   50    5      3.63   51    5      3.63
                    52    5      3.63   53    5      3.63   54    5      3.63
                    55    5      3.63   56    5      3.63   57    5      3.63
                    58    5      3.63   59    5      3.63   60    5      3.63
                    61    5      3.63   62    5      3.63   63    5      3.63
                    64    5      3.63   65    5      3.63   66    5      3.63
                    67    5      3.63   68    5      3.63   69    5      3.63
                    70    5      3.63   71    5      3.63   72    5      3.63
                    73    5      3.63   74    5      3.63   75    5      3.63
                    76    5      3.63   77    5      3.63   78    5      3.63
                    79    5      3.63   80    5      3.63   81    5      3.63
                    82    5      3.63   83    5      3.63   84    5      3.63
                    85    5      3.63   86    5      3.63   87    5      3.63
                    88    5      3.63   89    5      3.63   90    5      3.63
```

```
                   91    5      3.63   92    5      3.63   93    5      3.63
                   94    5      3.63
   3 .238    7    0
   4 .475   16   12   95    6      3.63   96    6      3.63   97    6      3.63
                   98    6      3.63   99    6      3.63  100    6      3.63
                  101    6      3.63  102    6      3.63  103    6      3.63
                  104    6      3.63  105    6      3.63  106    6      3.63
   5 .589   17    0
   21.963363.9    3    5  25.  25.
   1  1.0    8    0
   285.28    9   12   95    3      3.63   96    3      3.63   97    3      3.63
                   98    3      3.63   99    3      3.63  100    3      3.63
                  101    3      3.63  102    3      3.63  103    3      3.63
                  104    3      3.63  105    3      3.63  106    3      3.63
   3107.7   10    0
   1  1.0   11    0
   2  1.0   12    0
   31.366   13    0
   41.543   14    0
   51.625   15    0
calc     1    0    0
                                       0.4
      30
oper     1         3    1                                             1
     20.0       200.     .00001 .00184485      300.    .000000        0.0
.8907.7947.7805.7436.7100.6980.6779.6049
   10
   0.    0..0443  0.0.0444 .476.0786 .476.1470.9951.21541.163
.28391.173.35231.157.42071.145.48911.116.55761.117.62601.096
.69441.042.7629 .911.8313 .611.8655 .611.8656   0.  1.0  0.
outp 11011
endd

 data from iterative solution using the recirculation module
 time =    0.0000    dt = ******    implicit dt = 0.0000    explicit dt = 0.0750    mode =  0


 iteration  sweep          peak clad            total flow    pressure                 error
    no.      no.   --------------------------    (lbm/s)     drop(psi)   -----------------------------------
                   temp(f)  fluid  rod  ass.                              total     flow    fluid     rod
                                                                          energy            energy    energy

     1        1     348.4    16    19    1     0.809e-10   0.0088424   -0.3473   1.0051   0.1109   0.0171
              2     348.5    15    19    1                             -0.1869   1.0051   0.0240   0.0160

     2        1     348.2    16    19    1     0.487e-10   0.0093990   -0.1235   2.0106   0.0621   0.0115
              2     202.5    20    19    1                             -0.1291   2.0106   0.0053   0.0472

     3        1     201.6    22    19    1     0.200e-10   0.0093313   -0.1456   0.8532   0.0139   0.0082
              2     242.1    20    19    1                             -0.1374   0.8532   0.0026   0.0095

     4        1     241.8    20    19    1    -0.148e-11   0.0090818    0.7801   0.9176   0.0063   0.0132
              2     200.5    18    19    1                              0.6566   0.9176   0.0038   0.0092

     5        1     200.2    18    19    1    -0.138e-10   0.0089950    0.5961   1.1205   0.0133   0.0024
              2     241.6    18    19    1                              0.5632   1.1205   0.0016   0.0059

     6        1     241.8    18    19    1    -0.214e-10   0.0090224    0.5304   2.7087   0.0032   0.0011
              2     241.9    19    19    1                              0.5099   2.7087   0.0020   0.0016
```

7	1	242.7	19	19	1	-0.256e-10	0.0009269	-0.3207	8.3501	0.0191	0.0089
	2	259.0	20	19	1			-0.1876	8.3501	0.0071	0.0048
8	1	259.4	20	19	1	-0.284e-10	0.0007786	-0.1191	3.5186	0.0189	0.0019
	2	271.4	19	19	1			-0.0952	3.5186	0.0193	0.0065
9	1	271.5	19	19	1	-0.290e-10	0.0006713	-0.0866	2.5009	0.0048	0.0049
	2	273.8	19	19	1			-0.0725	2.5009	0.0195	0.0023
10	1	273.7	19	19	1	-0.222e-10	0.0006427	0.0300	3.3555	0.0064	0.0045
	2	272.1	19	19	1			0.0157	3.3555	0.0123	0.0018
11	1	272.2	19	19	1	-0.166e-10	0.0006438	0.0107	3.7082	0.0054	0.0026
	2	272.6	19	19	1			0.0091	3.7082	0.0071	0.0025
12	1	272.7	19	19	1	-0.114e-10	0.0006466	0.0090	3.1113	0.0032	0.0017
	2	273.3	19	19	1			0.0090	3.1113	0.0029	0.0016
13	1	273.3	19	19	1	-0.749e-11	0.0006496	-0.0004	2.4162	0.0019	0.0007
	2	273.9	19	19	1			0.0015	2.4162	0.0018	0.0005
14	1	273.9	19	19	1	-0.483e-11	0.0006505	0.0035	1.5469	0.0008	0.0005
	2	274.5	19	19	1			0.0042	1.5469	0.0007	0.0003
15	1	274.5	19	19	1	-0.366e-11	0.0006524	0.0050	0.5309	0.0009	0.0002
	2	274.7	19	19	1			0.0053	0.5309	0.0007	0.0003
16	1	274.7	19	19	1	-0.207e-11	0.0006569	0.0118	0.5077	0.0016	0.0005
	2	274.2	19	19	1			0.0109	0.5077	0.0014	0.0006
17	1	274.2	19	19	1	-0.860e-12	0.0006592	0.0111	0.4431	0.0005	0.0004
	2	274.2	19	19	1			0.0109	0.4431	0.0005	0.0002
18	1	274.2	19	19	1	-0.248e-12	0.0006608	0.0110	0.2744	0.0005	0.0001
	2	274.1	19	19	1			0.0110	0.2744	0.0005	0.0001
19	1	274.1	19	19	1	-0.822e-14	0.0006630	0.0124	0.2466	0.0015	0.0004
	2	273.8	19	19	1			0.0122	0.2466	0.0012	0.0005
20	1	273.8	19	19	1	0.356e-13	0.0006641	0.0126	0.2010	0.0004	0.0003
	2	273.8	19	19	1			0.0124	0.2010	0.0004	0.0002
21	1	273.8	19	19	1	0.110e-13	0.0006651	0.0125	0.1948	0.0005	0.0001
	2	273.7	19	19	1			0.0124	0.1948	0.0005	0.0001
22	1	273.7	19	19	1	-0.451e-13	0.0006665	0.0115	0.1631	0.0013	0.0003
	2	273.5	19	19	1			0.0117	0.1631	0.0011	0.0004
23	1	273.5	19	19	1	-0.113e-12	0.0006673	0.0123	0.1504	0.0004	0.0003
	2	273.5	19	19	1			0.0122	0.1504	0.0004	0.0002
24	1	273.5	19	19	1	-0.112e-12	0.0006681	0.0123	0.1840	0.0005	0.0001
	2	273.5	19	19	1			0.0123	0.1840	0.0005	0.0001
25	1	273.5	19	19	1	-0.944e-13	0.0006693	0.0106	0.1325	0.0012	0.0003
	2	273.3	19	19	1			0.0111	0.1325	0.0010	0.0004
26	1	273.3	19	19	1	-0.647e-13	0.0006698	0.0117	0.1124	0.0004	0.0003
	2	273.3	19	19	1			0.0116	0.1124	0.0004	0.0002

```
27      1     273.3    19    19    1      -0.495e-13    0.0086705      0.0118   0.1455   0.0005   0.0001
        2     273.3    19    19    1                                   0.0118   0.1455   0.0005   0.0001

28      1     273.3    19    19    1      -0.562e-13    0.0086714      0.0099   0.0985   0.0011   0.0003
        2     273.2    19    19    1                                   0.0104   0.0985   0.0009   0.0003

29      1     273.2    19    19    1      -0.738e-13    0.0086717      0.0116   0.0832   0.0004   0.0002
        2     273.2    19    19    1                                   0.0116   0.0832   0.0004   0.0001

30      1     273.2    19    19    1      -0.493e-13    0.0086724      0.0112   0.1185   0.0005   0.0001
        2     273.1    19    19    1                                   0.0113   0.1185   0.0005   0.0001
```

```
 slab temperature summary        time =    0.0000 seconds
 (assembly no. - channel no.)


axial zone    (  1)     (  2)     (  3)     (  4)     (  5)     (  6)     (  7)     (  8)     (  9)     ( 10)
 (inches)

  0.0 -  7.4  134.77    136.93    134.25    137.48    140.08    139.62    140.94    139.87    133.13    136.40
  7.4 - 14.8  136.04    138.84    135.53    139.56    142.76    142.26    143.84    142.61    134.41    138.47
 14.8 - 22.2  137.97    141.10    137.46    141.93    145.56    145.03    146.78    145.47    136.35    140.87
 22.2 - 29.6  140.50    144.26    140.01    145.23    149.47    148.92    150.89    149.48    138.90    144.23
 29.6 - 37.0  143.43    147.79    142.94    148.93    153.81    153.25    155.46    153.94    141.83    147.99
 37.0 - 44.4  146.63    151.60    146.14    152.90    158.45    157.87    160.32    158.70    145.01    152.00
 44.4 - 51.9  149.93    155.43    149.44    156.90    163.08    162.47    165.18    163.46    148.28    156.02
 51.9 - 59.3  153.23    159.21    152.73    160.83    167.62    166.99    169.95    168.12    151.54    159.96
 59.3 - 66.7  156.42    162.83    155.91    164.62    171.98    171.32    174.53    172.59    154.69    163.73
 66.7 - 74.1  159.43    166.25    158.90    168.19    176.12    175.42    178.88    176.83    157.65    167.28
 74.1 - 81.5  162.18    169.39    161.65    171.48    179.95    179.21    182.92    180.77    160.35    170.53
 81.5 - 88.9  164.63    172.19    164.08    174.43    183.42    182.65    186.61    184.35    162.74    173.45
 88.9 - 96.3  166.70    174.62    166.14    177.01    186.55    185.73    189.95    187.58    164.77    176.01
 96.3 -103.7  168.34    176.63    167.76    179.18    189.27    188.42    192.91    190.43    166.37    178.15
103.7 -111.1  169.47    178.13    168.90    180.84    191.50    190.61    195.36    192.78    167.48    179.80
111.1 -118.5  170.02    179.03    169.45    181.92    193.14    192.21    197.25    194.57    168.02    180.87
118.5 -125.9  169.86    179.22    169.31    182.28    194.07    193.12    198.43    195.68    167.88    181.26
125.9 -133.3  168.91    178.56    168.39    181.80    194.11    193.16    198.73    195.94    167.00    180.82
133.3 -140.8  166.95    176.83    166.48    180.25    193.06    192.12    197.94    195.16    165.19    179.38
140.8 -148.2  163.87    173.83    163.51    177.45    190.68    189.79    195.83    193.15    162.40    176.79
148.2 -155.6  159.12    169.24    159.02    173.14    186.90    186.14    192.40    189.94    158.31    172.94
155.6 -163.0  152.21    161.96    152.76    166.33    180.48    180.04    186.38    184.43    152.98    167.14
163.0 -170.4  141.02    151.68    143.78    157.55    173.42    173.60    180.20    176.90    146.19    160.77
170.4 -177.8  119.80    136.56    132.52    147.14    166.73    168.03    174.93    174.39    139.76    155.30
```

```
 slab temperature summary        time =    0.0000 seconds
 (assembly no. - channel no.)


axial zone    ( 11)     ( 12)     ( 13)     ( 14)     ( 15)     ( 16)     ( 17)     ( 18)     ( 19)     ( 20)
 (inches)

  0.0 -  7.4  131.39    135.24    136.34    132.60    135.08    135.41    131.65    135.79    136.87    136.01
  7.4 - 14.8  132.67    137.27    138.55    134.11    137.09    137.56    133.17    137.97    139.36    138.51
```

```
  14.8 - 22.2     134.62     139.68     141.18     136.45     139.63     140.18     135.51     140.61     142.12     141.32
  22.2 - 29.6     137.16     143.66     144.82     139.51     143.15     143.83     138.57     144.25     146.08     145.35
  29.6 - 37.0     140.08     146.83     148.91     143.63     147.11     147.93     142.07     148.34     150.46     149.77
  37.0 - 44.4     143.23     150.84     153.28     146.81     151.35     152.29     145.83     152.72     155.08     154.41
  44.4 - 51.9     146.46     154.84     157.67     150.67     155.82     156.65     149.65     157.11     159.64     158.96
  51.9 - 59.3     149.66     158.74     161.97     154.48     159.80     160.91     153.42     161.42     164.04     163.33
  59.3 - 66.7     152.73     162.45     166.09     158.14     163.81     164.97     157.03     165.55     168.22     167.46
  66.7 - 74.1     155.62     165.94     169.98     161.59     167.59     168.80     160.43     169.46     172.12     171.31
  74.1 - 81.5     158.26     169.12     173.57     164.77     171.08     172.32     163.56     173.09     175.69     174.82
  81.5 - 88.9     160.58     171.96     176.82     167.64     174.25     175.49     166.39     176.38     178.89     177.96
  88.9 - 96.3     162.55     174.44     179.73     170.17     177.08     178.32     168.87     179.35     181.72     180.72
  96.3 -103.7     164.10     176.51     182.25     172.31     179.53     180.76     170.96     181.95     184.15     183.09
 103.7 -111.1     165.16     178.09     184.31     174.01     181.53     182.74     172.61     184.10     186.09     184.95
 111.1 -118.5     165.68     179.10     185.84     175.20     183.03     184.19     173.77     185.74     187.45     186.25
 118.5 -125.9     165.54     179.43     186.75     175.84     183.94     185.03     174.38     186.80     188.13     186.86
 125.9 -133.3     164.89     178.96     186.93     175.87     184.19     185.15     174.38     187.17     187.98     186.64
 133.3 -140.8     162.98     177.51     186.27     175.25     183.68     184.44     173.74     186.76     186.82     185.42
 140.8 -148.2     160.42     174.99     184.70     174.05     182.40     182.87     172.53     185.52     184.50     183.08
 148.2 -155.6     156.78     171.33     182.30     172.27     180.47     180.50     170.74     183.55     181.12     179.71
 155.6 -163.0     152.32     165.95     178.55     170.26     177.56     176.88     168.73     180.45     175.71     174.36
 163.0 -170.4     147.20     160.39     175.02     168.30     175.01     173.60     166.80     177.71     170.66     169.53
 170.4 -177.8     143.21     156.05     172.49     167.22     173.40     171.36     165.74     175.95     166.99     166.14


   slab temperature summary          time =    0.0000 seconds
   (assembly no. - channel no.)


  axial zone      ( 21)      ( 22)      ( 23)      ( 24)      ( 25)      ( 26)      ( 27)      ( 28)      ( 29)      ( 30)
   (inches)

   0.0 -  7.4     136.97     136.20     139.56     139.11     141.50     141.28     128.98     132.04     125.97     129.89
   7.4 - 14.8     139.49     138.70     142.39     141.93     144.65     144.46     130.27     134.21     127.27     132.28
  14.8 - 22.2     142.30     141.55     145.39     144.95     147.85     147.70     132.23     136.81     129.23     135.07
  22.2 - 29.6     146.33     145.62     149.55     149.12     152.23     152.13     134.77     140.39     131.74     138.81
  29.6 - 37.0     150.80     150.13     154.19     153.70     157.12     157.06     137.65     144.25     134.57     142.73
  37.0 - 44.4     155.53     154.87     159.13     158.74     162.33     162.30     140.75     148.27     137.58     146.73
  44.4 - 51.9     160.20     159.52     164.08     163.68     167.54     167.54     143.90     152.19     140.63     150.58
  51.9 - 59.3     164.71     164.01     168.93     168.52     172.65     172.66     147.01     155.97     143.62     154.25
  59.3 - 66.7     169.00     168.26     173.60     173.17     177.59     177.60     149.99     159.52     146.48     157.67
  66.7 - 74.1     173.01     172.22     178.05     177.59     182.30     182.32     152.78     162.83     149.15     160.83
  74.1 - 81.5     176.69     175.84     182.20     181.71     186.72     186.74     155.32     165.82     151.56     163.68
  81.5 - 88.9     180.00     179.08     186.03     185.51     190.82     190.84     157.55     168.46     153.68     166.17
  88.9 - 96.3     182.95     181.97     189.54     188.99     194.82     194.63     159.43     170.74     155.45     168.30
  96.3 -103.7     185.51     184.45     192.70     192.12     198.08     198.09     160.90     172.62     156.83     170.04
 103.7 -111.1     187.58     186.45     195.42     194.82     201.10     201.12     161.90     174.01     157.76     171.28
 111.1 -118.5     189.09     187.88     197.62     197.00     203.61     203.63     162.37     174.84     158.18     171.98
 118.5 -125.9     189.93     188.65     199.22     198.57     205.49     205.51     162.22     175.01     158.02     172.02
 125.9 -133.3     189.97     188.61     200.03     199.38     206.56     206.57     161.41     174.40     157.24     171.29
 133.3 -140.8     189.04     187.62     199.93     199.23     206.63     206.64     159.81     172.89     155.75     169.69
 140.8 -148.2     187.03     185.54     198.74     198.01     205.52     205.49     157.48     170.40     153.64     167.15
 148.2 -155.6     184.05     182.51     196.61     195.83     203.32     203.23     154.27     167.01     150.83     163.82
 155.6 -163.0     179.17     177.61     192.60     191.79     198.96     198.79     150.57     162.14     147.75     159.08
 163.0 -170.4     174.79     173.26     189.11     188.26     195.14     194.89     146.64     157.73     144.66     155.11
 170.4 -177.8     171.70     170.25     186.70     185.82     192.45     192.14     144.00     154.77     142.79     152.62
```

```
slab temperature summary          time =    0.0000 seconds
(assembly no. - channel no.)


axial zone      ( 31)      ( 32)      ( 33)      ( 34)      ( 35)      ( 36)      ( 37)      ( 38)      ( 39)      ( 40)
 (inches)

  0.0 -  7.4    132.66     129.60     133.86     130.56     126.50     131.72     140.93     140.49     138.85     137.48
  7.4 - 14.8    134.82     131.13     136.08     132.85     128.04     133.94     144.31     143.91     142.22     140.90
 14.8 - 22.2    137.55     133.48     138.79     135.73     130.39     136.73     147.73     147.38     145.71     144.41
 22.2 - 29.6    141.32     136.52     142.52     139.65     133.39     140.52     152.36     152.05     150.42     149.09
 29.6 - 37.0    145.49     139.99     146.67     143.87     136.77     144.70     157.48     157.21     155.56     154.20
 37.0 - 44.4    149.85     143.67     151.06     148.22     140.33     149.05     162.87     162.63     160.94     159.51
 44.4 - 51.9    154.14     147.40     155.42     152.43     143.91     153.34     168.23     168.00     166.22     164.72
 51.9 - 59.3    158.28     151.06     159.66     156.44     147.46     157.47     173.45     173.23     171.31     169.75
 59.3 - 66.7    162.18     154.57     163.71     160.20     150.73     161.37     178.46     178.25     176.17     174.54
 66.7 - 74.1    165.82     157.85     167.52     163.68     153.83     165.02     183.23     183.02     180.77     179.06
 74.1 - 81.5    169.14     160.87     171.03     166.84     156.67     168.36     187.70     187.48     185.04     183.28
 81.5 - 88.9    172.11     163.58     174.22     169.63     159.21     171.37     191.84     191.62     188.98     187.16
 88.9 - 96.3    174.72     165.95     177.08     172.08     161.42     174.05     195.69     195.47     192.61     190.75
 96.3 -103.7    176.95     167.94     179.58     174.15     163.26     176.36     199.20     198.98     195.90     194.01
103.7 -111.1    178.71     169.50     181.63     175.74     164.68     178.24     202.28     202.07     198.77     196.85
111.1 -118.5    179.95     170.57     183.19     176.81     165.62     179.61     204.85     204.65     201.11     199.18
118.5 -125.9    180.58     171.09     184.16     177.28     166.04     180.41     206.79     206.59     202.82     200.89
125.9 -133.3    180.49     171.03     184.44     177.03     165.89     180.51     207.87     207.68     203.68     201.75
133.3 -140.8    179.59     170.34     183.94     175.97     165.13     179.83     207.91     207.71     203.49     201.58
140.8 -148.2    177.84     169.16     182.60     174.08     163.85     178.34     206.67     206.44     202.04     200.13
148.2 -155.6    175.36     167.30     180.52     171.53     162.06     176.13     204.22     203.93     199.40     197.50
155.6 -163.0    171.67     165.31     177.28     167.77     160.11     172.80     199.44     199.06     194.50     192.58
163.0 -170.4    168.48     163.42     174.47     164.71     158.30     169.98     195.24     194.77     190.26     188.32
170.4 -177.8    166.45     162.40     172.67     162.87     157.35     168.23     192.29     191.76     187.34     185.38



slab temperature summary          time =    0.0000 seconds
(assembly no. - channel no.)


axial zone      ( 51)      ( 52)      ( 53)      ( 54)      ( 55)      ( 56)      ( 57)      ( 58)      ( 59)      ( 60)
 (inches)

  0.0 -  7.4    123.31     116.32     122.27     125.64     117.91     122.96     125.34     122.16     126.27     122.37
  7.4 - 14.8    127.02     119.53     123.57     128.37     119.22     125.64     128.22     123.74     128.99     125.21
 14.8 - 22.2    130.63     122.65     125.52     131.37     121.13     128.55     131.45     126.07     132.14     128.33
 22.2 - 29.6    135.09     126.35     127.98     135.07     123.50     131.99     135.43     128.98     136.08     132.05
 29.6 - 37.0    139.63     130.17     130.72     138.81     126.12     135.45     139.49     132.20     140.18     135.79
 37.0 - 44.4    144.16     133.99     133.61     142.53     128.86     138.88     143.51     135.56     144.30     139.48
 44.4 - 51.9    148.44     137.63     136.52     146.05     131.60     142.12     147.32     138.91     148.24     142.96
 51.9 - 59.3    152.47     141.08     139.36     149.36     134.28     145.17     150.89     142.15     151.96     146.22
 59.3 - 66.7    156.24     144.31     142.06     152.42     136.82     147.98     154.19     145.23     155.43     149.23
 66.7 - 74.1    159.74     147.30     144.58     155.20     139.17     150.53     157.21     148.09     158.61     151.97
 74.1 - 81.5    162.95     150.05     146.85     157.67     141.29     152.78     159.89     150.69     161.48     154.40
 81.5 - 88.9    165.85     152.54     148.83     159.79     143.15     154.71     162.23     153.00     164.02     156.50
 88.9 - 96.3    168.50     154.78     150.48     161.57     144.69     156.29     164.23     155.00     166.23     158.27
 96.3 -103.7    170.88     156.75     151.77     162.94     145.88     157.49     165.85     156.64     168.06     159.67
103.7 -111.1    172.85     158.39     152.61     163.82     146.66     158.21     167.00     157.88     169.46     160.61
111.1 -118.5    174.39     159.63     152.99     164.18     147.00     158.42     167.61     158.66     170.34     161.05
118.5 -125.9    175.38     160.39     152.81     163.87     146.84     158.04     167.63     158.94     170.64     160.92
```

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125.9 -133.3    175.63    160.52    152.07    162.87    146.17    157.01    166.95    158.68    170.26    160.16
133.3 -140.8    174.98    159.92    150.70    161.10    144.93    155.32    165.53    157.86    169.12    158.74
140.8 -148.2    173.25    158.46    148.81    158.60    143.26    153.05    163.39    156.56    167.25    156.75
148.2 -155.6    170.56    156.14    146.36    155.54    141.12    150.38    160.73    154.81    164.79    154.37
155.6 -163.0    165.88    152.54    143.79    151.80    138.96    147.33    157.31    152.97    161.51    151.57
163.0 -170.4    162.18    149.47    141.32    149.15    136.91    145.32    155.03    151.29    159.16    149.83
170.4 -177.8    159.82    147.53    139.95    148.05    135.83    144.66    154.12    150.45    158.07    149.33



 slab temperature summary         time =    0.0000 seconds
 (assembly no. - channel no.)

axial zone      ( 91)     ( 92)     ( 93)     ( 94)     ( 95)     ( 96)     ( 97)     ( 98)     ( 99)     (100)
 (inches)

  0.0 -  7.4     92.69     89.78     89.14     89.03     73.21     72.61     71.30     70.27     70.76     70.31
  7.4 - 14.8     94.07     91.12     90.39     90.32     75.88     76.13     73.52     72.23     73.41     72.80
 14.8 - 22.2     95.84     92.83     92.05     91.99     77.75     76.94     75.21     73.80     75.27     74.59
 22.2 - 29.6     97.82     94.74     93.89     93.86     79.38     78.54     76.74     75.27     76.86     76.15
 29.6 - 37.0     99.89     96.72     95.81     95.80     80.92     80.06     78.21     76.68     78.34     77.60
 37.0 - 44.4    101.97     98.71     97.74     97.74     82.41     81.54     79.62     78.05     79.76     79.00
 44.4 - 51.9    104.00    100.66     99.63     99.65     83.86     82.97     81.00     79.38     81.13     80.36
 51.9 - 59.3    105.95    102.52    101.44    101.47     85.24     84.33     82.31     80.64     82.43     81.64
 59.3 - 66.7    107.79    104.28    103.15    103.19     86.55     85.62     83.54     81.83     83.66     82.86
 66.7 - 74.1    109.48    105.90    104.73    104.78     87.75     86.80     84.67     82.92     84.80     83.98
 74.1 - 81.5    111.02    107.37    106.15    106.22     88.83     87.87     85.70     83.91     85.82     84.98
 81.5 - 88.9    112.37    108.67    107.41    107.49     89.78     88.80     86.59     84.77     86.71     85.86
 88.9 - 96.3    113.52    109.78    108.48    108.57     90.57     89.59     87.34     85.50     87.46     86.60
 96.3 -103.7    114.44    110.68    109.34    109.44     91.18     90.20     87.93     86.07     88.04     87.18
103.7 -111.1    115.10    111.34    109.96    110.08     91.61     90.62     88.35     86.47     88.44     87.57
111.1 -118.5    115.49    111.74    110.32    110.46     91.82     90.84     88.56     86.68     88.63     87.77
118.5 -125.9    115.57    111.85    110.39    110.55     91.80     90.84     88.56     86.69     88.62     87.76
125.9 -133.3    115.31    111.64    110.16    110.33     91.54     90.59     88.33     86.47     88.37     87.53
133.3 -140.8    114.70    111.08    109.59    109.77     91.01     90.09     87.85     86.00     87.87     87.04
140.8 -148.2    113.77    110.19    108.72    108.90     90.23     89.32     87.09     85.26     87.12     86.30
148.2 -155.6    112.46    108.91    107.48    107.63     89.12     88.19     85.94     84.14     86.05     85.19
155.6 -163.0    110.93    107.36    106.02    106.14     87.75     86.72     84.31     82.64     84.70     83.73
163.0 -170.4    109.20    105.63    104.34    104.44     86.01     84.61     81.51     80.52     82.95     81.59
170.4 -177.8    107.79    104.36    103.07    103.18     84.19     81.92     75.90     78.09     81.29     78.95



 side boundary temperature summary      time =    0.0000 seconds
 boundary slab node no.   106

axial zone      (  1)     (  2)     (  3)     (  4)     (  5)     (
 (inches)

  0.0 -  7.4     59.08     57.91     52.39     52.16     25.00
  7.4 - 14.8     58.52     57.37     51.94     51.71     25.00
 14.8 - 22.2     59.23     58.05     52.52     52.28     25.00
 22.2 - 29.6     60.16     58.94     53.26     53.02     25.00
 29.6 - 37.0     61.09     59.83     54.01     53.76     25.00
 37.0 - 44.4     61.99     60.70     54.75     54.49     25.00
 44.4 - 51.9     62.86     61.53     55.45     55.19     25.00
```

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  51.9 - 59.3       63.70        62.33        56.13        55.85        25.00
  59.3 - 66.7       64.47        63.07        56.76        56.48        25.00
  66.7 - 74.1       65.19        63.76        57.34        57.05        25.00
  74.1 - 81.5       65.83        64.38        57.86        57.57        25.00
  81.5 - 88.9       66.40        64.92        58.31        58.02        25.00
  88.9 - 96.3       66.87        65.37        58.69        58.40        25.00
  96.3 -103.7       67.24        65.72        58.99        58.69        25.00
 103.7 -111.1       67.49        65.97        59.20        58.90        25.00
 111.1 -118.5       67.63        66.09        59.31        59.00        25.00
 118.5 -125.9       67.62        66.09        59.30        59.00        25.00
 125.9 -133.3       67.47        65.94        59.18        58.88        25.00
 133.3 -140.8       67.16        65.64        58.93        58.63        25.00
 140.8 -148.2       66.65        65.16        58.52        58.23        25.00
 148.2 -155.6       65.91        64.45        57.93        57.64        25.00
 155.6 -163.0       64.83        63.42        57.06        56.78        25.00
 163.0 -170.4       63.48        62.12        55.96        55.69        25.00
 170.4 -177.8       62.02        60.73        54.79        54.53        25.00




 calculated rod temperatures at time =    0.0000 seconds
 rod no.   25
 assembly   1                    (fuel type  1 - cylinder)
0rod o.d. - 0.563 (in.)     zone-(fuel dia.(in.)) -  1-(0.477)

                                                *   fuel temperatures(f.)
                                                *
   axial zone  heat flux   type          hsurf  *   fluid    clad
      (in.)   (mbtu/hr-ft2)         (b/h-f-ft2) *
    0.0 -   7.4    0.0000    1              0.9     155.2    154.0
    7.4 -  14.8    0.0000    1              0.9     157.4    163.3
   14.8 -  22.2    0.0000    1              0.9     161.4    170.3
   22.2 -  29.6    0.0000    1              0.9     167.8    181.3
   29.6 -  37.0    0.0000    1              0.9     174.9    190.1
   37.0 -  44.4    0.0000    1              0.9     182.3    198.5
   44.4 -  51.9    0.0000    1              0.9     189.5    205.8
   51.9 -  59.3    0.0000    1              0.9     196.3    212.5
   59.3 -  66.7    0.0000    1              0.9     202.7    218.6
   66.7 -  74.1    0.0000    1              0.9     208.7    224.4
   74.1 -  81.5    0.0000    1              0.9     214.4    229.7
   81.5 -  88.9    0.0000    1              0.9     219.6    234.5
   88.9 -  96.3    0.0000    1              0.9     224.4    239.0
   96.3 - 103.7    0.0000    1              1.0     228.9    243.2
  103.7 - 111.1    0.0000    1              1.0     232.9    246.9
  111.1 - 118.5    0.0000    1              1.0     236.4    249.8
  118.5 - 125.9    0.0000    1              1.0     239.2    252.0
  125.9 - 133.3    0.0000    1              1.0     241.1    252.7
  133.3 - 140.8    0.0000    1              1.0     241.8    251.9
  140.8 - 148.2    0.0000    1              1.0     240.7    248.3
  148.2 - 155.6    0.0000    1              1.0     238.6    244.9
  155.6 - 163.0    0.0000    1              1.0     231.3    229.7
  163.0 - 170.4    0.0000    1              0.9     224.1    222.1
  170.4 - 177.8    0.0000    1              0.9     217.1    214.9



 calculated rod temperatures at time =    0.0000 seconds
 rod no.   25
```

```
 assembly   3                    (fuel type  1 - cylinder)
0rod o.d. - 0.563 (in.)      zone-(fuel dia.(in.)) -  1-(0.477)

                                                     *   fuel temperatures(f.)
                                                     *
  axial zone  heat flux   type              hsurf   *   fluid     clad
     (in.)   (mbtu/hr-ft2)              (b/h-f-ft2) *
   0.0 -   7.4     0.0000    1                  0.9      155.2     154.0
   7.4 -  14.8     0.0000    1                  0.9      157.2     162.3
  14.8 -  22.2     0.0000    1                  0.9      160.7     168.5
  22.2 -  29.6     0.0000    1                  0.9      166.7     178.6
  29.6 -  37.0     0.0000    1                  0.9      173.3     186.7
  37.0 -  44.4     0.0000    1                  0.9      180.2     194.6
  44.4 -  51.9     0.0000    1                  0.9      187.0     201.5
  51.9 -  59.3     0.0000    1                  0.9      193.5     207.9
  59.3 -  66.7     0.0000    1                  0.9      199.6     213.9
  66.7 -  74.1     0.0000    1                  0.9      205.6     219.6
  74.1 -  81.5     0.0000    1                  0.9      211.1     224.8
  81.5 -  88.9     0.0000    1                  0.9      216.3     229.6
  88.9 -  96.3     0.0000    1                  0.9      221.2     234.2
  96.3 - 103.7     0.0000    1                  0.9      225.8     238.6
 103.7 - 111.1     0.0000    1                  1.0      230.0     242.4
 111.1 - 118.5     0.0000    1                  1.0      233.7     245.7
 118.5 - 125.9     0.0000    1                  1.0      236.9     248.2
 125.9 - 133.3     0.0000    1                  1.0      239.1     249.4
 133.3 - 140.8     0.0000    1                  1.0      240.3     249.3
 140.8 - 148.2     0.0000    1                  1.0      239.9     246.6
 148.2 - 155.6     0.0000    1                  1.0      238.6     244.2
 155.6 - 163.0     0.0000    1                  1.0      232.7     231.3
 163.0 - 170.4     0.0000    1                  0.9      227.0     225.3
 170.4 - 177.8     0.0000    1                  0.9      221.8     220.0



 calculated rod temperatures at time =    0.0000 seconds
 rod no.   25
 assembly   6                    (fuel type  1 - cylinder)
0rod o.d. - 0.563 (in.)      zone-(fuel dia.(in.)) -  1-(0.477)

                                                     *   fuel temperatures(f.)
                                                     *
  axial zone  heat flux   type              hsurf   *   fluid     clad
     (in.)   (mbtu/hr-ft2)              (b/h-f-ft2) *
   0.0 -   7.4     0.0000    1                  0.9      143.6     144.5
   7.4 -  14.8     0.0000    1                  0.9      148.3     153.7
  14.8 -  22.2     0.0000    1                  0.9      153.9     161.0
  22.2 -  29.6     0.0000    1                  0.9      162.7     172.5
  29.6 -  37.0     0.0000    1                  0.9      170.9     181.6
  37.0 -  44.4     0.0000    1                  0.9      178.8     190.0
  44.4 -  51.9     0.0000    1                  0.9      185.7     196.9
  51.9 -  59.3     0.0000    1                  0.9      191.8     203.0
  59.3 -  66.7     0.0000    1                  0.9      197.3     208.4
  66.7 -  74.1     0.0000    1                  0.9      202.3     213.3
  74.1 -  81.5     0.0000    1                  0.9      206.7     217.7
  81.5 -  88.9     0.0000    1                  0.9      210.7     221.6
  88.9 -  96.3     0.0000    1                  0.9      214.3     225.1
  96.3 - 103.7     0.0000    1                  0.9      217.7     228.5
 103.7 - 111.1     0.0000    1                  0.9      220.5     231.3
 111.1 - 118.5     0.0000    1                  0.9      222.9     233.5
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+6000
   1      reaload2ann  full load, vaccum, vertical validation run.
prop     5    6
        1.         1.     114.8     .0128      .249   8.4137     .0373
        2.        81.     134.6     .0154      .249    10.09     .0432
        3.       261.     179.6     .0193      .250   13.496     .0532
        4.       441.     225.0     .0230      .252    16.89     .0622
       20.      1500.    1588.0     .1380      1.24   241.30     .1130
   1  can                           14.8
   2   cu                           215.
   3   ss                            9.8
   4   pb                           22.7
   5 lpr1                           0.60
   6 lpr2                           16.4
chan    11   24    0
    177.8      90.0
   1    1   25    0    0
   1    1    0    0    1
   11.7365.8942.874    2 .175 .772    3 .175 .772    4 .175 .772    8.5245 2.62
   2.1478.8843.8843    3 .175 .738
   3.29571.7691.769    4 .175 .738    9 .175 .738
   4.29571.7691.769    5 .175 .738   10 .175 .738
   5.29571.7691.769    6 .175 .738    8 .175 .772   11 .175 .738
   6.29571.7691.769    7 .175 .738    8 .175 .772   12 .175 .738
   7.29571.7691.769   14 .175 .772    8 .175 .772   13 .175 .738
   81.7365.8942.874   14.8584 2.62
   9.1478.8843.8843   10 .175 .738
  10.29571.7691.769   11 .175 .738   15 .175 .738
  11.29571.7691.769   12 .175 .738   16 .175 .738
  12.29571.7691.769   13 .175 .738   17 .175 .738
  13.29571.7691.769   14 .175 .772   18 .175 .738
  141.7365.8942.874   18 .175 .772   19.5245 2.62
  15.1478.8843.8843   16 .175 .738
  16.29571.7691.769   17 .175 .738   20 .175 .738
  17.29571.7691.769   18 .175 .738   21 .175 .738
  18.29571.7691.769   22 .175 .738
  191.7365.8942.874   22 .175 .772   24 .175 .772   25 .175 .772
  20.1478.8843.8843   21 .175 .738
  21.29571.7691.769   22 .175 .738   23 .175 .738
  22.29571.7691.769   24 .175 .738
  23.1478.8843.8843   24 .175 .738
  24.29571.7691.769   25 .175 .738
  25.1478.8843.8843
   2    2   44    0    0
   1    1    0    0    1
   11.7365.8942.874    2 .175 .772    3 .175 .772    4 .175 .772    8.5245 2.62
   2.29571.7691.769    3 .175 .738    9 .175 .738   15 .175 .772
   3.29571.7691.769    4 .175 .738   10 .175 .738
   4.29571.7691.769    5 .175 .738   11 .175 .738
   5.29571.7691.769    6 .175 .738    8 .175 .772   12 .175 .738
   6.29571.7691.769    7 .175 .738    8 .175 .772   13 .175 .738
   7.29571.7691.769   22 .175 .772    8 .175 .772   14 .175 .738
   81.7365.8942.874   22.8584 2.62
   9.29571.7691.769   10 .175 .738   15 .175 .772   16 .175 .738
  10.29571.7691.769   11 .175 .738   17 .175 .738
  11.29571.7691.769   12 .175 .738   18 .175 .738
  12.29571.7691.769   13 .175 .738   19 .175 .738
  13.29571.7691.769   14 .175 .738   20 .175 .738
  14.29571.7691.769   22 .175 .772   21 .175 .738
  151.7365.8942.874    1.8584 2.62   16 .175 .772   23.5245 2.62
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  16.29571.7691.769   17 .175 .738   24 .175 .738
  17.29571.7691.769   18 .175 .738   25 .175 .738
  18.29571.7691.769   19 .175 .738   26 .175 .738
  19.29571.7691.769   20 .175 .738   27 .175 .738
  20.29571.7691.769   21 .175 .738   28 .175 .738
  21.29571.7691.769   22 .175 .772   29 .175 .738
  221.7365.8942.874   30.5245 2.62
  231.7365.8942.874   24 .175 .772   31 .175 .772   37.8584 2.62   38 .175 .772
  24.29571.7691.769   25 .175 .738   31 .175 .738
  25.29571.7691.769   26 .175 .738   32 .175 .738
  26.29571.7691.769   27 .175 .738   33 .175 .738
  27.29571.7691.769   28 .175 .738   34 .175 .738
  28.29571.7691.769   29 .175 .738   35 .175 .738
  29.29571.7691.769   30 .175 .772   36 .175 .738
  301.7365.8942.874   36 .175 .772   43 .175 .772   44.8584 2.62
  31.29571.7691.769   32 .175 .738   38 .175 .738
  32.29571.7691.769   33 .175 .738   39 .175 .738
  33.29571.7691.769   34 .175 .738   40 .175 .738
  34.29571.7691.769   35 .175 .738   41 .175 .738
  35.29571.7691.769   36 .175 .738   42 .175 .738
  36.29571.7691.769   43 .175 .738
  371.7365.8942.874   38 .175 .772   39 .175 .772   40 .175 .772   44.5245 2.62
  38.29571.7691.769   39 .175 .738
  39.29571.7691.769   40 .175 .738
  40.29571.7691.769   41 .175 .738
  41.29571.7691.769   42 .175 .738   44 .175 .772
  42.29571.7691.769   43 .175 .738   44 .175 .772
  43.29571.7691.769   44 .175 .772
  441.7365.8942.874
   3    1   25    0    0
   1    1    0    0    1
   4    2   44    0    0
   1    1    0    0    1
   5    2   44    0    0
   1    1    0    0    1
   6    1   25    0    0
   1    1    0    0    1
   7    2   44    0    0
   1    1    0    0    1
   8    2   44    0    0
   1    1    0    0    1
   9    3    1    0    0
   0    1    0    0    2
   116.0718.11
  10    4    1    0    0
   0    1    0    0    2
   1 5.2413.78
  11    5    1    0
   0    1    0    0    2
   122.1820.18

rods    11    1    1    0    0    1
   1    1   28
   1 .563  1.0    1 .375    2 .125
   2 .563  1.0    1 .500    2 .250    3 .250
   3 .563  1.0    1 .500    3 .250    4 .250
   4 .563  1.0    1 .250    4 .250    5 .250    8 .250
   5 .563  1.0    5 .250    6 .250    8 .500
   6 .563  1.0    6 .250    7 .250    8 .500
   7 .563  1.0    7 .250    8 .375   14 .375
```

```
 8 .563  1.0   2 .125   3 .250   9 .125
 9 .563  1.0   3 .250   4 .250   9 .250  10 .250
10 .563  1.0   4 .250   5 .250  10 .250  11 .250
11 .563  1.0   5 .250   6 .250  11 .250  12 .250
12 .563  1.0   6 .250   7 .250  12 .250  13 .250
13 .563  1.0   7 .250  13 .250  14 .500
14 .563  1.0   9 .125  10 .250  15 .125
15 .563  1.0  10 .250  11 .250  15 .250  16 .250
16 .563  1.0  11 .250  12 .250  16 .250  17 .250
17 .563  1.0  12 .250  13 .250  17 .250  18 .250
18 .563  1.0  13 .250  14 .500  18 .250
19 .563  1.0  15 .125  16 .250  20 .125
20 .563  1.0  16 .250  17 .250  20 .250  21 .250
21 .563  1.0  17 .250  18 .250  21 .250  22 .250
22 .563  1.0  14 .250  18 .250  19 .250  22 .250
23 .563  1.0  20 .125  21 .250  23 .125
24 .563  1.0  21 .250  22 .250  23 .250  24 .250
25 .563  1.0  19 .500  22 .250  24 .250
26 .563  1.0  23 .125  24 .250  25 .125
27 .563  1.0  19 .500  24 .250  25 .250
28 .563  1.0  19 .375  25 .125
 2    2   49
 1 .563  1.0   1 .375   2 .250  15 .375
 2 .563  1.0   1 .500   2 .250   3 .250
 3 .563  1.0   1 .500   3 .250   4 .250
 4 .563  1.0   1 .250   4 .250   5 .250   8 .250
 5 .563  1.0   5 .250   6 .250   8 .500
 6 .563  1.0   6 .250   7 .250   8 .500
 7 .563  1.0   7 .250   8 .375  22 .375
 8 .563  1.0   2 .250   9 .250  15 .500
 9 .563  1.0   2 .250   3 .250   9 .250  10 .250
10 .563  1.0   3 .250   4 .250  10 .250  11 .250
11 .563  1.0   4 .250   5 .250  11 .250  12 .250
12 .563  1.0   5 .250   6 .250  12 .250  13 .250
13 .563  1.0   6 .250   7 .250  13 .250  14 .250
14 .563  1.0   7 .250  14 .250  22 .500
15 .563  1.0   9 .250  15 .500  16 .250
16 .563  1.0   9 .250  10 .250  16 .250  17 .250
17 .563  1.0  10 .250  11 .250  17 .250  18 .250
18 .563  1.0  11 .250  12 .250  18 .250  19 .250
19 .563  1.0  12 .250  13 .250  19 .250  20 .250
20 .563  1.0  13 .250  14 .250  20 .250  21 .250
21 .563  1.0  14 .250  21 .250  22 .500
22 .563  1.0  15 .250  16 .250  23 .250  24 .250
23 .563  1.0  16 .250  17 .250  24 .250  25 .250
24 .563  1.0  17 .250  18 .250  25 .250  26 .250
25 .563  1.0  18 .250  19 .250  26 .250  27 .250
26 .563  1.0  19 .250  20 .250  27 .250  28 .250
27 .563  1.0  20 .250  21 .250  28 .250  29 .250
28 .563  1.0  21 .250  22 .250  29 .250  30 .250
29 .563  1.0  23 .500  24 .250  31 .250
30 .563  1.0  24 .250  25 .250  31 .250  32 .250
31 .563  1.0  25 .250  26 .250  32 .250  33 .250
32 .563  1.0  26 .250  27 .250  33 .250  34 .250
33 .563  1.0  27 .250  28 .250  34 .250  35 .250
34 .563  1.0  28 .250  29 .250  35 .250  36 .250
35 .563  1.0  29 .250  30 .500  36 .250
36 .563  1.0  23 .500  31 .250  38 .250
37 .563  1.0  31 .250  32 .250  38 .250  39 .250
38 .563  1.0  32 .250  33 .250  39 .250  40 .250
```

```
   39 .563  1.0   33 .250   34 .250   40 .250   41 .250
   40 .563  1.0   34 .250   35 .250   41 .250   42 .250
   41 .563  1.0   35 .250   36 .250   42 .250   43 .250
   42 .563  1.0   30 .500   36 .250   43 .250
   43 .563  1.0   23 .375   37 .375   38 .250
   44 .563  1.0   37 .500   38 .250   39 .250
   45 .563  1.0   37 .500   39 .250   40 .250
   46 .563  1.0   37 .250   40 .250   41 .250   44 .250
   47 .563  1.0   41 .250   42 .250   44 .500
   48 .563  1.0   42 .250   43 .250   44 .500
   49 .563  1.0   30 .375   43 .250   44 .375
    3    1   28
    4    2   49
    5    2   49
    6    1   28
    7    2   49
    8    2   49
    9    0    0
   10    0    0
   11    0    0
  3.0 .059 655. .477  10.  0.1 409. .0321000. .563
slab    66   29  166
    1                          16.78     2860. 0.20 0.50 3.02
    2                          32.09     2860. 0.20 0.20 3.02
    3                          36.02     2860. 0.20 0.20 3.02
    4                         205.40      0.00
    5                        3476.73      0.00
    6                         195.51      0.00
    7                         173.79      0.00
    8                           1.99    5227.0  0.50 0.50 1.40
    9                         164.29      0.00
   10                         145.44      0.00
   11                           1.99    5227.0  0.50 0.50 1.40
   12                         169.10      0.00
   13                         130.02      0.00
   14                         150.61      0.00
   15                         215.73      0.00
   16                         211.44      0.00
   17                         237.38      0.00
   18                         220.26      0.00
   19                        6572.72      0.00
   20                        6017.34      0.00
   21                        4102.12      0.00
   22                        4592.99      0.00
   23                        4171.11      0.00
   24                        4400.98      0.00
   25                        5628.79      0.00
   26                        4925.06      0.00
   27                        5619.14      0.00
   28                        6041.59      0.00
   29                        7061.62      0.00
   30                        5680.39      0.00
   31                          32.97      73.2
   32                          51.81      55.5
   33                          50.22      53.4
   34                          52.68      56.3
   35                          69.03      73.2
   36                         136.66     146.4
   37                          69.60      73.2
   38                          36.13     2860. 0.20 0.20 3.02
```

```
39                  975.50    73220. 0.20 0.20 .118
40                   51.58     3724. 0.20 0.20 1.88
41                   65.25    2126.7 0.50 0.20 3.18
42                   95.88   3124.94 0.50 0.20 2.16
43                  106.71    3475.2 0.50 0.20 1.94
44                   73.77   2402.54 0.50 0.20 2.81
45                   51.95   1687.27 0.50 0.20 4.00
46                   77.59   2519.84 0.50 0.20 2.68
47                   43.18   1399.31 0.50 0.20 4.83
48                   97.34   3154.34 0.50 0.20 2.14
49                  102.40      0.00
50                  114.96      0.00
51                   81.84      0.00
52                   78.53      0.00
53                  146.95    599.25 0.20 0.60 6.23
54                  165.02    672.65 0.20 0.60 5.55
55                  117.47    478.55 0.20 0.60 7.80
56                  112.70    459.60 0.20 0.60 8.13
57                    0.00      0.00
58                    0.00      0.00
59                    0.00      0.00
60                    0.00      0.00
61                 3734.31      0.00
62                 4241.14      0.00
63                 5073.39      0.00
64                  217.60      0.00
65                  246.53      0.00
66                  294.06      0.00
67                 1693.87      0.00
68                 1921.92      0.00
69                 2296.33      0.00
70                   38.21     2860. 0.20 0.20 3.02
71                  301.27    22559. 0.20 0.20 0.38
72                   43.54     3260. 0.20 0.20 2.64
73                   44.87     3375. 0.20 0.20 2.56
74                  248.74    18701. 0.20 0.20 0.46
75                   48.91     3677. 0.20 0.20 2.35
76                   16.79     2860. 0.20 0.50 3.02
77                   16.77     2860. 0.20 0.50 3.02
78                   16.86     2860. 0.20 0.50 3.02
79                   16.84     2860. 0.20 0.50 3.02
80                   17.00     2860. 0.20 0.50 3.02
81                   16.99     2860. 0.20 0.50 3.02
82                   32.19     2860. 0.20 0.20 3.02
83                   32.37     2860. 0.20 0.20 3.02
84                   32.05     2860. 0.20 0.20 3.02
85                   32.11     2860. 0.20 0.20 3.02
86                   32.28     2860. 0.20 0.20 3.02
 1   2 1.64         2    2    1    3    4
 2   1 .569         1    4    5
 3   2 1.64         2    4    1    9    4
 4   1 .569         1    5    5
 5   1 .569         2    6    2    7    5
 6   1 .569         2    8    5   10    5
 7   1 .569         1    8    2
 8   1 .569         1   13    5
 9   2 1.64         2   10   76   11    4
10   1 .569         1   12    5
11   2 1.64         2   12   76   27    4
12   1 .569         1   19    5
```

```
13    1 .569          2   14   76   16    5
14    2 1.64          2   15   77   17    4
15    1 .569          1   18    5
16    1 .569          2   21    5   17   76
17    2 1.64          2   32    4   18   77
18    1 .569          1   23    5
19    1 .569          2   21    5   20   82
20    1 .569          2   28    5   22    5
21    1 .569          1   22   82
22    1 .569          1   31    5
23    1 .569          2   25    5   24   84
24    1 .569          2   33    5   26    5
25    1 .569          1   26   84
26    1 .569          1   37    5
27    2 1.64          2   29    4   28   78
28    1 .569          1   30    5
29    2 1.64          2   53    4   30   78
30    1 .569          1   41    5
31    1 .569          2   34    5   32   78
32    2 1.64          2   33   79   35    4
33    1 .569          1   36    5
34    1 .569          2   43    5   35   78
35    2 1.64          2   36   79   58    4
36    1 .569          1   45    5
37    1 .569          2   38   85   39    5
38    1 .569          1   40    5
39    1 .569          2   47    5   40   85
40    1 .569          1   49    5
41    1 .569          2   43    5   42   83
42    1 .569          2   54    5   44    5
43    1 .569          1   44   83
44    1 .569          1   57    5
45    1 .569          2   47    5   46   86
46    1 .569          2   59    5   48    5
47    1 .569          1   48   86
48    1 .569          1   63    5
49    1 .569          2   51    5   50    3
50    3 .807          2   64   28   52   29
51    1 .569          1   52    3
52    3 .874          1   92   30
53    2 1.64          2   55    4   54   80
54    1 .569          1   56    5
55    2 1.64          2   75    6   56   80
56    1 .569          1   67    5
57    1 .569          2   60    5   58   80
58    2 1.64          2   59   81   61    4
59    1 .569          1   62    5
60    1 .569          2   69    5   61   80
61    2 1.64          2   62   81   76    9
62    1 .569          1   71    5
63    1 .569          3   65    5   64   73   66   74
64    3 .634          1   66   27
65    1 .569          2   73    5   66   75
66    3 .702          1   91   26
67    1 .569          3   69    5   68   72   70   71
68    3 .711          2   70   19   80   31
69    1 .569          1   70   70
70    3 .846          1   82   20
71    1 .569          2   73    5   72   38
72    3 .779          3   88   24   74   25   73   39
```

```
 73   1 .569          1   74   40
 74   3 .588
 75   2 .729          2   79   32   77    7
 76   2 .485          3   86   36   87   16   82   34
 77   2 .634          2   78   33   83    6
 78   3 .477          1   79   22
 79   3 .594          1   80   23
 80   3 .384
 81   3 .367          2   82   21   85   35
 82   3 .576
 83   2 .792          2   84   12   95   41
 84   2 .539          2   85   13   95   42
 85   2 .485          2   86   14   96   43
 86   3 .384
 87   2 .657          1   88   11
 88   2 .701          2   89   15   96   44
 89   2  1.0          2   90   16   97   45
 90   2 .669          3   91   37   93   17   97   46
 91   3 .452
 92   3 .452          1   94   37
 93   2 1.20          2   98   47   94   18
 94   2 .534          1   98   48
 95   3 4.09          2   96   61   99   49
 96   3 3.66          2   97   62  100   50
 97   3 5.09          2   98   63  101   51
 98   3 5.33          1  102   52
 99   4 26.2          2  100   64  103   53
100   4 23.3          2  101   65  104   54
101   4 32.8          2  102   66  105   55
102   4 34.2          1  106   56
103   3 13.9          1  104   67
104   3 12.4          1  105   68
105   3 17.5          1  106   69
106   3 18.2
  1     6.69     2.94
  2    31.59     2.12
  3    28.77     2.31
  4    38.56     1.71
  5    39.98     1.68
  6    32.54     2.04
  7    55.50     1.19
  8    19.75     3.34
  9    24.96     2.64
 10    24.23     2.71
 11    51.55     1.29
 12    20.31     3.21
 13    19.04     3.46
 14    25.67     2.56
 15    24.85     2.64
 16    40.76     1.66
 17    38.53     1.76
 18     3.33     0.00
 19     0.68     2.91
 20     0.00     2.50
 21     0.61     3.26
 22     0.39     5.02
 23     6.69     2.94
 24     6.68     2.94
 25     6.71     2.94
 26     6.69     2.94
```

```
27      6.71      2.94
28      6.75      2.94
29      6.74      2.94
 2   1    1    1    1
 4   1    1    8    1
 5   1    1   14    1
 6   1    2   15   23
 7   1    1   19    1
 8   1    2   23   23
10   1    2    1   23
12   1    2    8   23
13   1    2   37   23
15   1    3    1   24
16   1    2   44   23
18   1    3    8   24
19   1    2   22   23
20   1    4   15   25
21   1    2   30   25
22   1    4   23   25
23   1    3   14   24
24   1    5   15   26
25   1    3   19   24
26   1    5   23   26
28   1    4    1   25
30   1    4    8   25
31   1    4   37   25
33   1    5    1   26
34   1    4   44   25
36   1    5    8   26
37   1    5   37   26
38   1    6    1   27
39   1    5   44   26
40   1    6    8   27
41   1    4   22   25
42   1    7   15   28
43   1    4   30   25
44   1    7   23   28
45   1    5   22   26
46   1    8   15   29
47   1    5   30   26
48   1    8   23   29
49   1    6   14   27
50   1   11    1   12
51   1    6   19   27
52   1   11    1   13
54   1    7    1   28
56   1    7    8   28
57   1    7   37   28
59   1    8    1   29
60   1    7   44   28
62   1    8    8   29
63   1    8   37   29
64   1   11    1   14
65   1    8   44   29
66   1   11    1   15
67   1    7   22   28
68   1    9    1    7
69   1    7   30   28
70   1    9    1    8
71   1    8   22   29
```

```
    72    1   10    1    9
    73    1    8   30   29
    74    1   10    1   10
    77    1    9    1   18
    78    1    9    1    2
    79    1    9  · 1    3
    80    1    9    1    4
    81    1    9    1    5
    82    1    9    1    6
    84    1    9    1   20
    86    1   10    1   11
    87    1   10    1   19
    89    1   10    1   21
    91    1   11    1   16
    92    1   11    1   17
    93    1   11    1   22

radg    11    2    3
     1    9
     1 .301    .2     1.0098     2.0008     3.0639     4.0958     5.2567     6.1132
                      7.0895     8.0568     9.3137
     2 .846    .2     1.0000     2.0067     3.1962     4.2224   · 5.1247     6.0876
                      7.0057     8.0442     9.3122
     3.5178    .2     1.0000     2.0000     3.0355     4.1605     5.0764     6.1744
                      7.0590     8.0326     9.1037
     4.4249    .2     1.0000     2.0000     3.0000     4.0160     5.0178     6.1019
                      7.0682     8.0109     9.0749
     5.5358    .2     1.0000     2.0000     3.0000     4.0000     5.0208     6.2649
                      7.2323     8.0364     9.0167
     6.5859    .2     1.0000     2.0000     3.0000     4.0000     5.0000     6.0429
                      7.1878     8.0029     9.1107
     7.4334    .2     1.0000     2.0000     3.0000     4.0000     5.0000     6.0000
                      7.0287     8.0329     9.1873
     8.1514    .2     1.0000     2.0000     3.0000     4.0000     5.0000     6.0000
                      7.0941     8.0493     9.2149
     9.6332    .2     1.0000     2.0000     3.0000     4.0000     5.0000     6.0000
                      7.1282     8.0514     9.0031
     2    5
     1 .384    .2     1.0330     2.2872     3.0637     4.5031     5.1130
     2.7850    .2     1.0000     2.0193     3.0004     4.0029     5.2370
     3.8077    .2     1.0000     2.0000     3.0099     4.1124     5.8470
     4.8658    .2     1.0000     2.0000     3.0000     4.0773     5.0480
     5.9702    .2     1.0000     2.0000     3.0000     4.0000     5.0154
     3    7
     1.3964    .2     1.0566     2.4404     3.1161     4.2547     5.1125     6.0115
                      7.0082
     2.6315    .2     1.0000     2.0329     3.0042     4.1467     5.1500     6.0565
                      7.3333
     3.6166    .2     1.0000     2.0000     3.0167     4.2734     5.1038     6.0993
                      7.4271
     4.7680    .2     1.0000     2.0000     3.0000     4.0104     5.0028     6.0475
                      7.4699
     5.8268    .2     1.0000     2.0000     3.0000     4.0000     5.0326     6.2904
                      7.4292
     6.4206    .2     1.0000     2.0000     3.0000     4.0000     5.0000     6.0825
                      7.0205
     7 1.20    .2     1.0000     2.0000     3.0000     4.0000     5.0000     6.0000
                      7.0009
     1    1    4    2    4    5    7
     2    2    8   10   12   19   21   16   13    8    6
```

```
    3    1    4   15   18   23   25
    4    2    8   28   30   41   43   34   31   22   20
    5    2    8   33   36   46   47   39   37   26   24
    6    1    4   38   40   49   51
    7    2    8   54   56   67   69   60   57   44   42
    8    2    8   59   62   71   73   65   63   48   46
    9   -1    9   68   70   82   81   78   79   80   77   84
   10   -2    5   86   72   74   87   89
   11   -3    7   91   66   64   50   52   92   93
heat    1         1
               1.000               1.000
  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
drag    2    5
 100. -1.0               100. -1.0
  64. -1.0                64. -1.0
    1    5    0
    9    1   25  .01  2.2  .14  2.2  .25  2.2  .36  2.2  .47  2.2  .58  2.2
                 .69  2.2  .80  2.2  .99  2.2
    9    8    8  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    9   14   14  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    9   19   19  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    9    1    1  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    2    8    0
    9    1   44  .01  2.2  .14  2.2  .25  2.2  .36  2.2  .47  2.2  .58  2.2
                 .69  2.2  .80  2.2  .99  2.2
    9    1    1  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    9    8    8  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    9   15   15  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    9   22   23  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    9   30   30  .01  2.2  .14  2.2  .25  2.2  .36  2.2  .47  2.2  .58  2.2
                 .69  2.2  .80  2.2  .99  2.2
    9   37   37  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    9   44   44  .01  1.7  .14  1.7  .25  1.7  .36  1.7  .47  1.7  .58  1.7
                 .69  1.7  .80  1.7  .99  1.7
    3    1    0
    2    1    1  .01  7.5  .99  7.5
    4    1    0
    2    1    1  .01  7.5  .99  7.5
    5    1    0
    2    1    1  .01  4.0  .99  4.0
bdry   17    1    4    2
    1 2.054e-04
    2 1.173e-07 2.523e+08       .28
    3 8.729e-04
    4   3.22e-6             0.20  .78
    5   5.40e-7
    6   7.86e-5
    7   2.47e-4
    8   1.33e-7
    9 1.877e-4
   10   3.22e-6             0.20  .30
```

```
 11   2.66e-5
 12  5.222e-5
 13  3.723e-6
 14  1.068e-4
 15   2.40e-6               0.20  .30
 16   1.07e-4
 17   3.22e-6                .20  .30
  1    2   0.  14.   1.  14.
103     46.485    1
  1  1.     1   1.    1
  21.029    1   1.    2
  31.183    1   1.    3
  41.183    1   1.    4
104     45.777    1
  1  1.     1   1.    1
  21.029    1   1.    2
  31.183    1   1.    3
  41.183    1   1.    4
105     48.121    1
  1  1.     1   1.    1
  21.029    1   1.    2
  31.183    1   1.    3
  41.183    1   1.    4
106     48.289    1
  1  1.     1   1.    1
  21.029    1   1.    2
  31.183    1   1.    3
  41.183    1   1.    4
  1 385.   0.    5    0  14.  14.
  1  1.0    5    0
  2  1.0    6   94    1    5      3.63    2    5      3.63    3    5      3.63
                      4    5      3.63    5    5      3.63    6    5      3.63
                      7    5      3.63    8    5      3.63    9    5      3.63
                     10    5      3.63   11    5      3.63   12    5      3.63
                     13    5      3.63   14    5      3.63   15    5      3.63
                     16    5      3.63   17    5      3.63   18    5      3.63
                     19    5      3.63   20    5      3.63   21    5      3.63
                     22    5      3.63   23    5      3.63   24    5      3.63
                     25    5      3.63   26    5      3.63   27    5      3.63
                     28    5      3.63   29    5      3.63   30    5      3.63
                     31    5      3.63   32    5      3.63   33    5      3.63
                     34    5      3.63   35    5      3.63   36    5      3.63
                     37    5      3.63   38    5      3.63   39    5      3.63
                     40    5      3.63   41    5      3.63   42    5      3.63
                     43    5      3.63   44    5      3.63   45    5      3.63
                     46    5      3.63   47    5      3.63   48    5      3.63
                     49    5      3.63   50    5      3.63   51    5      3.63
                     52    5      3.63   53    5      3.63   54    5      3.63
                     55    5      3.63   56    5      3.63   57    5      3.63
                     58    5      3.63   59    5      3.63   60    5      3.63
                     61    5      3.63   62    5      3.63   63    5      3.63
                     64    5      3.63   65    5      3.63   66    5      3.63
                     67    5      3.63   68    5      3.63   69    5      3.63
                     70    5      3.63   71    5      3.63   72    5      3.63
                     73    5      3.63   74    5      3.63   75    5      3.63
                     76    5      3.63   77    5      3.63   78    5      3.63
                     79    5      3.63   80    5      3.63   81    5      3.63
                     82    5      3.63   83    5      3.63   84    5      3.63
                     85    5      3.63   86    5      3.63   87    5      3.63
                     88    5      3.63   89    5      3.63   90    5      3.63
```

```
                    91    5      3.63   92    5      3.63   93    5      3.63
                    94    5      3.63
   3 .238    7    0
   4 .475   16   12   95    6      3.63   96    6      3.63   97    6      3.63
                    98    6      3.63   99    6      3.63  100    6      3.63
                   101    6      3.63  102    6      3.63  103    6      3.63
                   104    6      3.63  105    6      3.63  106    6      3.63
   5 .589   17    0
   21.963363.9    3    5  14.  14.
   1  1.0    8    0
   285.28    9   12   95    3      3.63   96    3      3.63   97    3      3.63
                    98    3      3.63   99    3      3.63  100    3      3.63
                   101    3      3.63  102    3      3.63  103    3      3.63
                   104    3      3.63  105    3      3.63  106    3      3.63
   3107.7   10    0
   1  1.0   11    0
   2  1.0   12    0
   31.366   13    0
   41.543   14    0
   51.625   15    0
calc     1    0    0
                                                         0.1
      30
oper     1         3    1                                                  1
     20.0      200.     .00001 .00184485     300.   .000000       0.0
.8960.7998.7858.7479.7143.7010.6809.6079
   18
   0.   0..0443  0.0.0444 .478.0788 .478.1470.9951.21541.163
.28391.173.35231.157.42071.145.48911.118.55761.117.62601.098
.69441.042.7629 .911.8313 .611.8655 .611.8656   0.  1.0   0.
outp 11011
endd

 data from iterative solution using the recirculation module
 time =    0.0000    dt = ******    implicit dt = 0.0000    explicit dt = ******    mode =  0


 iteration  sweep          peak clad            total flow    pressure                error
    no.      no.   ---------------------------   (lbm/s)     drop(psi)    -----------------------------------
                   temp(f)  fluid  rod  ass.                                total     flow    fluid     rod
                                                                            energy            energy   energy

     1        1     451.1    18     19    1    0.783e-10  -0.0000005    -0.3142  0.6645  0.1149  0.0194
              2     451.6    17     19    1                              -0.1186  0.6645  0.0458  0.0225

     2        1     453.5    18     19    1    0.457e-10   0.0000000    -0.0068  0.2839  0.0858  0.0278
              2     454.7    16     19    1                              -0.0404  0.2839  0.0384  0.0133

     3        1     455.4    15     19    1    0.259e-10   0.0000000    -0.0342  0.0547  0.0338  0.0079
              2     455.8    15     19    1                              -0.0453  0.0547  0.0282  0.0062

     4        1     454.5    15     19    1    0.178e-10   0.0000000     0.1442  0.0089  0.0212  0.0082
              2     441.3    14     19    1                               0.1113  0.0089  0.0182  0.0053

     5        1     438.8    14     19    1    0.928e-11   0.0000000     0.0936  0.0026  0.0112  0.0019
              2     436.6    14     19    1                               0.0807  0.0026  0.0035  0.0012

     6        1     435.6    14     19    1    0.346e-11   0.0000000     0.0722  0.0007  0.0030  0.0010
              2     434.7    14     19    1                               0.0677  0.0007  0.0026  0.0007
```

```
  7        1     433.9    14    19    1     0.179e-12    0.0000000     0.0236   0.0004   0.0060   0.0018
           2     431.3    13    19    1                                0.0271   0.0004   0.0022   0.0014

  8        1     430.8    12    19    1    -0.767e-12    0.0000000     0.0279   0.0004   0.0022   0.0009
           2     430.3    12    19    1                                0.0258   0.0004   0.0022   0.0005

  9        1     429.9    12    19    1    -0.884e-12    0.0000000     0.0235   0.0003   0.0022   0.0006
           2     429.4    12    19    1                                0.0218   0.0003   0.0022   0.0004

 10        1     429.0    12    19    1    -0.620e-12    0.0000000     0.0168   0.0002   0.0031   0.0009
           2     427.9    12    19    1                                0.0154   0.0002   0.0021   0.0007

 11        1     427.5    12    19    1    -0.326e-12    0.0000000     0.0142   0.0001   0.0022   0.0005
           2     427.1    12    19    1                                0.0124   0.0001   0.0022   0.0003

 12        1     426.9    12    19    1    -0.132e-12    0.0000000     0.0165   0.0001   0.0022   0.0004
           2     426.5    12    19    1                                0.0093   0.0001   0.0022   0.0003

 13        1     426.2    12    19    1    -0.674e-13    0.0000000     0.0107   0.0001   0.0025   0.0005
           2     425.3    12    19    1                                0.0086   0.0001   0.0021   0.0004

 14        1     425.2    12    19    1    -0.144e-13    0.0000000     0.0073   0.0000   0.0021   0.0003
           2     424.8    12    19    1                                0.0057   0.0000   0.0021   0.0002

 15        1     424.7    12    19    1     0.297e-14    0.0000000     0.0042   0.0000   0.0021   0.0002
           2     424.4    11    19    1                                0.0031   0.0000   0.0021   0.0002

 16        1     424.2    12    19    1    -0.693e-14    0.0000000     0.0077   0.0000   0.0025   0.0004
           2     423.9    11    19    1                                0.0053   0.0000   0.0021   0.0003

 17        1     423.7    11    19    1    -0.399e-14    0.0000000     0.0039   0.0000   0.0021   0.0002
           2     423.7    11    19    1                                0.0025   0.0000   0.0021   0.0001

 18        1     423.4    11    19    1    -0.323e-14    0.0000000     0.0012   0.0000   0.0021   0.0002
           2     423.4    11    19    1                                0.0003   0.0000   0.0021   0.0002



 slab temperature summary        time =    0.0000 seconds
 (assembly no. - channel no.)


axial zone     (  1)      (  2)      (  3)      (  4)      (  5)      (  6)      (  7)      (  8)      (  9)      ( 10)
 (inches)

 0.0 -  7.4    252.24     251.00     251.42     250.03     247.57     246.64     246.05     244.45     249.77     247.47
 7.4 - 14.8    255.85     259.79     255.10     260.44     264.04     262.74     264.54     261.52     253.47     258.02
14.8 - 22.2    262.10     268.51     261.39     270.30     277.95     276.47     279.98     276.14     259.75     268.04
22.2 - 29.6    268.57     277.04     267.91     280.72     292.39     290.72     295.92     291.31     266.26     278.57
29.6 - 37.0    275.76     286.25     275.11     289.71     303.52     301.77     307.89     302.95     273.41     287.62
37.0 - 44.4    281.83     292.99     281.18     296.76     311.78     310.00     316.64     311.58     279.45     294.70
44.4 - 51.9    287.59     298.83     286.92     302.67     318.00     316.22     323.01     317.94     285.14     300.58
51.9 - 59.3    291.86     303.02     291.18     306.85     322.20     320.42     327.23     322.20     289.36     304.73
59.3 - 66.7    295.43     306.45     294.72     310.22     325.39     323.60     330.34     325.32     292.86     308.03
66.7 - 74.1    297.37     308.28     296.65     311.99     326.98     325.19     331.86     326.85     294.76     309.76
74.1 - 81.5    298.40     309.18     297.67     312.81     327.55     325.74     332.30     327.28     295.75     310.52
81.5 - 88.9    297.62     308.24     296.88     311.81     326.30     324.51     330.96     325.95     294.97     309.50
88.9 - 96.3    295.88     306.46     295.14     309.99     324.33     322.52     328.90     323.87     293.22     307.66
```

```
 96.3 -103.7     292.06     302.65     291.33     306.17     320.44     318.64     324.98     319.93     289.45     303.87
103.7 -111.1     287.27     297.78     286.55     301.26     315.34     313.53     319.78     314.74     284.70     299.00
111.1 -118.5     280.10     290.47     279.42     293.90     307.69     305.93     312.04     307.08     277.65     291.73
118.5 -125.9     272.00     282.10     271.36     285.43     298.70     296.98     302.87     298.02     269.68     283.35
125.9 -133.3     261.38     270.90     260.81     274.03     286.42     284.81     290.30     285.74     259.30     272.15
133.3 -140.8     249.88     258.48     249.41     261.31     272.35     270.91     275.80     271.68     248.12     259.68
140.8 -148.2     235.99     243.06     235.71     245.47     254.60     253.47     257.48     254.13     234.83     244.34
148.2 -155.6     221.00     226.84     221.11     228.92     236.22     235.51     238.59     236.21     220.94     228.63
155.6 -163.0     203.21     204.51     204.33     206.01     209.29     209.62     210.67     210.49     205.66     207.73
163.0 -170.4     181.65     183.75     186.14     187.31     192.39     193.97     194.76     196.01     190.89     193.20
170.4 -177.8     146.97     157.73     166.60     168.75     179.89     183.51     184.55     187.20     178.77     182.98
```

```
 slab temperature summary         time =    0.0000 seconds
 (assembly no. - channel no.)


axial zone       ( 11)      ( 12)      ( 13)      ( 14)      ( 15)      ( 16)      ( 17)      ( 18)      ( 19)      ( 20)
 (inches)

  0.0 -   7.4    247.37     245.52     239.66     237.75     235.82     237.84     235.96     233.55     241.45     240.19
  7.4 -  14.8    251.03     255.78     251.77     243.62     246.48     249.58     241.85     246.02     258.21     254.76
 14.8 -  22.2    257.22     265.55     263.54     252.34     257.64     261.05     250.56     258.60     268.89     267.28
 22.2 -  29.6    263.65     275.86     278.05     261.69     269.69     273.30     259.88     271.95     282.21     280.45
 29.6 -  37.0    270.71     284.75     286.46     270.79     279.99     283.54     268.93     282.95     292.69     290.83
 37.0 -  44.4    276.67     291.76     294.60     278.37     288.20     291.59     276.47     291.50     300.64     298.72
 44.4 -  51.9    282.27     297.56     300.88     284.65     294.55     297.82     282.69     297.90     306.69     304.73
 51.9 -  59.3    286.44     301.68     305.24     289.18     298.99     302.16     287.17     302.28     310.84     308.86
 59.3 -  66.7    289.87     304.94     308.37     292.41     302.88     305.26     290.36     305.27     313.94     311.93
 66.7 -  74.1    291.74     306.65     309.91     294.05     303.60     306.78     291.97     306.70     315.50     313.48
 74.1 -  81.5    292.70     307.39     310.31     294.49     303.91     307.16     292.40     306.93     316.00     313.97
 81.5 -  88.9    291.92     306.38     309.05     293.35     302.63     305.91     291.25     305.59     314.78     312.76
 88.9 -  96.3    290.18     304.54     306.88     291.12     300.38     303.74     289.03     303.32     312.79     310.77
 96.3 -103.7     286.46     300.78     302.95     287.15     296.43     299.84     285.09     299.39     308.97     306.98
103.7 -111.1     281.77     295.96     297.82     282.03     291.26     294.74     280.01     294.21     303.96     301.99
111.1 -118.5     274.83     288.77     290.48     274.88     283.99     287.47     272.93     286.92     296.61     294.78
118.5 -125.9     267.01     280.51     281.88     266.61     275.46     278.96     264.72     278.26     287.99     286.15
125.9 -133.3     256.86     269.52     270.64     256.25     264.52     267.90     254.45     267.06     276.45     274.73
133.3 -140.8     246.01     257.36     258.11     245.08     252.42     255.62     243.37     254.48     263.41     261.86
140.8 -148.2     233.26     242.50     243.15     232.53     238.29     241.03     230.92     239.61     247.39     246.10
148.2 -155.6     220.22     227.51     228.39     220.33     224.64     226.77     218.82     225.00     231.42     230.45
155.6 -163.0     206.46     207.88     209.51     208.57     208.32     208.75     207.17     207.00     209.06     208.73
163.0 -170.4     194.33     195.04     198.89     200.39     199.42     198.90     199.08     197.50     197.12     197.38
170.4 -177.8     186.00     188.88     193.12     196.16     195.06     193.85     194.93     193.01     190.66     191.49
```

```
 slab temperature summary         time =    0.0000 seconds
 (assembly no. - channel no.)


axial zone       ( 21)      ( 22)      ( 23)      ( 24)      ( 25)      ( 26)      ( 27)      ( 28)      ( 29)      ( 30)
 (inches)

  0.0 -   7.4    238.93     237.62     227.87     225.68     224.16     220.24     244.17     241.14     240.32     238.27
  7.4 -  14.8    254.16     252.64     247.16     245.06     246.68     243.13     247.76     250.96     243.81     247.89
 14.8 -  22.2    267.38     265.71     264.90     262.96     267.16     264.09     253.81     260.35     249.69     257.04
```

22.2 - 29.6	281.33	279.49	283.14	281.29	287.90	285.19	260.11	270.27	255.81	266.74
29.6 - 37.0	292.25	290.30	296.81	295.01	302.99	300.48	267.01	278.87	262.52	275.15
37.0 - 44.4	300.54	298.53	306.76	304.96	313.66	311.23	272.86	285.68	268.23	281.82
44.4 - 51.9	306.73	304.68	313.47	311.64	320.53	318.08	278.34	291.33	273.56	287.36
51.9 - 59.3	310.95	308.87	317.75	315.88	324.76	322.24	282.43	295.37	277.55	291.33
59.3 - 66.7	314.00	311.90	320.47	318.55	327.31	324.70	285.78	298.53	280.81	294.43
66.7 - 74.1	315.49	313.38	321.64	319.69	328.33	325.66	287.61	300.20	282.59	296.06
74.1 - 81.5	315.88	313.76	321.57	319.59	328.10	325.37	288.53	300.69	283.46	296.73
81.5 - 88.9	314.58	312.47	319.99	318.02	326.40	323.66	287.75	299.90	282.69	295.74
88.9 - 96.3	312.48	310.38	317.61	315.63	323.96	321.21	286.02	298.07	280.98	293.93
96.3 -103.7	308.62	306.53	313.68	311.74	320.05	317.35	282.36	294.39	277.40	290.31
103.7 -111.1	303.52	301.46	308.36	306.44	314.66	312.00	277.75	289.65	272.88	285.64
111.1 -118.5	296.14	294.13	300.81	298.94	307.00	304.41	270.97	282.69	266.29	278.81
118.5 -125.9	287.44	285.50	291.53	289.70	297.42	294.84	263.33	274.67	258.05	270.96
125.9 -133.3	275.86	274.03	279.18	277.39	284.49	281.93	253.49	264.11	249.35	260.66
133.3 -140.8	262.78	261.09	264.64	262.87	268.95	266.31	243.03	252.51	239.31	249.36
140.8 -148.2	246.82	245.34	246.86	245.10	249.67	246.92	230.89	238.55	227.79	235.87
148.2 -155.6	231.05	229.80	228.74	226.91	229.64	226.61	218.74	224.79	216.46	222.69
155.6 -163.0	209.15	208.35	204.25	202.46	202.04	198.76	206.38	207.22	205.25	205.96
163.0 -170.4	198.06	197.57	192.63	190.79	189.20	185.72	196.20	196.78	196.45	196.35
170.4 -177.8	192.44	192.22	187.59	185.74	183.82	180.28	189.97	191.03	191.43	191.26

slab temperature summary   time =   0.0000 seconds
(assembly no. - channel no.)

axial zone (inches)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)
0.0 - 7.4	233.12	232.41	227.60	229.82	227.46	222.81	208.06	202.35	201.44	193.33
7.4 - 14.8	244.37	238.23	240.42	240.83	233.11	235.09	232.55	227.28	225.05	216.93
14.8 - 22.2	255.42	246.80	253.33	251.60	241.39	247.52	255.17	250.41	246.87	238.87
22.2 - 29.6	267.24	255.97	266.88	263.15	250.27	260.57	277.70	273.35	268.60	260.66
29.6 - 37.0	277.15	264.85	277.91	272.83	258.86	271.24	293.72	289.57	284.04	276.05
37.0 - 44.4	284.99	272.25	286.42	280.51	266.04	279.49	304.75	300.67	294.69	286.62
44.4 - 51.9	291.06	278.34	292.68	286.43	271.93	285.56	311.47	307.32	301.15	292.93
51.9 - 59.3	295.29	282.72	296.92	290.58	276.18	289.70	315.40	311.16	304.93	296.58
59.3 - 66.7	298.29	285.83	299.77	293.50	279.18	292.46	317.57	313.20	306.99	298.48
66.7 - 74.1	299.78	287.40	301.12	294.95	280.69	293.76	318.31	313.86	307.68	299.08
74.1 - 81.5	300.12	287.79	301.27	295.27	281.05	293.89	317.82	313.29	307.17	298.49
81.5 - 88.9	298.89	286.66	299.93	294.06	279.94	292.58	316.05	311.52	305.45	296.77
88.9 - 96.3	296.74	284.46	297.67	291.93	277.77	290.34	313.60	309.06	303.04	294.38
96.3 -103.7	292.92	280.59	293.84	288.18	274.00	286.61	309.90	305.43	299.46	290.91
103.7 -111.1	287.92	275.59	288.75	283.26	269.12	281.63	304.67	300.26	294.38	285.93
111.1 -118.5	280.84	268.65	281.64	276.34	262.38	274.71	297.31	293.01	287.29	279.04
118.5 -125.9	272.55	260.59	273.12	268.21	254.53	266.41	287.82	283.57	278.11	270.02
125.9 -133.3	261.85	250.53	262.12	257.75	244.80	255.75	274.94	270.76	265.71	257.87
133.3 -140.8	249.97	239.68	249.64	246.16	234.20	243.65	259.00	254.77	250.35	242.67
140.8 -148.2	235.98	227.49	234.88	232.55	222.51	229.42	239.09	234.76	231.19	223.74
148.2 -155.6	222.38	215.85	220.23	219.38	211.09	215.27	217.80	213.22	210.70	203.33
155.6 -163.0	205.42	204.28	202.22	202.98	200.16	198.07	188.67	183.80	182.74	175.64
163.0 -170.4	196.35	196.42	192.73	194.33	192.61	188.91	174.97	169.91	169.57	162.50
170.4 -177.8	191.88	192.40	188.30	190.14	188.76	184.64	169.36	164.25	164.17	157.13

```
slab temperature summary          time =    0.0000 seconds
(assembly no. - channel no.)

axial zone     ( 51)     ( 52)     ( 53)     ( 54)     ( 55)     ( 56)     ( 57)     ( 58)     ( 59)     ( 60)
 (inches)

  0.0 -  7.4   156.79    143.71    235.73    232.00    230.61    228.09    221.78    220.99    213.74    216.91
  7.4 - 14.8   174.46    157.46    239.12    240.95    233.89    236.39    231.99    226.37    225.20    226.42
 14.8 - 22.2   191.66    170.91    244.77    249.47    239.32    244.32    241.97    234.24    236.65    235.72
 22.2 - 29.6   207.63    184.22    250.80    258.53    245.00    252.77    252.70    242.69    248.77    245.76
 29.6 - 37.0   219.35    193.96    257.15    266.46    251.22    260.28    261.74    250.87    258.67    254.31
 37.0 - 44.4   227.53    200.90    262.69    272.82    256.58    266.39    268.97    257.73    266.39    261.22
 44.4 - 51.9   232.33    205.07    267.86    278.12    261.56    271.52    274.57    263.36    272.09    266.60
 51.9 - 59.3   235.14    207.59    271.73    281.95    265.31    275.27    278.53    267.44    276.00    270.44
 59.3 - 66.7   236.46    208.75    274.88    284.92    268.34    278.17    281.30    270.30    278.59    273.12
 66.7 - 74.1   236.82    209.09    276.60    286.50    270.00    279.72    282.68    271.74    279.82    274.47
 74.1 - 81.5   236.16    208.46    277.43    287.12    270.78    280.33    282.96    272.05    279.91    274.74
 81.5 - 88.9   234.74    207.21    276.66    286.17    270.02    279.42    281.80    270.97    278.65    273.61
 88.9 - 96.3   232.63    205.24    274.97    284.39    268.36    277.66    279.72    268.85    276.49    271.58
 96.3 -103.7   229.86    202.72    271.49    280.89    264.97    274.25    276.14    265.22    272.93    268.10
103.7 -111.1   225.77    199.00    267.08    276.37    260.68    269.82    271.40    260.49    268.16    263.49
111.1 -118.5   220.45    194.33    260.69    269.83    254.50    263.47    264.82    254.02    261.62    257.14
118.5 -125.9   213.29    188.02    253.49    262.30    247.54    256.16    257.08    246.47    253.76    249.66
125.9 -133.3   204.06    180.18    244.35    252.55    238.77    246.79    247.23    237.16    243.76    240.23
133.3 -140.8   192.32    170.22    234.73    241.92    229.55    236.61    236.31    227.07    232.42    229.80
140.8 -148.2   178.10    158.56    223.83    229.42    219.21    224.76    223.63    215.90    219.19    217.80
148.2 -155.6   162.61    146.65    213.26    217.38    209.25    213.43    211.40    205.03    206.13    206.27
155.6 -163.0   142.41    130.31    203.02    202.45    199.79    199.70    196.41    194.71    190.22    192.40
163.0 -170.4   132.46    121.94    195.21    194.14    192.67    191.98    188.49    187.55    181.83    184.96
170.4 -177.8   128.31    118.39    190.95    189.96    188.86    188.09    184.67    183.92    177.91    181.35
```

```
slab temperature summary          time =    0.0000 seconds
(assembly no. - channel no.)

axial zone     ( 91)     ( 92)     ( 93)     ( 94)     ( 95)     ( 96)     ( 97)     ( 98)     ( 99)     (100)
 (inches)

  0.0 -  7.4    99.97     96.82     95.27     95.62     74.21     73.56     72.14     71.12     71.25     70.76
  7.4 - 14.8   102.94     99.94     97.88     98.47     78.03     77.21     75.52     74.26     75.01     74.36
 14.8 - 22.2   106.28    103.45    100.90    101.71     80.59     79.72     77.93     76.58     77.52     76.81
 22.2 - 29.6   109.95    107.28    104.27    105.30     82.99     82.11     80.27     78.90     79.84     79.10
 29.6 - 37.0   112.85    110.23    106.91    108.09     84.68     83.78     81.90     80.50     81.42     80.67
 37.0 - 44.4   115.43    112.82    109.30    110.58     86.28     85.37     83.45     82.03     82.93     82.17
 44.4 - 51.9   117.08    114.40    110.78    112.08     87.20     86.28     84.30     82.84     83.77     82.99
 51.9 - 59.3   118.35    115.61    111.93    113.25     87.99     87.04     85.03     83.53     84.50     83.70
 59.3 - 66.7   118.84    116.02    112.32    113.64     88.19     87.21     85.15     83.62     84.64     83.82
 66.7 - 74.1   119.03    116.16    112.46    113.77     88.25     87.26     85.17     83.62     84.68     83.85
 74.1 - 81.5   118.53    115.61    111.92    113.23     87.76     86.76     84.65     83.08     84.19     83.35
 81.5 - 88.9   117.83    114.90    111.25    112.54     87.23     86.23     84.11     82.54     83.67     82.82
 88.9 - 96.3   116.43    113.51    109.88    111.16     86.12     85.12     83.01     81.44     82.58     81.74
 96.3 -103.7   114.96    112.09    108.50    109.76     85.07     84.09     82.01     80.47     81.60     80.77
103.7 -111.1   112.66    109.84    106.31    107.56     83.38     82.41     80.36     78.84     79.97     79.16
111.1 -118.5   110.38    107.65    104.22    105.43     81.89     80.95     78.97     77.50     78.59     77.80
```

```
118.5 -125.9    107.20    104.52    101.22    102.38     79.70     78.78     76.85     75.41     76.50     75.73
125.9 -133.3    104.12    101.53     98.44     99.51     77.87     76.98     75.13     73.75     74.81     74.07
133.3 -140.8    100.22     97.63     94.82     95.77     75.40     74.54     72.74     71.40     72.49     71.76
140.8 -148.2     96.60     94.02     91.57     92.37     73.44     72.60     70.87     69.57     70.68     69.98
148.2 -155.6     92.60     89.94     87.91     88.52     71.14     70.30     68.60     67.32     68.53     67.03
155.6 -163.0     89.17     86.41     84.92     85.29     69.44     68.58     66.85     65.64     66.97     66.23
163.0 -170.4     86.56     83.78     82.56     82.80     67.97     66.97     65.01     64.09     65.59     64.71
170.4 -177.8     85.20     82.49     81.36     81.57     67.36     66.06     63.02     63.35     64.90     63.65
```

```
  side boundary temperature summary     time =    0.0000 seconds
  boundary slab node no.   100


 axial zone     (  1)      (  2)      (  3)      (  4)      (  5)      (
  (inches)

  0.0 -  7.4     56.74      55.22      48.47      48.17      14.00
  7.4 - 14.8     56.32      54.81      48.13      47.83      14.00
 14.8 - 22.2     57.66      56.10      49.21      48.90      14.00
 22.2 - 29.6     58.80      57.18      50.14      49.82      14.00
 29.6 - 37.0     60.04      58.37      51.13      50.80      14.00
 37.0 - 44.4     60.73      59.03      51.71      51.37      14.00
 44.4 - 51.9     61.40      59.68      52.24      51.89      14.00
 51.9 - 59.3     61.60      59.87      52.41      52.07      14.00
 59.3 - 66.7     61.77      60.03      52.53      52.19      14.00
 66.7 - 74.1     61.53      59.80      52.36      52.02      14.00
 74.1 - 81.5     61.31      59.59      52.17      51.82      14.00
 81.5 - 88.9     60.70      59.01      51.67      51.34      14.00
 88.9 - 96.3     60.26      58.53      51.26      50.93      14.00
 96.3 -103.7     59.24      57.61      50.49      50.17      14.00
103.7 -111.1     58.52      56.92      49.96      49.58      14.00
111.1 -118.5     57.25      55.70      48.89      48.58      14.00
118.5 -125.9     56.34      54.83      48.13      47.83      14.00
125.9 -133.3     54.84      53.39      46.93      46.65      14.00
133.3 -140.8     53.79      52.39      46.07      45.79      14.00
140.8 -148.2     52.26      50.92      44.84      44.57      14.00
148.2 -155.6     51.20      49.91      43.96      43.71      14.00
155.6 -163.0     49.94      48.70      42.95      42.70      14.00
163.0 -170.4     49.08      47.87      42.25      42.01      14.00
170.4 -177.8     48.45      47.27      41.74      41.51      14.00
```

```
 calculated rod temperatures at time =    0.0000 seconds
 rod no.   25
 assembly   1                    (fuel type  1 - cylinder)
0rod o.d. - 0.563 (in.)     zone-(fuel dia.(in.)) -  1-(0.477)

                                             *   fuel temperatures(f.)
                                             *
  axial zone  heat flux   type          hsurf  *   fluid    clad
     (in.)   (mbtu/hr-ft2)           (b/h-f-ft2) *
   0.0 -   7.4    0.0000     1             0.3     247.4    247.2
   7.4 -  14.8    0.0000     1             0.3     298.9    306.6
  14.8 -  22.2    0.0000     1             0.3     323.8    333.4
  22.2 -  29.6    0.0000     1             0.3     354.8    368.1
  29.6 -  37.0    0.0000     1             0.3     370.0    383.7
```

```
  37.0 -  44.4    0.0000    1              0.3     380.4    394.8
  44.4 -  51.9    0.0000    1              0.3     385.9    399.8
  51.9 -  59.3    0.0000    1              0.3     389.0    402.9
  59.3 -  66.7    0.0000    1              0.3     391.2    404.7
  66.7 -  74.1    0.0000    1              0.3     392.0    405.6
  74.1 -  81.5    0.0000    1              0.3     392.0    405.3
  81.5 -  88.9    0.0000    1              0.3     390.0    403.4
  88.9 -  96.3    0.0000    1              0.3     388.3    401.5
  96.3 - 103.7    0.0000    1              0.3     385.0    398.6
 103.7 - 111.1    0.0000    1              0.3     380.3    393.7
 111.1 - 118.5    0.0000    1              0.3     372.8    386.6
 118.5 - 125.9    0.0000    1              0.3     363.9    377.3
 125.9 - 133.3    0.0000    1              0.3     349.9    363.2
 133.3 - 140.8    0.0000    1              0.3     332.8    344.9
 140.8 - 148.2    0.0000    1              0.3     306.2    318.9
 148.2 - 155.6    0.0000    1              0.3     285.9    295.3
 155.6 - 163.0    0.0000    1              0.3     209.2    209.1
 163.0 - 170.4    0.0000    1              0.2     192.2    192.0
 170.4 - 177.8    0.0000    1              0.2     179.0    178.3



 calculated rod temperatures at time =    0.0000 seconds
 rod no.   25
 assembly   3                    (fuel type  1 - cylinder)
0rod o.d. - 0.563 (in.)     zone-(fuel dia.(in.)) -  1-(0.477)

                                                 *  fuel temperatures(f.)
                                                 *
   axial zone  heat flux   type           hsurf  *  fluid    clad
      (in.)   (mbtu/hr-ft2)          (b/h-f-ft2) *
    0.0 -   7.4    0.0000    1              0.3     227.3    227.6
    7.4 -  14.8    0.0000    1              0.3     279.8    287.1
   14.8 -  22.2    0.0000    1              0.3     307.6    316.6
   22.2 -  29.6    0.0000    1              0.3     340.9    352.9
   29.6 -  37.0    0.0000    1              0.3     358.0    370.3
   37.0 -  44.4    0.0000    1              0.3     369.7    382.3
   44.4 -  51.9    0.0000    1              0.3     375.6    387.9
   51.9 -  59.3    0.0000    1              0.3     378.9    391.1
   59.3 -  66.7    0.0000    1              0.3     380.7    392.7
   66.7 -  74.1    0.0000    1              0.3     381.3    393.3
   74.1 -  81.5    0.0000    1              0.3     380.8    392.5
   81.5 -  88.9    0.0000    1              0.3     378.6    390.4
   88.9 -  96.3    0.0000    1              0.3     376.5    388.2
   96.3 - 103.7    0.0000    1              0.3     373.2    385.1
  103.7 - 111.1    0.0000    1              0.3     368.2    380.0
  111.1 - 118.5    0.0000    1              0.3     360.9    372.9
  118.5 - 125.9    0.0000    1              0.3     351.7    363.5
  125.9 - 133.3    0.0000    1              0.3     337.6    349.4
  133.3 - 140.8    0.0000    1              0.3     320.2    331.1
  140.8 - 148.2    0.0000    1              0.3     294.2    303.8
  148.2 - 155.6    0.0000    1              0.3     273.9    282.7
  155.6 - 163.0    0.0000    1              0.3     203.8    204.1
  163.0 - 170.4    0.0000    1              0.2     192.0    192.5
  170.4 - 177.8    0.0000    1              0.2     186.9    187.5
```

```
 calculated rod temperatures at time =    0.0000 seconds
 rod no.   25
 assembly   6                    (fuel type  1 - cylinder)
0rod o.d. - 0.563 (in.)     zone-(fuel dia.(in.)) -  1-(0.477)

                                                  *   fuel temperatures(f.)
                                                  *
   axial zone  heat flux   type           hsurf   *   fluid     clad
      (in.)   (mbtu/hr-ft2)             (b/h-f-ft2) *
    0.0 -   7.4    0.0000    1               0.2      169.5     171.4
    7.4 -  14.8    0.0000    1               0.3      224.8     235.4
   14.8 -  22.2    0.0000    1               0.3      253.5     266.7
   22.2 -  29.6    0.0000    1               0.3      287.4     304.3
   29.6 -  37.0    0.0000    1               0.3      303.9     321.7
   37.0 -  44.4    0.0000    1               0.3      314.8     333.2
   44.4 -  51.9    0.0000    1               0.3      319.5     337.7
   51.9 -  59.3    0.0000    1               0.3      321.8     339.9
   59.3 -  66.7    0.0000    1               0.3      322.7     340.6
   66.7 -  74.1    0.0000    1               0.3      322.7     340.5
   74.1 -  81.5    0.0000    1               0.3      321.6     339.3
   81:5 -  88.9    0.0000    1               0.3      319.5     337.0
   88.9 -  96.3    0.0000    1               0.3      317.6     335.1
   96.3 - 103.7    0.0000    1               0.3      315.0     332.6
  103.7 - 111.1    0.0000    1               0.3      310.9     328.4
  111.1 - 118.5    0.0000    1               0.3      305.0     322.4
  118.5 - 125.9    0.0000    1               0.3      297.1     314.2
  125.9 - 133.3    0.0000    1               0.3      284.9     301.3
  133.3 - 140.8    0.0000    1               0.3      268.9     284.2
  140.8 - 148.2    0.0000    1               0.3      244.3     257.5
  148.2 - 155.6    0.0000    1               0.3      225.2     237.0
  155.6 - 163.0    0.0000    1               0.2      154.0     155.7
  163.0 - 170.4    0.0000    1               0.2      142.6     144.5
  170.4 - 177.8    0.0000    1               0.2      138.2     139.6


 calculated rod temperatures at time =    0.0000 seconds
 rod no.   25
 assembly   7                    (fuel type  1 - cylinder)
0rod o.d. - 0.563 (in.)     zone-(fuel dia.(in.)) -  1-(0.477)

                                                  *   fuel temperatures(f.)
                                                  *
   axial zone  heat flux   type           hsurf   *   fluid     clad
      (in.)   (mbtu/hr-ft2)             (b/h-f-ft2) *
    0.0 -   7.4    0.0000    1               0.3      224.5     224.3
    7.4 -  14.8    0.0000    1               0.4      281.5     283.0
   14.8 -  22.2    0.0000    1               0.4      306.2     308.0
   22.2 -  29.6    0.0000    1               0.4      338.8     341.3
   29.6 -  37.0    0.0000    1               0.4      353.2     355.6
   37.0 -  44.4    0.0000    1               0.4      363.1     365.7
   44.4 -  51.9    0.0000    1               0.4      367.5     370.0
   51.9 -  59.3    0.0000    1               0.4      370.0     372.6
   59.3 -  66.7    0.0000.   1               0.4      371.5     374.0
   66.7 -  74.1    0.0000    1               0.4      372.1     374.7
   74.1 -  81.5    0.0000    1               0.4      371.7     374.2
   81.5 -  88.9    0.0000    1               0.4      369.7     372.2
   88.9 -  96.3    0.0000    1               0.4      368.0     370.5
   96.3 - 103.7    0.0000    1               0.4      365.3     367.9
```

103.7 - 111.1	0.0000	1	0.4	361.0	363.5
111.1 - 118.5	0.0000	1	0.4	354.6	357.2
118.5 - 125.9	0.0000	1	0.4	346.7	349.0
125.9 - 133.3	0.0000	1	0.4	334.0	336.5
133.3 - 140.8	0.0000	1	0.4	318.3	320.4
140.8 - 148.2	0.0000	1	0.4	293.3	295.3
148.2 - 155.6	0.0000	1	0.3	276.5	278.2
155.6 - 163.0	0.0000	1	0.3	198.2	198.3
163.0 - 170.4	0.0000	1	0.3	190.1	190.2
170.4 - 177.8	0.0000	1	0.3	186.2	186.2

APPENDIX F

TN-24P PWR CASK PERFORMANCE TEST SIMULATIONS INPUT, OUTPUT, AND CONVERGENCE LISTS

APPENDIX F

TN-24P PWR CASK PERFORMANCE TEST SIMULATIONS INPUT, OUTPUT, AND CONVERGENCE LISTS

	Page Number		
Test Case	Input	Convergence List	Output
Vertical, helium	F.2	F.14	F.16
Horizontal, helium	F.20	F.32	F.34

```
+8000
    1    1      tn-24 vertical helium  full-load validation analyses
prop      7     5
        1.         0.       100.0      .0780       1.24      83.33      .0410
        2.       200.       348.0      .0970       1.24     119.76      .0533
        3.       400.       596.0      .1150       1.24     156.25      .0641
        5.       600.       844.0      .1290       1.24     192.31      .0727
       10.       800.      1092.0      .1380       1.24     229.36      .0823
       15.      1000.      1340.0      .1380       1.24     265.25      .0907
       20.      1500.      1588.0      .1380       1.24     357.14      .1138
    1 alum                            58.88
    2steel                              24.
    3rescu                            10.69
    4radme                           4.0000
    5stilt                            119.0
chan      7   18
     159.5         0.0
    1    1  136    0    0
    1    1    0    0    1
    1.0663.5750.1657    2.1984 .486
    2.30041.226.6629    3.1410 .486    4.1984 .563
    3.0885.6630.6630    5.1410 .563
    4.30041.226.6629    5.1410 .486    7.1984 .563
    5.17701.3261.326    6.1410 .563    8.1410 .563
    6.0768.7115.4972    9.0790 .563
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    8.17701.3261.326    9.1410 .563   12.1410 .563
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   25.15351.423.9943   26.1410 .563   32.1410 .563
   26.17701.3261.326   27.1410 .563   33.1410 .563
   27.17701.3261.326   28.1410 .563   34.1410 .563
   28.0885.6630.6630   35.1410 .563
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   41.15351.423.9943   42.1410 .563   50.1410 .563
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 88.15351.423.9943   89.0790 .563  101.0790 .563
 89.15351.423.9943   90.1410 .563  102.0790 .563
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 95.15351.423.9943   96.1410 .563  109.1410 .563
 96.17701.3261.326   97.1410 .563  110.1410 .563
 97.15351.423.9943   98.0790 .563  111.1410 .563
 98.15351.423.9943   99.1410 .563  112.1410 .563
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27 .422  1.  27  .25  28  .25  34  .25  35  .25
28 .422  1.  28 .125  35  .25  36 .125
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34 .422  1.  34  .25  35  .25  42  .25  43  .25
35 .422  1.  35  .25  36  .25  43  .25  44  .25
36 .422  0.  36 .125  44  .25  45 .125
37 .422  1.  37  .25  38  .25  46  .25  47  .25
38 .422  1.  38  .25  39  .25  47  .25  48  .25
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  3 .422   1.     33.000   113.000
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  5 .422   1.     53.000   133.000
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10 .422   1.   102.500  182.500
11 .422   1.   112.500  192.500
12 .422   1.   122.500  202.500
13 .422   1.   132.500  212.500
14 .422   1.   142.500  222.500
15 .422   1.   152.500  232.500
16 .422   1.   162.500  242.500
17 .422  .75   172.000  252.000
18 .422  .75   182.000  262.000
19 .422  .75   192.000  272.000
20 .422  .75   202.000  282.000
21 .422  .75   212.000  292.000
22 .422  .75   222.000  302.000
23 .422  .75   232.000  312.000
24 .422  .75   242.000  322.000
25 .422   1.   251.500  331.500
26 .422   1.   261.500  341.500
27 .422   1.   271.500  351.500
28 .422   1.   281.500  361.500
29 .422   1.   291.500  371.500
30 .422   1.   301.500  381.500
31 .422   1.   311.500  391.500
32 .422   1.   321.500  401.500
33 .422   1.   331.000  411.000
34 .422   1.   341.000  421.000
35 .422   1.   351.000  431.000
36 .422   1.   361.000  441.000
37 .422   1.   371.000  451.000
38 .422   1.   381.000  461.000
39 .422   1.   391.000  471.000
40 .422   1.   401.000  481.000
41 .422   1.   410.500  490.500
42 .422   1.   420.500  500.500
43 .422   1.   430.500  510.500
44 .422   1.   440.500  520.500
45 .422   1.   450.500  530.500
46 .422   1.   460.500  540.500
47 .422   1.   470.500  550.500
48 .422   1.   480.500  560.500
49 .422   1.    10.375   80.375   90.125  160.125
50 .422   1.    10.250   20.250   90.250  100.250
51 .422   1.    20.375   30.375  100.125  110.125
52 .422   1.    30.250   40.250  110.250  120.250
53 .422   1.    40.375   50.375  120.125  130.125
54 .422   1.    50.250   60.250  130.250  140.250
55 .422   1.    60.375   70.375  140.125  150.125
56 .422   1.    70.250   80.250  150.250  160.250
57 .422   1.    80.375   90.375  160.125  170.125
58 .422   1.    90.250  100.250  170.250  180.250
59 .422   1.   100.375  110.375  180.125  190.125
60 .422   1.   110.250  120.250  190.250  200.250
61 .422   1.   120.375  130.375  200.125  210.125
62 .422   1.   130.250  140.250  210.250  220.250
63 .422   1.   140.375  150.375  220.125  230.125
64 .422   1.   150.250  160.250  230.250  240.250
65 .422   0.   160.375  170.375  240.125  250.125
66 .422   1.   170.250  180.250  250.250  260.250
67 .422   0.   180.375  190.375  260.125  270.125
68 .422   1.   190.250  200.250  270.250  280.250
69 .422   0.   200.375  210.375  280.125  290.125
```

```
 70 .422   1.   210.250   220.250   290.250   300.250
 71 .422   0.   220.375   230.375   300.125   310.125
 72 .422   1.   230.250   240.250   310.250   320.250
 73 .422   1.   240.375   250.375   320.125   330.125
 74 .422   0.   250.250   260.250   330.250   340.250
 75 .422   1.   260.375   270.375   340.125   350.125
 76 .422   0.   270.250   280.250   350.250   360.250
 77 .422   1.   280.375   290.375   360.125   370.125
 78 .422   0.   290.250   300.250   370.250   380.250
 79 .422   1.   300.375   310.375   380.125   390.125
 80 .422   0.   310.250   320.250   390.250   400.250
 81 .422   0.   320.375   330.375   400.125   410.125
 82 .422   1.   330.250   340.250   410.250   420.250
 83 .422   0.   340.375   350.375   420.125   430.125
 84 .422   1.   350.250   360.250   430.250   440.250
 85 .422   0.   360.375   370.375   440.125   450.125
 86 .422   1.   370.250   380.250   450.250   460.250
 87 .422   0.   380.375   390.375   460.125   470.125
 88 .422   1.   390.250   400.250   470.250   480.250
 89 .422   1.   400.375   410.375   480.125   490.125
 90 .422   1.   410.250   420.250   490.250   500.250
 91 .422   1.   420.375   430.375   500.125   510.125
 92 .422   1.   430.250   440.250   510.250   520.250
 93 .422   1.   440.375   450.375   520.125   530.125
 94 .422   1.   450.250   460.250   530.250   540.250
 95 .422   1.   460.375   470.375   540.125   550.125
 96 .422   1.   470.250   480.250   550.250   560.250
 97 .422   1.   490.375   500.375   570.250
 98 .422   1.   490.250   500.250   570.500
 99 .422   1.   500.375   510.375   570.250
100 .422   1.   510.250   520.250   570.500
101 .422   1.   520.375   530.375   570.250
102 .422   1.   530.250   540.250   570.500
103 .422   1.   540.375   550.375   570.250
104 .422   1.   550.250   560.250   570.500
105 .422   0.   571.000
  3    1  120
  4    2  105
  5    0    0
  6    0    0
  7    0    0
 3.0 .059 655. .300  10.  0.1 409..02431000. .422
slab   20   18   51
  1                        3344.3      0.00
  2                           3.4      0.00
  3                         105.6      0.00
  4                        2954.7      0.00
  5                         247.5     29.870  0.5  .007.715
  6                         202.9      0.00
  7                          88.1      0.00
  8                         361.6      0.00
  9                          68.7      0.00
 10                         332.2      0.00
 11                          3.60      0.00
 12                        161.39      0.00
 13                        350.69      0.00
 14                        194.48      0.00
 15                        353.45
 16                        303.43
 17                         95.22
```

```
18                    713.38
19                    388.96
20                   6217.60
 1   10.858             1   2  18
 2   10.858             1   3  19
 3   10.078             2   4  14   7  19
 4   11.715             1   5  13
 5   11.715             1   6  14
 6   10.078             1  12  14
 7   10.858             1   8  18
 8   10.858             1   9  19
 9   10.078             2  10  14  18  19
10   11.715             1  11  13
11   11.715             1  14  14
12   11.715             1  13  13
13   11.715             1  14  14
14   10.155             2  15  14  24  14
15   11.715             1  16  13
16   11.715             1  17  14
17   10.078             1  28  12
18   10.858             1  19  18
19   10.858             1  20  19
20   10.078             2  21  17  22  14
21   10.151             1  28  20
22   11.715             1  23  18
23   11.280
24   11.715             1  25  15
25   11.684             1  29  20
26   11.397             2  27  11  31  20
27   11.048
28   215.64             2  29  10  32   9
29   215.64             2  30  10  33   9
30   215.64             2  31  10  34   9
31   215.64             1  35   9
32   217.03             2  33   8  36   7
33   217.03             2  34   8  37   7
34   217.03             2  35   8  38   7
35   217.03             1  39   7
36   238.21             2  37   6  40   5
37   238.21             2  38   6  41   5
38   238.21             2  39   6  42   5
39   238.21             1  43   5
40   343.41             2  41   4  44   3
41   343.41             2  42   4  45   3
42   343.41             2  43   4  46   3
43   343.41             1  47   3
44   23.459             2  45   1  48   2
45   23.459             2  46   1  49   2
46   23.459             2  47   1  50   2
47   23.459             1  51   2
48   2
49   2
50   2
51   2
 1   34.645    5.546
 2   69.290    2.806
 3   85.380    4.009
 4   140.58    1.386
 5   99.610    1.531
 6    2.032    4.295
```

```
   7     1.206     3.665
   8    1.3692    4.3505
   9   14.5490    6.4694
  10    10.580     6.563
  11    1.3940    4.2716
  12    1.8340    3.2480
  13     2.161    1.4700
  14    1.3692    4.3250
  15    1.3692    4.3615
  16    1.3692    5.2730
  17    34.645    6.0456
  18    1.3692    4.3913
   1    8    1    1    9    1    2   10    1    4   10    1    7   10
             1   11   10    1   16   10    1   22   10    1   29   10
   2    8    1   37   10    1   46   10    1   56   10    1   67   10
             1   79   10    1   92   10    1  106   10    1  121    9
   4    9    1  121    9    1  122   10    1  123   10    1  124   10
             1  125   10    1  126   10    1  127   10    1  128   10
             2    1    8
   5    9    1  129   10    1  130   10    1  131   10    1  132   10
             1  133   10    1  134   10    1  135   10    1  136    9
             2    2    8
   7    1    2    8    8
   8    1    2    7    8
  10    2    2    6    8    4    1    8
  11    2    2    5    8    4    2    8
  12    9    2    3    8    3    1    9    3    2   10    3    4   10
             3    7   10    3   11   10    3   16   10    3   22   10
             3   29   10
  13    9    2    4    8    3   29   10    3   46   10    3   56   10
             3   67   10    3   79   10    3   92   10    3  106   10
             3  121    9
  15    9    3  121    9    3  122   10    3  123   10    3  124   10
             3  125   10    3  126   10    3  127   10    3  128   10
             5    1   15
  16    9    3  129   10    3  130   10    3  131   10    3  132   10
             3  133   10    3  134   10    3  135   10    3  136    9
             5    1    8
  18    1    4    8    8
  19    1    4    7    8
  21    1    6    1   13
  22    2    4    6    8    6    1   16
  23    2    4    5    8    6    1   16
  24    2    4    3    8    5    1    8
  25    2    4    4    8    5    1   14
  26    1    5    1    7
  27    1    7    1    6
  28    1    6    1   17
  29    3    4    5    4    5    1    5    6    1    3
  30    1    5    1    1
  31    2    5    1    2    7    1    2

radg    7    2    3
   1    5
   11.470   .8    1.0191    2.4664    3.0576    4.0478    5.4091
   26.045   .9    1.1134    2.0468    3.0023    4.2402    5.0033
   34.009   .9    1.0211    2.0035    3.0339    4.9158    5.0257
   45.273   .8    1.0133    2.2754    3.6962    4.0151    5.0
   54.391   .8    1.1369    2.0305    3.0235    4.0       5.0091
   2    8
```

```
    14.351   .8    1.0000    2.0000    3.0163    4.2583    5.1317    6.2192
                   7.0928    8.2817
    24.325   .8    1.0000    2.0000    3.2078    4.4189    5.0677    6.1126
                   7.1105    8.0825
    31.531   .9    1.0463    2.5870    3.0000    4.0000    5.0000    6.0583
                   7.1092    8.2072
    45.545   .9    1.2026    2.3267    3.0000    4.0000    5.0000    6.0339
                   7.1900    8.2468
    52.806   .9    1.2042    2.1044    3.0000    4.0000    5.0000    6.1895
                   7.3127    8.1892
    63.665   .8    1.2602    2.1329    3.0210    4.0513    5.1450    6.0000
                   7.3051    8.0845
    74.351   .8    1.0928    2.1098    3.0384    4.2422    5.2017    6.2571
                   7.0000    8.0000
    84.362   .8    1.2810    2.0818    3.0727    4.3139    5.1217    6.0710
                   7.0579    8.0000
    3    2
    14.295   .8    1.3139    2.6861
    22.806   .9    1.9843    2.0157
    1    1    4    1    2    4    5
    2    2    8    4    5   12   13   11   10    6    7
    3    1    4   12   13   15   16
    4    2    8   10   11   24   25   23   22   19   18
    5   -2    8   24   25   29   30   31   26   16   15
    6   -1    5   21   28   29   23   22
    7   -3    2   27   31
heat     1    0    1
              3.66                3.66
  1.0  1.0  1.0  1.0  1.0
drag     1    5
  100. -1.0              100. -1.0
    1   16    0
    7    5  120.0388   2..1919   2..3562   2..5204   2..6846   2..8488   2.
              .9657   2.
    7    2    2.0388   1..1919   1..3562   1..5204   1..6846   1..8488   1.
              .9657   1.
    7    3    4.0388   1..1919   1..3562   1..5204   1..6846   1..8488   1.
              .9657   1.
    7    6    7.0388   1..1919   1..3562   1..5204   1..6846   1..8488   1.
              .9657   1.
    7   10   11.0388   1..1919   1..3562   1..5204   1..6846   1..8488   1.
              .9657   1.
    7   15   16.0388   1..1919   1..3562   1..5204   1..6846   1..8488   1.
              .9657   1.
    7   21   22.0388   1..1919   1..3562   1..5204   1..6846   1..8488   1.
              .9657   1.
    7   28   29.0388   1..1919   1..3562   1..5204   1..6846   1..8488   1.
              .9657   1.
    7   36   37.0388   1..1919   1..3562   1..5204   1..6846   1..8488   1.
              .9657   1.
    7   45   46.0388   1..1919   1..3562   1..5204   1..6846   1..8488   1.
              .9657   1.
    7   55   56.0388   1..1919   1..3562   1..5204   1..6846   1..8488   1.
              .9657   1.
    7   66   67.0388   1..1919   1..3562   1..5204   1..6846   1..8488   1.
              .9657   1.
    7   78   79.0388   1..1919   1..3562   1..5204   1..6846   1..8488   1.
              .9657   1.
    7   91   92.0388   1..1919   1..3562   1..5204   1..6846   1..8488   1.
              .9657   1.
```

```
   7  105  106.0388   1..1919   1..3562   1..5204   1..6846   1..8488   1.
                .9657   1.
   7  120  135.0388   1..1919   1..3562   1..5204   1..6846   1..8488   1.
                .9657   1.
   7    1    1.0388   .5.1919   .5.3562   .5.5204   .5.6846   .5.8488   .5
                .9657   .5
   7  136  136.0388   .5.1919   .5.3562   .5.5204   .5.6846   .5.8488   .5
                .9657   .5
   2    2    0
   7    9   57.0388   2..1919   2..3562   2..5204   2..6846   2..8488   2.
                .9657   2.
   7    1    8.0388   1..1919   1..3562   1..5204   1..6846   1..8488   1.
                .9657   1.
   3    1    0
   2    1    16.001  1.5.9999  1.5
   4    1    0
   2    1    16.001  1.5.9999  1.5
   5    1    0
   2    1    16.001  1.5.9999  1.5
bdry    19    1    4    2
   1   5.24e-8   3.66e+2 0.3333333   .88
   2   4.73e-5
   3   4.60e-5
   4   1.32e-9   7.74e+7 0.3333333   .88
   5   1.89e-6
   6   3.26e-5
   7   1.15e-8   9.85e+4 0.3333333   .88
   8   2.82e-5
   9   9.36e-5
  10   3.94e-6       1.0       .25
  11   2.24e-8
  12   1.89e-7
  13   4.57e-4
  14   5.70e-9   8.02e+5 0.3333333   .88
  15   9.36e-5
  16   6.56e-5
  17   7.05e-5
  18   7.14e-5
  19   1.44e-4
   1    2   0.  65.   1.  65.
  48     18.820    1
   1   1.    1   1.    1
  49     18.820    1
   1   1.    1   1.    1
  50     18.820    1
   1   1.    1   1.    1
  51     18.820    1
   1   1.    1   1.    1
   131.05322.2    7    4 65.0 65.0
   110.39    8    0
   20.649   15    0
   3  1.0   16    0
   4  2.0   17    0
   5  3.0   18    0
   6 3.75   19   12   28    2     8.02   29    2     8.02   30    2     8.02
                     31    2     8.02   32    2     8.02   33    2     8.02
                     34    2     8.02   35    2     8.02   36    2     8.02
                     37    2     8.02   38    2     8.02   39    2     8.02
   712.90   14    0
   1  1.0    8    0
```

```
  2 1.0    9   27   1    4      1.50    2    4      1.50    3    4      1.50
                    4    4      1.50    5    4      1.50    6    4      1.50
                    7    4      1.50    8    4      1.50    9    4      1.50
                   10    4      1.50   11    4      1.50   12    4      1.50
                   13    4      1.50   14    4      1.50   15    4      1.50
                   16    4      1.50   17    4      1.50   18    4      1.50
                   19    4      1.50   20    4      1.50   21    4      1.50
                   22    4      1.50   23    4      1.50   24    4      1.50
                   25    4      1.50   26    4      1.50   27    5      1.50
  3 1.0    9    0
  4 1.0   10    0
  212.85322.2   3    3 65.0 65.0
  1 1.00   5    0
  211.31   6   12  28    2      5.61   29    2      5.61   30    2      5.61
                   31    2      5.61   32    2      5.61   33    2      5.61
                   34    2      5.61   35    2      5.61   36    2      5.61
                   37    2      5.61   38    2      5.61   39    2      5.61
  315.50   7    0
  1 1.00   2    0
  2 1.00   3    0
  3 1.00   4    0
calc    1

      30
oper    1       3    1                                         1
  20.          145.     1.e-4.001908250      185.  -.000001       0.0
.9186.8535.8690.8535
  14
  0.  0.0.0001  0.0.0002 0.32.0627 0.79.1254 1.04.1881 1.10
.2508 1.10.5643 1.10.6897 1.10.7524 1.06.8150 0.80.9404 0.18
.9405  0.01.000  0.0
outp 1101                            2
endd


 data from iterative solution using the recirculation module
 time =    0.0000    dt = ******    implicit dt = 0.0000    explicit dt = 4.6509    mode =  0


 iteration  sweep          peak clad             total flow     pressure                 error
    no.      no.   ---------------------------    (lbm/s)      drop(psi)    -----------------------------------
                    temp(f)  fluid  rod  ass.                                total     flow    fluid    rod
                                                                             energy            energy   energy

     1        1      217.1     18    35    1      0.884e-11    0.0005410     0.5738  16.6257   0.0186   0.0003
              2      217.5     17    35    1                                 0.5291  16.6257   0.0447   0.0002

     2        1      253.4     15    35    1      0.366e-11    0.0008201     0.4146   2.0054   0.0285   0.0018
              2      283.0     14    35    1                                 0.4072   2.0054   0.0113   0.0008

     3        1      297.9     14    35    1      0.216e-11    0.0008231     0.4091   2.3556   0.0103   0.0003
              2      311.4     13    35    1                                 0.4048   2.3556   0.0083   0.0003

     4        1      320.1     13    35    1      0.128e-11    0.0007724    -0.0384   3.2562   0.0443   0.0031
              2      356.6     12    35    1                                -0.0046   3.2562   0.0143   0.0055

     5        1      367.3     12    28    1      0.106e-11    0.0007708     0.0155   4.5580   0.0100   0.0004
              2      378.2     12    35    1                                 0.0226   4.5580   0.0028   0.0003
```

6	1	384.4	12	35	1	0.597e-12	0.0007672	0.0311	4.0149	0.0042	0.0001
	2	390.5	11	35	1			0.0352	4.0149	0.0026	0.0002
7	1	394.5	11	35	1	0.331e-12	0.0007626	0.0237	4.9098	0.0041	0.0002
	2	398.8	12	35	1			0.0288	4.9098	0.0018	0.0004
8	1	401.8	12	35	1	0.225e-12	0.0007598	0.0338	1.8768	0.0019	0.0001
	2	405.3	12	28	1			0.0369	1.8768	0.0016	0.0001
9	1	407.8	12	28	1	0.111e-12	0.0007573	0.0398	1.6098	0.0015	0.0001
	2	410.6	12	28	1			0.0419	1.6098	0.0014	0.0001
10	1	412.6	12	28	1	0.128e-13	0.0007517	0.0028	4.9612	0.0035	0.0003
	2	417.3	12	28	1			0.0080	4.9612	0.0013	0.0005
11	1	419.2	12	28	1	-0.105e-13	0.0007503	0.0111	1.4475	0.0011	0.0001
	2	421.4	12	28	1			0.0131	1.4475	0.0012	0.0001
12	1	422.0	12	28	1	-0.329e-13	0.0007491	0.0147	0.7751	0.0011	0.0000
	2	424.3	12	28	1			0.0160	0.7751	0.0012	0.0000
13	1	425.4	12	28	1	-0.512e-13	0.0007468	0.0027	1.7608	0.0018	0.0001
	2	427.3	12	28	1			0.0048	1.7608	0.0013	0.0002
14	1	428.2	12	28	1	-0.467e-13	0.0007461	0.0062	0.5092	0.0011	0.0000
	2	429.2	12	28	1			0.0072	0.5092	0.0012	0.0000
15	1	429.9	12	28	1	-0.457e-13	0.0007455	0.0080	0.3478	0.0012	0.0000
	2	430.6	12	28	1			0.0086	0.3478	0.0012	0.0000
16	1	431.1	12	28	1	-0.452e-13	0.0007443	0.0012	0.5548	0.0016	0.0001
	2	432.1	12	28	1			0.0023	0.5548	0.0013	0.0001
17	1	432.6	12	28	1	-0.387e-13	0.0007439	0.0031	0.2352	0.0012	0.0000
	2	433.1	12	28	1			0.0035	0.2352	0.0012	0.0000
18	1	433.4	12	28	1	-0.305e-13	0.0007436	0.0039	0.1667	0.0012	0.0000
	2	433.8	12	28	1			0.0043	0.1667	0.0013	0.0000
19	1	434.0	12	28	1	-0.288e-13	0.0007430	0.0007	0.2269	0.0014	0.0000
	2	434.5	12	28	1			0.0012	0.2269	0.0013	0.0001
20	1	434.7	12	28	1	-0.223e-13	0.0007428	0.0016	0.1117	0.0012	0.0000
	2	435.0	12	28	1			0.0018	0.1117	0.0013	0.0000
21	1	435.1	12	28	1	-0.182e-13	0.0007427	0.0020	0.0810	0.0013	0.0000
	2	435.3	12	28	1			0.0022	0.0810	0.0013	0.0000
22	1	435.4	12	28	1	-0.160e-13	0.0007424	0.0004	0.1039	0.0014	0.0000
	2	435.6	12	28	1			0.0006	0.1039	0.0013	0.0000
23	1	435.8	12	28	1	-0.119e-13	0.0007423	0.0008	0.0548	0.0013	0.0000
	2	435.9	12	28	1			0.0010	0.0548	0.0013	0.0000
24	1	435.9	12	28	1	-0.115e-13	0.0007422	0.0011	0.0461	0.0013	0.0000
	2	436.0	12	28	1			0.0012	0.0461	0.0013	0.0000
25	1	436.1	12	28	1	-0.898e-14	0.0007421	0.0003	0.0514	0.0013	0.0000
	2	436.2	12	28	1			0.0004	0.0514	0.0013	0.0000

```
 26        1      436.3     12     28     1       -0.731e-14     0.0007420       0.0005   0.0266   0.0013   0.0000
           2      436.3     12     28     1                                      0.0006   0.0266   0.0013   0.0000

 27        1      436.3     12     28     1       -0.512e-14     0.0007420       0.0006   0.0191   0.0013   0.0000
           2      436.4     12     28     1                                      0.0007   0.0191   0.0013   0.0000

 28        1      436.4     12     28     1       -0.619e-14     0.0007419       0.0002   0.0266   0.0013   0.0000
           2      436.5     12     28     1                                      0.0003   0.0266   0.0013   0.0000

 29        1      436.5     12     28     1       -0.300e-14     0.0007419       0.0004   0.0137   0.0013   0.0000
           2      436.5     12     28     1                                      0.0004   0.0137   0.0013   0.0000

 30        1      436.5     12     28     1       -0.172e-14     0.0007419       0.0005   0.0099   0.0013   0.0000
           2      436.6     12     28     1                                      0.0005   0.0099   0.0013   0.0000


 slab temperature summary        time =    0.0000 seconds
 (assembly no. - channel no.)


axial zone     ( 11)      ( 12)      ( 13)      ( 14)      ( 15)      ( 16)      ( 17)      ( 18)      ( 19)      ( 20)
 (inches)

  0.0 -  8.9   205.25     210.48     206.72     203.86     200.95     194.92     190.86     202.19     193.60     187.60
  8.9 - 17.7   239.23     248.35     241.78     236.66     232.27     224.59     220.26     234.78     220.98     211.30
 17.7 - 26.6   269.24     282.21     272.86     265.62     259.64     249.62     244.11     263.56     245.12     232.29
 26.6 - 35.4   292.28     308.34     296.78     287.91     280.69     268.82     262.43     285.61     263.67     248.56
 35.4 - 44.3   309.00     327.32     314.15     304.11     296.03     282.90     275.93     301.62     277.23     260.56
 44.3 - 53.2   320.98     340.92     326.59     315.73     307.03     293.02     285.67     313.15     287.07     269.35
 53.2 - 62.0   329.40     350.48     336.33     323.87     314.72     300.09     292.48     321.29     294.00     275.63
 62.0 - 70.9   335.03     356.92     341.18     329.29     319.82     304.74     296.94     326.78     298.80     279.87
 70.9 - 79.7   338.36     360.83     344.66     332.47     322.75     307.35     299.43     330.07     301.61     282.37
 79.7 - 88.6   339.65     362.49     346.03     333.63     323.74     308.11     300.11     331.40     302.67     283.26
 88.6 - 97.5   338.89     361.94     345.31     332.80     322.78     307.02     298.99     330.77     301.98     282.53
 97.5 -106.3   335.79     358.82     342.18     329.66     319.61     303.82     295.81     327.88     299.31     280.00
106.3 -115.2   329.56     352.24     335.83     323.49     313.54     297.94     290.05     321.97     294.02     275.12
115.2 -124.1   318.72     340.48     324.73     312.90     303.35     288.40     280.85     311.55     284.90     266.90
124.1 -132.9   301.63     321.82     307.22     296.45     287.85     274.33     267.54     294.87     270.54     254.26
132.9 -141.8   280.57     298.14     285.58     276.28     268.97     257.45     251.71     274.24     252.91     238.86
141.8 -150.6   259.59     274.81     264.00     256.23     250.30     240.91     236.27     253.57     235.27     223.46
150.6 -159.5   244.27     257.41     248.26     241.67     236.84     229.10     225.32     238.25     221.98     211.60



 side boundary temperature summary      time =    0.0000 seconds
 boundary slab node no.    48


axial zone     (  1)      (  2)      (
 (inches)

  0.0 -  8.9   138.63      65.00
  8.9 - 17.7   142.40      65.00
 17.7 - 26.6   147.25      65.00
 26.6 - 35.4   152.10      65.00
 35.4 - 44.3   156.46      65.00
```

```
   44.3 - 53.2      160.11       65.00
   53.2 - 62.0      162.95       65.00
   62.0 - 70.9      164.94       65.00
   70.9 - 79.7      166.07       65.00
   79.7 - 88.6      166.35       65.00
   88.6 - 97.5      165.78       65.00
   97.5 -106.3      164.37       65.00
  106.3 -115.2      162.16       65.00
  115.2 -124.1      159.24       65.00
  124.1 -132.9      155.78       65.00
  132.9 -141.8      152.11       65.00
  141.8 -150.6      148.68       65.00
  150.6 -159.5      146.21       65.00




  calculated rod temperatures at time =     0.0000 seconds
  rod no.   32
  assembly   1                  (fuel type  1 - cylinder)
 0rod o.d. - 0.422 (in.)     zone-(fuel dia.(in.)) -  1-(0.366)

                                                  *   fuel temperatures(f.)
                                                  *
    axial zone  heat flux   type            hsurf *   fluid    clad
       (in.)   (mbtu/hr-ft2)            (b/h-f-ft2) *
     0.0 -   8.9     0.0000    1              10.0     224.3    224.3
     8.9 -  17.7     0.0000    1              10.6     287.2    287.2
    17.7 -  26.6     0.0000    1              11.0     333.9    333.8
    26.6 -  35.4     0.0000    1              11.3     365.7    365.6
    35.4 -  44.3     0.0000    1              11.5     387.3    387.2
    44.3 -  53.2     0.0000    1              11.6     402.6    402.6
    53.2 -  62.0     0.0000    1              11.7     413.5    413.4
    62.0 -  70.9     0.0000    1              11.8     420.9    420.8
    70.9 -  79.7     0.0000    1              11.8     425.6    425.5
    79.7 -  88.6     0.0000    1              11.8     428.0    427.9
    88.6 -  97.5     0.0000    1              11.8     428.1    428.0
    97.5 - 106.3     0.0000    1              11.8     425.7    425.6
   106.3 - 115.2     0.0000    1              11.8     419.8    419.8
   115.2 - 124.1     0.0000    1              11.7     407.6    407.6
   124.1 - 132.9     0.0000    1              11.5     382.3    382.3
   132.9 - 141.8     0.0000    1              11.1     348.5    348.4
   141.8 - 150.6     0.0000    1              10.8     311.8    311.8
   150.6 - 159.5     0.0000    1              10.5     270.0    270.0



  calculated rod temperatures at time =     0.0000 seconds
  rod no.   74
  assembly   2                  (fuel type  1 - cylinder)
 0rod o.d. - 0.422 (in.)     zone-(fuel dia.(in.)) -  1-(0.366)

                                                  *   fuel temperatures(f.)
                                                  *
    axial zone  heat flux   type            hsurf *   fluid    clad
       (in.)   (mbtu/hr-ft2)            (b/h-f-ft2) *
     0.0 -   8.9     0.0000    1               9.4     219.6    219.7
     8.9 -  17.7     0.0000    1               9.9     275.2    275.2
```

```
   17.7 -  26.6    0.0000    1               10.3       316.5     316.5
   26.6 -  35.4    0.0000    1               10.5       344.9     345.0
   35.4 -  44.3    0.0000    1               10.7       364.3     364.4
   44.3 -  53.2    0.0000    1               10.8       378.1     378.2
   53.2 -  62.0    0.0000    1               10.9       387.8     387.9
   62.0 -  70.9    0.0000    1               10.9       394.4     394.5
   70.9 -  79.7    0.0000    1               11.0       398.5     398.6
   79.7 -  88.6    0.0000    1               11.0       400.5     400.6
   88.6 -  97.5    0.0000    1               11.0       400.3     400.4
   97.5 - 106.3    0.0000    1               11.0       397.8     397.9
  106.3 - 115.2    0.0000    1               10.9       391.9     392.0
  115.2 - 124.1    0.0000    1               10.8       380.2     380.3
  124.1 - 132.9    0.0000    1               10.6       356.8     356.9
  132.9 - 141.8    0.0000    1               10.3       326.1     326.1
  141.8 - 150.6    0.0000    1               10.1       293.2     293.3
  150.6 - 159.5    0.0000    1                9.8       263.8     263.8



  calculated rod temperatures at time =    0.0000 seconds
  rod no.   74
  assembly   3                  (fuel type  1 - cylinder)
 0rod o.d. - 0.422 (in.)     zone-(fuel dia.(in.)) -  1-(0.366)

                                                 *   fuel temperatures(f.)
                                                 *
    axial zone  heat flux   type           hsurf *   fluid     clad
       (in.)    (mbtu/hr-ft2)           (b/h-f-ft2) *
    0.0 -   8.9    0.0000    1                9.9       214.5     214.5
    8.9 -  17.7    0.0000    1               10.4       266.7     266.6
   17.7 -  26.6    0.0000    1               10.7       303.2     303.1
   26.6 -  35.4    0.0000    1               10.9       326.9     326.8
   35.4 -  44.3    0.0000    1               11.1       342.4     342.4
   44.3 -  53.2    0.0000    1               11.2       353.5     353.4
   53.2 -  62.0    0.0000    1               11.3       361.2     361.2
   62.0 -  70.9    0.0000    1               11.3       366.4     366.4
   70.9 -  79.7    0.0000    1               11.3       369.5     369.5
   79.7 -  88.6    0.0000    1               11.3       370.8     370.7
   88.6 -  97.5    0.0000    1               11.3       370.2     370.2
   97.5 - 106.3    0.0000    1               11.3       367.6     367.6
  106.3 - 115.2    0.0000    1               11.3       362.4     362.3
  115.2 - 124.1    0.0000    1               11.2       352.0     351.9
  124.1 - 132.9    0.0000    1               11.0       330.3     330.3
  132.9 - 141.8    0.0000    1               10.7       302.0     301.9
  141.8 - 150.6    0.0000    1               10.4       271.6     271.6
  150.6 - 159.5    0.0000    1               10.2       243.3     243.3



  calculated rod temperatures at time =    0.0000 seconds
  rod no.   78
  assembly   4                  (fuel type  1 - cylinder)
 0rod o.d. - 0.422 (in.)     zone-(fuel dia.(in.)) -  1-(0.366)

                                                 *   fuel temperatures(f.)
                                                 *
    axial zone  heat flux   type           hsurf *   fluid     clad
```

```
      (in.)    (mbtu/hr-ft2)          (b/h-f-ft2) *
   0.0 -   8.9    0.0000    1              9.3      208.0     208.0
   8.9 -  17.7    0.0000    1              9.7      251.7     251.7
  17.7 -  26.6    0.0000    1             10.0      282.6     282.6
  26.6 -  35.4    0.0000    1             10.1      302.6     302.6
  35.4 -  44.3    0.0000    1             10.3      315.8     315.8
  44.3 -  53.2    0.0000    1             10.3      325.3     325.3
  53.2 -  62.0    0.0000    1             10.4      332.0     332.0
  62.0 -  70.9    0.0000    1             10.4      336.6     336.6
  70.9 -  79.7    0.0000    1             10.5      339.3     339.3
  79.7 -  88.6    0.0000    1             10.5      340.4     340.4
  88.6 -  97.5    0.0000    1             10.5      339.9     339.9
  97.5 - 106.3    0.0000    1             10.4      337.6     337.6
 106.3 - 115.2    0.0000    1             10.4      332.8     332.8
 115.2 - 124.1    0.0000    1             10.3      323.4     323.4
 124.1 - 132.9    0.0000    1             10.2      303.6     303.6
 132.9 - 141.8    0.0000    1              9.9      277.9     277.9
 141.8 - 150.6    0.0000    1              9.7      250.5     250.5
 150.6 - 159.5    0.0000    1              9.5      224.9     224.8
```

```
+8000
    1    1     tn-24 horizontal helium  full-load validation analysis
prop     7    5
        1.        0.      100.0      .0780       1.24     83.33      .0410
        2.      200.      340.0      .0970       1.24    119.76      .0533
        3.      400.      596.0      .1150       1.24    156.25      .0641
        5.      600.      844.0      .1290       1.24    192.31      .0727
       10.      800.     1092.0      .1380       1.24    229.36      .0823
       15.     1000.     1340.0      .1380       1.24    265.25      .0907
       20.     1500.     1588.0      .1380       1.24    357.14      .1138
    1 alum                           58.88
    2steel                             24.
    3rescu                           10.69
    4radme                          4.0000
    5stilt                           119.0
chan     22   18
     159.5        90.0
    1    1   67    0    0
    1    1    0    0    1
    11.4188.9594.806   2.19844.427    8.19844.427    9.9870 .288
    21.4188.9594.806   3.19844.427   10 .987 .288
    32.1699.1574.806   4.19844.427   11 .987 .486
    42.1699.1574.806   5.19844.427   12 .987 .486
    52.9209.3554.806   6.19844.427   13 .987 .688
    62.9209.3554.806   7.19844.427   14 .987 .688
    72.1699.1574.806   8.19844.427   15 .987 .486
    82.1699.1574.806  16.9870 .486
    91.1518.6198.619  10.14101.971   16.14101.971   17.8460.5630
   101.1518.6198.619  11.14101.971   18 .846 .563
   111.1518.6198.619  12.14101.971   19 .846 .563
   121.1518.6198.619  13.14101.971   20 .846 .563
   131.1518.6198.619  14.14101.971   21 .846 .563
   141.1518.6198.619  15.14101.971   22 .846 .563
   151.1518.6198.619  16.14101.971   23 .846 .563
   161.1518.6198.619  24.8460.5630
   17.89137.6336.132  18 .0793.097   24.1410 .563   25.519 .563
   18.89137.6336.132  19 .0793.097   26 .519 .563
   19.89137.6336.132  20 .0793.097   27 .519 .563
   20.89137.6336.132  21 .0793.097   28 .519 .563
   21.89137.6336.132  22 .0793.097   29 .519 .563
   22.89137.6336.132  23 .0793.097   30 .519 .563
   23.89137.6336.132  24 .0793.097   31 .519 .563
   24.89137.6336.132  32 .519 .563
   25.71436.3074.806  26 .0792.534   32 .0792.534   33.502 .563
   26.71436.3074.806  27 .0792.534   34 .502 .563
   27.71436.3074.806  28 .0792.535   35 .502 .563
   28.71436.3074.806  29 .0792.534   36 .502 .563
   29.71436.3074.806  30 .0792.534   37 .502 .563
   30.71436.3074.806  31 .0792.534   38 .502 .563
   31.71436.3074.806  32 .0792.534   39 .502 .563
   32.71436.3074.806  40 .502 .563
   33.56084.8843.812  34 .0791.971   40.07901.971   41.361 .563
   34.56084.8843.812  35 .0791.971   42 .361 .563
   35.56084.8843.812  36 .0791.971   43 .361 .563
   36.56084.8843.812  37 .0791.971   44 .361 .563
   37.56084.8843.812  38 .0791.971   45 .361 .563
   38.56084.8843.812  39 .0791.971   46 .361 .563
   39.56084.8843.812  40 .0791.971   47 .361 .563
   40.56084.8843.812  48 .361 .563
   41.43083.3643.149  42 .0791.408   48 .0791.408   49.282 .563
```

```
42.43083.3643.149   43 .0791.408   50 .282 .563
43.43083.3643.149   44 .0791.408   51 .282 .563
44.43083.3643.149   45 .0791.408   52 .282 .563
45.43083.3643.149   46 .0791.408   53 .282 .563
46.43083.3643.149   47 .0791.408   54 .282 .563
47.43083.3643.149   48 .0791.408   55 .282 .563
48.43083.3643.149   56 .282 .563
49.26551.9891.989   50 .141.8445   56.1410.8445   57.1410 .563
50.26551.9891.989   51 .141.8445   57 .141 .563
51.26551.9891.989   52 .141.8445   57 .141 .563
52.26551.9891.989   53 .141.8445   57 .141 .563
53.26551.9891.989   54 .141.8445   57 .141 .563
54.26551.9891.989   55 .141.8445   57 .141 .563
55.26551.9891.989   56 .141.8445   57 .141 .563
56.26551.9891.989   57 .141 .563
57.61405.6923.977
  2    1   57    0    0    0
  1    1    0    0    1
  3    1   57    0    0    0
  1    1    0    0    1
  4    1   57    0    0    0
  1    1    0    0    1
  5    2    1    0    0    0
  1    1    0    0    1
 158.6932.15
  6    3    1    0    0    0
  1    1    0    0    1
 17.89918.68
  7    4    1    0    0    0
  1    1    0    0    1
 19.22512.51
  8    1   57    0    0    0
  1    1    0    0    1
  9    1   57    0    0    0
  1    1    0    0    1
 10    2    1    0    0    0
  1    1    0    0    1
 11    3    1    0    0    0
  1    1    0    0    1
 12    1   57    0    0    0
  1    1    0    0    1
 13    1   57    0    0    0
  1    1    0    0    1
 14    1   57    0    0    0
  1    1    0    0    1
 15    1   57    0    0    0.
  1    1    0    0    1
 16    2    1    0    0    0
  1    1    0    0    1
 17    3    1    0    0    0
  1    1    0    0    1
 18    4    1    0    0    0
  1    1    0    0    1
 19    1   57    0    0    0
  1    1    0    0    0
 20    1   57    0    0    0
  1    1    0    0    1
 21    2    1    0    0    0
  1    1    0    0    1
 22    3    1    0    0    0
```

```
    1    1    0    0    1

rods    22    1    1    0    0    1
    1    1  105
    1 .422   1.     13.000    93.000
    2 .422   1.     23.000   103.000
    3 .422   1.     33.000   113.000
    4 .422   1.     43.000   123.000
    5 .422   1.     53.000   133.000
    6 .422   1.     63.000   143.000
    7 .422   1.     73.000   153.000
    8 .422   1.     83.000   163.000
    9 .422   1.     92.500   172.500
   10 .422   1.    102.500   182.500
   11 .422   1.    112.500   192.500
   12 .422   1.    122.500   202.500
   13 .422   1.    132.500   212.500
   14 .422   1.    142.500   222.500
   15 .422   1.    152.500   232.500
   16 .422   1.    162.500   242.500
   17 .422  .75    172.000   252.000
   18 .422  .75    182.000   262.000
   19 .422  .75    192.000   272.000
   20 .422  .75    202.000   282.000
   21 .422  .75    212.000   292.000
   22 .422  .75    222.000   302.000
   23 .422  .75    232.000   312.000
   24 .422  .75    242.000   322.000
   25 .422   1.    251.500   331.500
   26 .422   1.    261.500   341.500
   27 .422   1.    271.500   351.500
   28 .422   1.    281.500   361.500
   29 .422   1.    291.500   371.500
   30 .422   1.    301.500   381.500
   31 .422   1.    311.500   391.500
   32 .422   1.    321.500   401.500
   33 .422   1.    331.000   411.000
   34 .422   1.    341.000   421.000
   35 .422   1.    351.000   431.000
   36 .422   1.    361.000   441.000
   37 .422   1.    371.000   451.000
   38 .422   1.    381.000   461.000
   39 .422   1.    391.000   471.000
   40 .422   1.    401.000   481.000
   41 .422   1.    410.500   490.500
   42 .422   1.    420.500   500.500
   43 .422   1.    430.500   510.500
   44 .422   1.    440.500   520.500
   45 .422   1.    450.500   530.500
   46 .422   1.    460.500   540.500
   47 .422   1.    470.500   550.500
   48 .422   1.    480.500   560.500
   49 .422   1.     10.375    80.375    90.125   160.125
   50 .422   1.     10.250    20.250    90.250   100.250
   51 .422   1.     20.375    30.375   100.125   110.125
   52 .422   1.     30.250    40.250   110.250   120.250
   53 .422   1.     40.375    50.375   120.125   130.125
   54 .422   1.     50.250    60.250   130.250   140.250
   55 .422   1.     60.375    70.375   140.125   150.125
   56 .422   1.     70.250    80.250   150.250   160.250
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 58 .422   1.    90.250  100.250  170.250  180.250
 59 .422   1.   100.375  110.375  180.125  190.125
 60 .422   1.   110.250  120.250  190.250  200.250
 61 .422   1.   120.375  130.375  200.125  210.125
 62 .422   1.   130.250  140.250  210.250  220.250
 63 .422   1.   140.375  150.375  220.125  230.125
 64 .422   1.   150.250  160.250  230.250  240.250
 65 .422   0.   160.375  170.375  240.125  250.125
 66 .422   1.   170.250  180.250  250.250  260.250
 67 .422   0.   180.375  190.375  260.125  270.125
 68 .422   1.   190.250  200.250  270.250  280.250
 69 .422   0.   200.375  210.375  280.125  290.125
 70 .422   1.   210.250  220.250  290.250  300.250
 71 .422   0.   220.375  230.375  300.125  310.125
 72 .422   1.   230.250  240.250  310.250  320.250
 73 .422   1.   240.375  250.375  320.125  330.125
 74 .422   0.   250.250  260.250  330.250  340.250
 75 .422   1.   260.375  270.375  340.125  350.125
 76 .422   0.   270.250  280.250  350.250  360.250
 77 .422   1.   280.375  290.375  360.125  370.125
 78 .422   0.   290.250  300.250  370.250  380.250
 79 .422   1.   300.375  310.375  380.125  390.125
 80 .422   0.   310.250  320.250  390.250  400.250
 81 .422   0.   320.375  330.375  400.125  410.125
 82 .422   1.   330.250  340.250  410.250  420.250
 83 .422   0.   340.375  350.375  420.125  430.125
 84 .422   1.   350.250  360.250  430.250  440.250
 85 .422   0.   360.375  370.375  440.125  450.125
 86 .422   1.   370.250  380.250  450.250  460.250
 87 .422   0.   380.375  390.375  460.125  470.125
 88 .422   1.   390.250  400.250  470.250  480.250
 89 .422   1.   400.375  410.375  480.125  490.125
 90 .422   1.   410.250  420.250  490.250  500.250
 91 .422   1.   420.375  430.375  500.125  510.125
 92 .422   1.   430.250  440.250  510.250  520.250
 93 .422   1.   440.375  450.375  520.125  530.125
 94 .422   1.   450.250  460.250  530.250  540.250
 95 .422   1.   460.375  470.375  540.125  550.125
 96 .422   1.   470.250  480.250  550.250  560.250
 97 .422   1.   490.375  500.375  570.250
 98 .422   1.   490.250  500.250  570.500
 99 .422   1.   500.375  510.375  570.250
100 .422   1.   510.250  520.250  570.500
101 .422   1.   520.375  530.375  570.250
102 .422   1.   530.250  540.250  570.500
103 .422   1.   540.375  550.375  570.250
104 .422   1.   550.250  560.250  570.500
105 .422   0.   571.000
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  3    1 105
  4    1 105
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  6    0   0
  7    0   0
  8    1 105
  9    1 105
 10    0   0
 11    0   0
 12    1 105
```

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   14    1  105
   15    1  105
   16    0    0
   17    0    0
   18    0    0
   19    1  105
   20    1  105
   21    0    0
   22    0    0
  3.0 .059 655. .366  10.  0.1 409..02431000. .422
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    2                           3.4       0.00
    3                         185.6       0.00
    4                        2954.7       0.00
    5                         247.5     29.878  0.5  .887.715
    6                         202.9       0.00
    7                          88.1       0.00
    8                         381.8       0.00
    9                          68.7       0.00
   10                         332.2       0.00
   11                          3.60       0.00
   12                        181.39       0.00
   13                        356.69       0.00
   14                        194.48       0.00
   15                        353.45
   16                        383.43
   17                         95.22
   18                        713.38
   19                        388.96
   20                       6198.60
   21                        1270.9
   22                       11215.0
    1   10.851               2    2   18  142   19
    2   10.858               1    3   19
    3   10.078               2    4   14    7   19
    4   11.715               1    5   13
    5   11.715               1    6   14
    6   10.078               3   12   14   58   14   82   14
    7   10.858               1    8   18
    8   10.858               1    9   19
    9   10.078               2   10   14   18   19
   10   11.715               1   11   13
   11   11.715               1   14   14
   12   11.715               1   13   13
   13   11.715               1   14   14
   14   10.155               2   15   14   24   14
   15   11.715               1   16   13
   16   11.715               1   17   14
   17   10.078               3   26   12   68   14   76   12
   18   10.858               1   19   18
   19   10.858               1   20   19
   20   10.078               2   21   17   22   14
   21   10.151               1   28   22
   22   11.715               1   23   16
   23   11.280
   24   11.715               1   25   15
   25   11.684               1   29   22
   26   11.397               2   27   11   31   22
```

27	11.048							
28	215.64	2	29	10	32	9		
29	215.64	2	30	10	33	9		
30	215.64	2	31	10	34	9		
31	215.64	2	35	9	80	10		
32	217.03	2	33	8	36	7		
33	217.03	2	34	8	37	7		
34	217.03	2	35	8	38	7		
35	217.03	2	39	7	84	8		
36	238.21	2	37	6	40	5		
37	238.21	2	38	6	41	5		
38	238.21	2	39	6	42	5		
39	238.21	2	43	5	88	6		
40	343.41	2	41	4	44	3		
41	343.41	2	42	4	45	3		
42	343.41	2	43	4	46	3		
43	343.41	2	47	3	92	4		
44	23.459	2	45	1	48	2		
45	23.459	2	46	1	49	2		
46	23.459	2	47	1	50	2		
47	23.459	2	51	2	96	1		
48	2							
49	2							
50	2							
51	2							
52	11.715	2	53	13	142	14		
53	11.715	1	54	14				
54	10.155	3	55	14	57	14	101	14
55	11.715	1	56	13				
56	11.715							
57	11.715	1	58	13				
58	11.715	1	59	14				
59	10.155	3	60	14	67	14	104	14
60	11.715	1	61	13				
61	11.715	1	64	14				
62	11.715	1	63	13				
63	11.715	1	64	14				
64	10.155	2	65	14	73	14		
65	11.715	1	66	13				
66	11.715							
67	11.715	1	68	13				
68	11.715	1	69	14				
69	10.155	3	70	17	71	14	112	14
70	10.151	2	77	20	118	20		
71	11.715	1	72	16				
72	11.280							
73	11.715	1	74	15				
74	11.684	1	78	20				
75	11.397	2	76	11	80	20		
76	11.048							
77	215.64	3	78	10	81	9	116	10
78	215.64	2	79	10	82	9		
79	215.64	2	80	10	83	9		
80	215.64	1	84	9				
81	217.03	3	82	8	85	7	122	8
82	217.03	2	83	8	86	7		
83	217.03	2	84	8	87	7		
84	217.03	1	88	7				
85	238.21	3	86	6	89	5	126	6
86	238.21	2	87	6	90	5		

```
 87    238.21         2   88    6   91    5
 88    238.21         1   92    5
 89    343.41         3   90    4   93    3  130    4
 90    343.41         2   91    4   94    3
 91    343.41         2   92    4   95    3
 92    343.41         1   96    3
 93    23.459         3   94    1   97    2  134    1
 94    23.459         2   95    1   98    2
 95    23.459         2   96    1   99    2
 96    23.459         1  100    2
 97    2
 98    2
 99    2
100    2
101    11.715         1  102   13
102    11.715         1  103   14
103    10.155         3  106   14  153   14  147   14
104    11.715         1  105   13
105    11.715         1  106   14
106    11.715         1  107   13
107    11.715         1  108   14
108    10.155         2  109   14  114   14
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112    11.715         1  113   16
113    11.280
114    11.715         1  115   15
115    11.684         1  119   20
116    11.397         2  117   11  121   20
117    11.048
118    215.64         2  119   10  122    9
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122    217.03         2  123    8  126    7
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126    238.21         2  127    6  130    5
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130    343.41         2  131    4  134    3
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133    343.41         2  137    3  183    4
134    23.459         2  135    1  138    2
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136    23.459         2  137    1  140    2
137    23.459         2  141    2  187    1
138    2
139    2
140    2
141    2
142    10.155         1  143   19
143    10.885         1  144   18
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145    10.155         2  146   14  148   19
146    11.715         1  147   13
```

```
147    11.715
148    10.885          1  149   16
149    10.885          1  150   19
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154    11.715          1  155   14
155    10.155          2  156   14  164   14
156    11.715          1  157   13
157    11.715
158    10.885          1  159   18
159    10.885          1  160   19
160    10.155          2  161   17  162   14
161    10.151          1  168   21
162    11.715          1  163   16
163    11.280
164    11.715          1  165   15
165    11.684          1  169   21
166    11.397          2  167   11  171   21
167    11.048
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169    215.64          2  170   10  173    9
170    215.64          2  171   10  174    9
171    215.64          1  175    9
172    217.03          2  173    8  176    7
173    217.03          2  174    8  177    7
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176    238.21          2  177    6  180    5
177    238.21          2  178    6  181    5
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179    238.21          1  183    5
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183    343.41          1  187    3
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188    2
189    2
190    2
191    2
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  8     1     2     7     8
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 18     1     4     8     8
 19     1     4     7     8
 21     1     6     1    13
 22     2     4     6     8     6     1    18
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 27     1     7     1     6
 28     1     6     1    17
 29     3     4     5     4     5     1     5     6     1     3
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 31     2     5     1     2     7     1     2
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 53     2     1     2     8    12     5     8
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 63     2     8     5     8     3     2     8
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 66     2     3     4     8    10     1     8
 67     2     9     1     8    15     6     8
 68     2     9     2     8    15     5     8
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 72     2     9     4     8    11     1    16
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 74     2     9     5     8    10     1    14
 75     1    10     1     7
 76     1     7     1     6
 77     1    11     1    17
 78     3     9     5     4    10     1     5    11     1     3
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 80     2    10     1     2     7     1     2
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102     2    12     3     8    13     8     8
104     2    13     4     8    15     7     8
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166   1  21   1   7
167   1  18   1   6
168   1  22   1  17
169   3  20   2   4  21   1   5  22   1   3
170   1  21   1   1
171   2  21   1   2  18   1   2

radg   22   1   3
  1   5
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  54.391  .8   1.1369   2.0365   3.0235   4.0      5.0091
  2   8
  14.351  .8   1.0000   2.0000   3.0163   4.2583   5.1317   6.2192
               7.0928   8.2817
  24.325  .8   1.0000   2.0000   3.2078   4.4189   5.0677   6.1126
               7.1105   8.0825
  31.531  .9   1.0463   2.5870   3.0000   4.0000   5.0000   6.0583
               7.1092   8.2072
  45.545  .9   1.2026   2.3267   3.0000   4.0000   5.0000   6.0339
               7.1900   8.2468
  52.606  .9   1.2042   2.1044   3.0000   4.0000   5.0000   6.1895
               7.3127   8.1892
  63.665  .8   1.2602   2.1329   3.0216   4.0513   5.1450   6.0000
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               7.0000   8.0000
  84.362  .8   1.2810   2.0818   3.0727   4.3139   5.1217   6.0710
```

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   32.994   .9    1.0000    2.0000    3.0157    4.9843
   44.295   .8    1.0000    2.0000    3.6861    4.3139
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   2    1    8    4    5   12   13   11   10    8    7
   3    1    8   62   63   65   66   16   15   13   12
   4    1    8   10   11   24   25   23   22   19   18
   5   -2    8   24   25   29   30   31   26   16   15
   6   -1    5   21   28   29   23   22
   7   -3    4   27   31   80   76
   8    1    8   57   58   60   61   63   62   56   55
   9    1    8   67   68   71   72   74   73   61   60
  10   -2    8   73   74   78   79   80   75   66   65
  11   -1    5   70   77   78   72   71
  12    1    8  146  147  102  101   53   52  143  144
  13    1    8  106  107  105  104   58   57  101  102
  14    1    8  156  157  110  109  107  106  153  154
  15    1    8  114  115  113  112   68   67  104  105
  16   -2    8  114  115  119  120  121  116  110  109
  17   -1    5   70  118  119  113  112
  18   -3    4  117  121  171  167
  19    1    8  151  152  154  153  147  146  148  149
  20    1    8  162  163  165  164  152  151  158  159
  21   -2    8  164  165  169  170  171  166  157  156
  22   -1    5  161  168  169  163  162
heat    1    0    1
              3.66                3.66
  1.0  1.0  1.0  1.0  1.0
drag    1    4
 100. -1.0                100. -1.0
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              .9657   2.
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              .9657   1.
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   4    1    0
   2    1    10.001  1.5.9999  1.5
bdry    19   1   16    2
   1   5.24e-8   3.66e+2 0.3333333  .88
   2   4.73e-5
   3   4.60e-5
   4   1.32e-9   7.74e+7 0.3333333  .88
   5   1.89e-6
   6   3.26e-5
   7   1.15e-8   9.85e+4 0.3333333  .88
   8   2.82e-5
   9   9.36e-5
  10   3.94e-6        1.0        .25
  11   2.24e-8
  12   1.89e-7
  13   4.57e-4
  14   5.70e-9   8.02e+5 0.3333333  .88
  15   9.36e-5
```

```
16   2.62e-4
17   2.82e-4
18   2.86e-4
19   5.76e-4
 1    2   0.  65.   1.  65.
48     18.820    1
 1   1.    1   1.    1
49     18.820    1
 1   1.    1   1.    1
50     18.820    1
 1   1.    1   1.    1
51     18.820    1
 1   1.    1   1.    1
97     18.820    1
 1   1.    1   1.    1
98     18.820    1
 1   1.    1   1.    1
99     18.820    1
 1   1.    1   1.    1
100    18.820    1
 1   1.    1   1.    1
138    18.820    1
 1   1.    1   1.    1
139    18.820    1
 1   1.    1   1.    1
140    18.820    1
 1   1.    1   1.    1
141    18.820    1
 1   1.    1   1.    1
188    18.820    1
 1   1.    1   1.    1
189    18.820    1
 1   1.    1   1.    1
190    18.820    1
 1   1.    1   1.    1
191    18.820    1
 1   1.    1   1.    1
  1124.21289.    7    4 65.0 65.0
  110.39    8    0
  20.649   15    0
  3  1.0   16    0
  4  2.0   17    0
  5  3.0   18    0
  6 3.75   19   12   28    2      0.02   29    2      0.02   30    2      0.02
                     31    2      0.02   32    2      0.02   33    2      0.02
                     34    2      0.02   35    2      0.02   36    2      0.02
                     37    2      0.02   38    2      0.02   39    2      0.02
  712.90   14    0
  1  1.0    8    0
  2  1.0    9   95    1    4      1.50    2    4      1.50    3    4      1.50
                      4    4      1.50    5    4      1.50    6    4      1.50
                      7    4      1.50    8    4      1.50    9    4      1.50
                     10    4      1.50   11    4      1.50   12    4      1.50
                     13    4      1.50   14    4      1.50   15    4      1.50
                     16    4      1.50   17    4      1.50   18    4      1.50
                     19    4      1.50   20    4      1.50   21    4      1.50
                     22    4      1.50   23    4      1.50   24    4      1.50
                     25    4      1.50   26    4      1.50   27    5      1.50
                     52    4      1.50   53    4      1.50   54    4      1.50
                     55    4      1.50   56    4      1.50   57    4      1.50
```

```
                58   4      1.50   59   4      1.50   60   4      1.50
                61   4      1.50   62   4      1.50   63   4      1.50
                64   4      1.50   65   4      1.50   66   4      1.50
                67   4      1.50   68   4      1.50   69   4      1.50
                70   4      1.50   71   4      1.50   72   4      1.50
                73   4      1.50   74   4      1.50   75   4      1.50
                76   5      1.50  101   4      1.50  102   4      1.50
               103   4      1.50  104   4      1.50  105   4      1.50
               106   4      1.50  107   4      1.50  108   4      1.50
               109   4      1.50  110   4      1.50  111   4      1.50
               112   4      1.50  113   4      1.50  114   4      1.50
               115   4      1.50  116   5      1.50  117   4      1.50
               142   4      1.50  143   4      1.50  144   4      1.50
               145   4      1.50  146   4      1.50  147   4      1.50
               148   4      1.50  149   4      1.50  150   4      1.50
               151   4      1.50  152   4      1.50  153   4      1.50
               154   4      1.50  155   4      1.50  156   4      1.50
               157   4      1.50  158   4      1.50  159   4      1.50
               160   4      1.50  161   4      1.50  162   4 .    1.50
               163   4      1.50  164   4      1.50  165   4      1.50
               166   4      1.50  167   5      1.50
   3  1.0    9    0
   4  1.0    4    0
   251.401289.    3    3 65.0 65.0
   1 1.00    5    0
   211.31    6   12   28   2      5.61   29   2      5.61   30   2      5.61
                      31   2      5.61   32 . 2      5.61   33   2      5.61
                      34   2      5.61   35   2      5.61   36   2      5.61
                      37   2      5.61   38   2      5.61   39   2      5.61
   315.50    7    0
   1 1.00    2    0
   2 1.00    3    0
   3 1.00    4    0
calc     1

      25
oper     1        3    1                                            1
  20.          145.      1.e-4.001908250      185.    .000000        0.0
.9105.8625.8625.8449.0000.0000.0000.8449.8449.0000.0000.8625
.8449.8449.8449.0000.0000.0000.8625.8449.0000.0000
   14
   0.   0.0.0001  0.0.0002 0.32.0627 0.79.1254 1.04.1881 1.10
.2508 1.10.5643 1.10.6897 1.10.7524 1.05.8150 0.80.9404 0.18
.9405  0.01.000  0.0
outp 1101
endd


 data from iterative solution using the recirculation module
 time =    0.0000    dt = ******    implicit dt = 0.0000    explicit dt = ******    mode =  0


 iteration  sweep          peak clad              total flow    pressure               error
    no.      no.   ---------------------------    (lbm/s)     drop(psi)   -----------------------------------
                    temp(f)  fluid  rod  ass.                              total     flow     fluid    rod
                                                                           energy             energy   energy

     1        1     214.3     18   104    1      0.356e-10   -0.0003075    0.5590  16.3208  0.0149   0.0004
              2     214.7     17   104    1                                0.5347  16.3208  0.0328   0.0006
```

```
2    1   254.0   15  104  1    0.146e-10   0.0000000    0.4204  1.0631  0.0291  0.0026
     2   281.5   14  104  1                             0.4139  1.0631  0.0142  0.0007

3    1   296.1   13  104  1    0.524e-11   0.0000000    0.4238  0.2048  0.0110  0.0003
     2   307.0   13  104  1                             0.4210  0.2048  0.0088  0.0003

4    1   310.0   13  104  1   -0.107e-11   0.0000000   -0.0784  0.1035  0.0391  0.0040
     2   354.0   11  104  1                            -0.0355  0.1035  0.0112  0.0066

5    1   365.8   11  104  1   -0.302e-11   0.0000000   -0.0098  0.0375  0.0046  0.0005
     2   376.0   10  104  1                             0.0020  0.0375  0.0025  0.0003

6    1   382.3   10  104  1   -0.123e-10   0.0000000    0.0132  0.0245  0.0025  0.0002
     2   387.5   10  104  1                             0.0200  0.0245  0.0023  0.0002

7    1   391.9   10  104  1   -0.244e-10   0.0000000    0.0157  0.0160  0.0039  0.0002
     2   395.8   10  104  1                             0.0225  0.0160  0.0026  0.0004

8    1   399.2   10  104  1   -0.321e-10   0.0000000    0.0286  0.0165  0.0016  0.0001
     2   402.3   10  104  1                             0.0323  0.0165  0.0023  0.0001

9    1   405.1   10  104  1   -0.241e-10   0.0000000    0.0360  0.0068  0.0018  0.0001
     2   407.5   10  104  1                             0.0383  0.0068  0.0023  0.0001

10   1   409.8   10  104  1   -0.135e-10   0.0000000   -0.0006  0.0044  0.0038  0.0003
     2   414.2   10  104  1                             0.0050  0.0044  0.0025  0.0006

11   1   416.3   10  104  1   -0.568e-11   0.0000000    0.0085  0.0029  0.0020  0.0001
     2   418.2   10  104  1                             0.0105  0.0029  0.0023  0.0001

12   1   419.6   10  104  1   -0.136e-11   0.0000000    0.0124  0.0019  0.0021  0.0001
     2   420.9   10  104  1                             0.0137  0.0019  0.0023  0.0001

13   1   421.9   10  104  1    0.337e-12   0.0000000    0.0009  0.0012  0.0029  0.0001
     2   423.0   10  104  1                             0.0031  0.0012  0.0024  0.0002

14   1   424.5   10  104  1    0.720e-12   0.0000000    0.0046  0.0008  0.0022  0.0001
     2   425.4   10  104  1                             0.0055  0.0008  0.0023  0.0001

15   1   426.0   10  104  1    0.568e-12   0.0000000    0.0063  0.0005  0.0022  0.0001
     2   426.6   10  104  1                             0.0068  0.0005  0.0023  0.0001

16   1   427.1   10  104  1    0.289e-12   0.0000000    0.0002  0.0003  0.0026  0.0001
     2   427.9   10  104  1                             0.0013  0.0003  0.0023  0.0001

17   1   428.3   10  104  1    0.102e-12   0.0000000    0.0019  0.0002  0.0022  0.0001
     2   428.7   10  104  1                             0.0024  0.0002  0.0023  0.0001

18   1   429.0   10  104  1    0.350e-14   0.0000000    0.0027  0.0001  0.0023  0.0001
     2   429.3   10  104  1                             0.0030  0.0001  0.0023  0.0001

19   1   429.5   10  104  1   -0.413e-13   0.0000000    0.0001  0.0001  0.0024  0.0001
     2   429.8   10  104  1                             0.0006  0.0001  0.0023  0.0001

20   1   430.0   10  104  1   -0.414e-13   0.0000000    0.0009  0.0001  0.0023  0.0001
     2   430.2   10  104  1                             0.0011  0.0001  0.0023  0.0001

21   1   430.3   10  104  1   -0.300e-13   0.0000000    0.0013  0.0000  0.0023  0.0001
     2   430.4   10  104  1                             0.0014  0.0000  0.0023  0.0001
```

```
 22        1     430.6    10   104    1      -0.224e-13    0.0000000       0.0001   0.0000   0.0024   0.0001
           2     430.7    10   104    1                                    0.0003   0.0000   0.0023   0.0001

 23        1     430.8    10   104    1      -0.127e-13    0.0000000       0.0004   0.0000   0.0023   0.0001
           2     430.9    10   104    1                                    0.0005   0.0000   0.0023   0.0001

 24        1     430.9    10   104    1      -0.673e-14    0.0000000       0.0006   0.0000   0.0023   0.0001
           2     431.0    10   104    1                                    0.0007   0.0000   0.0023   0.0001


 slab temperature summary          time =    0.0000 seconds
 (assembly no. - channel no.)


axial zone      ( 11)     ( 12)     ( 13)     ( 14)     ( 15)     ( 16)     ( 17)     ( 18)     ( 19)     ( 20)
 (inches)

  0.0 -  8.9    244.45    258.07    247.77    241.36    235.49    225.59    219.87    239.49    223.68    212.93
  8.9 - 17.7    277.21    291.88    281.42    273.24    266.22    255.31    249.71    270.87    250.67    236.87
 17.7 - 26.6    303.44    320.38    308.26    298.69    290.52    277.94    271.44    296.23    272.74    256.65
 26.6 - 35.4    321.38    339.72    326.56    316.15    307.23    293.53    286.43    313.62    288.07    270.57
 35.4 - 44.3    332.87    351.99    338.26    327.38    318.06    303.74    296.32    324.78    298.06    279.78
 44.3 - 53.2    340.15    359.68    345.64    334.50    324.95    310.29    302.68    331.68-   304.50    285.79
 53.2 - 62.0    344.50    364.24    350.04    338.76    329.00    314.24    306.54    336.14    308.43    289.48
 62.0 - 70.9    346.67    366.49    352.23    340.80    331.16    316.23    308.48    338.29    310.43    291.39
 70.9 - 79.7    347.01    366.82    352.58    341.23    331.49    316.54    308.79    338.65    310.80    291.76
 79.7 - 88.6    345.60    365.29    351.11    339.84    330.13    315.24    307.51    337.29    309.58    290.64
 88.6 - 97.5    342.18    361.63    347.63    336.49    326.89    312.14    304.48    333.99    306.62    287.89
 97.5 -106.3    336.22    355.22    341.54    330.65    321.25    306.77    299.25    328.23    301.48    283.16
106.3 -115.2    326.66    344.87    331.76    321.32    312.28    298.34    291.09    318.99    293.32    275.72
115.2 -124.1    311.82    328.65    316.56    306.92    298.59    285.71    278.99    304.58    280.75    264.42
124.1 -132.9    290.27    304.92    294.49    286.23    279.18    268.19    262.45    283.45    262.46    248.22
132.9 -141.8    265.50    277.62    269.14    262.48    256.98    248.32    243.78    259.06    241.32    229.48
141.8 -150.6    242.33    252.14    245.45    240.29    236.30    229.91    226.56    236.07    221.22    211.54
150.6 -159.5    226.43    234.72    229.25    225.14    222.27    217.59    215.15    220.06    206.96    198.63




 side boundary temperature summary      time =    0.0000 seconds
 boundary slab node no.    48


axial zone      (  1)     (  2)      (
 (inches)

  0.0 -  8.9    137.54     65.00
  8.9 - 17.7    143.44     65.00
 17.7 - 26.6    149.94     65.00
 26.6 - 35.4    155.58     65.00
 35.4 - 44.3    160.06     65.00
 44.3 - 53.2    163.37     65.00
 53.2 - 62.0    165.61     65.00
 62.0 - 70.9    166.86     65.00
```

```
  70.9 - 79.7     167.18       65.00
  79.7 - 88.6     166.61       65.00
  88.6 - 97.5     165.14       65.00
  97.5 -106.3     162.79       65.00
 106.3 -115.2     159.55       65.00
 115.2 -124.1     155.46       65.00
 124.1 -132.9     150.66       65.00
 132.9 -141.8     145.36       65.00
 141.8 -150.6     139.97       65.00
 150.6 -159.5     135.55       65.00




 calculated rod temperatures at time =    0.0000 seconds
 rod no.   74
 assembly   1                    (fuel type  1 - cylinder)
0rod o.d. - 0.422 (in.)     zone-(fuel dia.(in.)) -  1-(0.366)

                                                   *  fuel temperatures(f.)
                                                   *
   axial zone  heat flux   type              hsurf *  fluid    clad
      (in.)    (mbtu/hr-ft2)             (b/h-f-ft2) *
    0.0 -   8.9    0.0000    1               10.0     287.7    287.6
    8.9 -  17.7    0.0000    1               10.4     337.0    337.0
   17.7 -  26.6    0.0000    1               10.7     371.9    372.0
   26.6 -  35.4    0.0000    1               10.9     392.8    392.9
   35.4 -  44.3    0.0000    1               11.0     405.0    405.1
   44.3 -  53.2    0.0000    1               11.1     412.6    412.7
   53.2 -  62.0    0.0000    1               11.1     417.1    417.2
   62.0 -  70.9    0.0000    1               11.1     419.3    419.4
   70.9 -  79.7    0.0000    1               11.1     419.6    419.7
   79.7 -  88.6    0.0000    1               11.1     418.0    418.1
   88.6 -  97.5    0.0000    1               11.1     414.4    414.5
   97.5 - 106.3    0.0000    1               11.1     407.9    408.0
  106.3 - 115.2    0.0000    1               11.0     397.4    397.5
  115.2 - 124.1    0.0000    1               10.8     379.5    379.6
  124.1 - 132.9    0.0000    1               10.5     348.1    348.2
  132.9 - 141.8    0.0000    1               10.2     310.3    310.3
  141.8 - 150.6    0.0000    1                9.9     272.9    272.9
  150.6 - 159.5    0.0000    1                9.6     242.2    242.2



 calculated rod temperatures at time =    0.0000 seconds
 rod no.   74
 assembly   2                    (fuel type  1 - cylinder)
0rod o.d. - 0.422 (in.)     zone-(fuel dia.(in.)) -  1-(0.366)

                                                   *  fuel temperatures(f.)
                                                   *
   axial zone  heat flux   type              hsurf *  fluid    clad
      (in.)    (mbtu/hr-ft2)             (b/h-f-ft2) *
    0.0 -   8.9    0.0000    1                9.9     277.7    277.7
    8.9 -  17.7    0.0000    1               10.3     324.6    324.6
   17.7 -  26.6    0.0000    1               10.6     357.9    357.9
   26.6 -  35.4    0.0000    1               10.8     377.9    378.0
   35.4 -  44.3    0.0000    1               10.9     389.7    389.7
```

```
  44.3 -  53.2    0.0000    1              11.0      397.0    397.1
  53.2 -  62.0    0.0000    1              11.0      401.4    401.5
  62.0 -  70.9    0.0000    1              11.0      403.6    403.7
  70.9 -  79.7    0.0000    1              11.0      403.9    404.0
  79.7 -  88.6    0.0000    1              11.0      402.4    402.5
  88.6 -  97.5    0.0000    1              11.0      398.9    399.1
  97.5 - 106.3    0.0000    1              10.9      392.8    392.9
 106.3 - 115.2    0.0000    1              10.8      382.8    382.9
 115.2 - 124.1    0.0000    1              10.7      365.9    366.1
 124.1 - 132.9    0.0000    1              10.4      336.1    336.2
 132.9 - 141.8    0.0000    1              10.1      300.3    300.4
 141.8 - 150.6    0.0000    1               9.8      264.9    265.0
 150.6 - 159.5    0.0000    1               9.6      235.7    235.7



 calculated rod temperatures at time =    0.0000 seconds
 rod no.   76
 assembly   3                    (fuel type  1 - cylinder)
0rod o.d. - 0.422 (in.)     zone-(fuel dia.(in.)) -  1-(0.366)

                                                *   fuel temperatures(f.)
                                                *
   axial zone  heat flux   type           hsurf *   fluid    clad
      (in.)   (mbtu/hr-ft2)          (b/h-f-ft2) *
   0.0 -   8.9    0.0000    1               9.8      259.6    259.7
   8.9 -  17.7    0.0000    1              10.1      302.8    302.8
  17.7 -  26.6    0.0000    1              10.4      332.2    332.2
  26.6 -  35.4    0.0000    1              10.5      349.5    349.5
  35.4 -  44.3    0.0000    1              10.6      359.6    359.6
  44.3 -  53.2    0.0000    1              10.7      366.0    366.1
  53.2 -  62.0    0.0000    1              10.7      369.9    369.9
  62.0 -  70.9    0.0000    1              10.7      371.8    371.9
  70.9 -  79.7    0.0000    1              10.7      372.1    372.1
  79.7 -  88.6    0.0000    1              10.7      370.8    370.9
  88.6 -  97.5    0.0000    1              10.7      367.8    367.8
  97.5 - 106.3    0.0000    1              10.7      362.4    362.5
 106.3 - 115.2    0.0000    1              10.6      353.9    353.9
 115.2 - 124.1    0.0000    1              10.5      339.5    339.5
 124.1 - 132.9    0.0000    1              10.2      313.4    313.4
 132.9 - 141.8    0.0000    1              10.0      281.9    282.0
 141.8 - 150.6    0.0000    1               9.7      250.7    250.7
 150.6 - 159.5    0.0000    1               9.5      224.2    224.2



 calculated rod temperatures at time =    0.0000 seconds
 rod no.   78
 assembly   4                    (fuel type  1 - cylinder)
0rod o.d. - 0.422 (in.)     zone-(fuel dia.(in.)) -  1-(0.366)

                                                *   fuel temperatures(f.)
                                                *
   axial zone  heat flux   type           hsurf *   fluid    clad
      (in.)   (mbtu/hr-ft2)          (b/h-f-ft2) *
   0.0 -   8.9    0.0000    1               9.6      244.9    244.9
   8.9 -  17.7    0.0000    1              10.0      283.9    283.8
  17.7 -  26.6    0.0000    1              10.2      310.9    310.9
```

```
 26.6 -  35.4   0.0000   1         10.4     326.7    326.7
 35.4 -  44.3   0.0000   1         10.4     335.9    335.9
 44.3 -  53.2   0.0000   1         10.5     341.9    341.8
 53.2 -  62.0   0.0000   1         10.5     345.5    345.5
 62.0 -  70.9   0.0000   1         10.5     347.3    347.3
 70.9 -  79.7   0.0000   1         10.5     347.7    347.7
 79.7 -  88.6   0.0000   1         10.5     346.5    346.6
 88.6 -  97.5   0.0000   1         10.5     343.8    343.8
 97.5 - 106.3   0.0000   1         10.5     339.1    339.1
106.3 - 115.2   0.0000   1         10.4     331.4    331.5
115.2 - 124.1   0.0000   1         10.3     318.4    318.4
124.1 - 132.9   0.0000   1         10.1     293.9    294.0
132.9 - 141.8   0.0000   1          9.8     264.2    264.2
141.8 - 150.6   0.0000   1          9.5     234.1    234.1
150.6 - 159.5   0.0000   1          9.3     207.6    207.6
```

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