

CRWMS/M&O

Design Analysis Cover Sheet

INFORMATION ONLY
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1. Purpose

The purpose of this analysis is to evaluate the transient behavior and consequences of a worst case criticality event involving intact pressurized water reactor (PWR) spent nuclear fuel (SNF) in a degraded basket configuration inside a 21 PWR assembly waste package (WP). The objective of this analysis is to demonstrate that the consequences of a worst case criticality event involving intact PWR SNF are insignificant in their effect on the overall radioisotopic inventory in a WP.

2. Quality Assurance

The Quality Assurance (QA) program applies to this analysis. The work reported in this document is part of the preliminary waste package (WP) design analysis that will eventually support the License Application Design phase. This activity, when appropriately confirmed, can impact the proper functioning of the Mined Geologic Disposal System (MGDS) waste package; the waste package has been identified as an MGDS Q-List item important to safety and waste isolation (Ref. 5.1, pp. 4, 15). The waste package is on the Q-List by direct inclusion by the Department of Energy (DOE), without conducting a QAP-2-3 *Classification of Permanent Items* evaluation. The responsible manager for the Waste Package Development Department has evaluated this activity in accordance with QAP-2-0, *Conduct of Activities*. The *Perform Criticality, Thermal, Structural, and Shielding Analyses* (Ref. 5.2) activity evaluation has determined that work associated with the commercial SNF waste package design task is subject to *Quality Assurance Requirements and Description* (QARD) (Ref. 5.3) requirements. As specified in NLP-3-18, *Documentation of QA Controls on Drawings, Specifications, Design Analyses, and Technical Documents*, this activity is subject to QA controls.

Design inputs which are identified in this document are for the preliminary stage of the WP design process; all of these design inputs will require subsequent confirmation (or superseding inputs) as the waste package design proceeds. Consequently, use of any data from this analysis for input into documents supporting construction, fabrication, or procurement is required to be controlled as "to be verified" (TBV) in accordance with the appropriate procedures.

3. Method

An internal WP criticality is modeled in a manner analogous to transient phenomena in a nuclear reactor core. The light water reactor (LWR) transient analysis code, RELAP5/MOD3 (Ref. 5.4), is used to calculate the time evolution of the power level and other characteristics of a criticality involving PWR SNF. Reactivity tables based on changes in k_{eff} from a baseline configuration must be included in the RELAP5 input. The Monte Carlo N-Particle computer program, MCNP4A (Ref. 5.5), is used to calculate a baseline k_{eff} for criticality safety evaluations and to determine the change in reactivity from one configuration to another. MCNP4A does not have an associated cross section library with sufficient temperature dependent data to calculate the reactivity changes

associated with fuel and moderator temperature changes required for this analysis. The SAS2H sequence of SCALE4.3 (Ref. 5.10) does have the necessary cross sections. SAS2H employs a one-dimensional (1-D) assembly-cell discrete-ordinates technique (XSDRNPM) for calculation of the multiplication factor (k_{eff}) for a configuration. A correction for finite dimensions can be made through use of various buckling terms. Initially, infinite MCNP cases were run with which to compare the results from infinite SAS2H cases in order to develop the appropriate SAS2H model to match MCNP results. Corrections were then made to the SAS2H model to account for finite dimensions using the appropriate buckling terms for inclusion in the models based on the baseline MCNP finite case. The resulting SAS2H model incorporating the buckling terms is then used for calculating temperature and density reactivity effects. The reactivity changes calculated by MCNP4A and SAS2H are used as input to RELAP5 to track the transient behavior of a criticality. The ORIGEN-S program in the SCALE4.3 code package is used to calculate the changes to the radioisotopic inventory as a result of the analyzed criticality events.

4. Design Inputs

4.1 Design Parameters

4.1.1 Spent Fuel Assembly Parameters

The fuel assembly which this calculation is based upon is the B&W 15X15 fuel assembly. The mechanical parameters for this assembly type are shown in Table 4.1-1. Note that inches are converted to centimeters exactly (2.54 cm/in.); this is not an indication of tolerance (accuracy), but is done for consistency between calculations using English and metric units. The theoretical density of natural UO_2 is 10.96 g/cm³ (Ref. 5.10, Table M8.2.1). This information represents B&W fuel assembly dimensions prior to irradiation and is considered qualified data.

| Table 4.1-1. Mechanical Parameters of B&W 15X15 Fuel Assembly | | | | | | |
|---|---------|---------|----------|---------|-------------|-------------------|
| Parameter | Value | Units | Metric | Units | Radius (cm) | Reference |
| Fuel Rods | 208 | /assbly | 208 | /assbly | - | 5.7, p. 2.1.2.2-6 |
| Fuel Rods on a Lattice Side | 15 | /side | 15 | /side | - | 5.7, p. 2.1.2.2-6 |
| Guide Tubes | 16 | /assbly | 16 | /assbly | - | 5.7, p. 2.1.2.2-6 |
| Instrumentation Tubes | 1 | /assbly | 1 | /assbly | - | 5.7, p. 2.1.2.2-6 |
| Total Guide + Instrument Tubes | 17 | /assbly | 17 | /assbly | - | - |
| Clad/Tube Material | Zirc-4 | | Zirc-4 | | - | 5.7, p. 2.1.2.2-6 |
| Fuel Pellet OD | 0.3686 | inches | 0.936244 | cm | 0.468122 | 5.7, p. 2.1.2.2-6 |
| Fuel Stack Height | 141.8 | inches | 360.172 | cm | - | 5.7, p. 2.1.2.2-6 |
| Fuel Assembly Height | 165.625 | inches | 420.6875 | cm | - | 5.8, p. 2A-8 |
| Mass of U | 1023 | lb | 464 | kg | - | 5.8, p. 2A-8 |
| Mass of UO_2 | 1160.64 | lb | 526.38 | kg | - | 5.7, p. 2.1.2.2-6 |

| Table 4.1-1. Mechanical Parameters of B&W 15X15 Fuel Assembly | | | | | | |
|---|--------|---------------------|----------|----------------|-------------|-------------------|
| Parameter | Value | Units | Metric | Units | Radius (cm) | Reference |
| Percent of Theoretical Density | 95 | % | 95 | % | - | 5.7, p. 2.1.2.2-6 |
| Fuel Clad OD | 0.430 | inches | 1.0922 | cm | 0.5461 | 5.7, p. 2.1.2.2-6 |
| Clad Thickness | 0.0265 | inches | 0.06731 | cm | - | 5.7, p. 2.1.2.2-6 |
| Fuel Clad ID* | 0.377 | inches | 0.95758 | cm | 0.47879 | - |
| Fuel Rod Pitch | 0.568 | inches | 1.44272 | cm | - | 5.7, p. 2.1.2.2-6 |
| Guide Tube OD | 0.530 | inches | 1.3462 | cm | 0.6731 | 5.7, p. 2.1.2.2-6 |
| Guide Tube Thickness | 0.016 | inches | 0.04064 | cm | - | 5.7, p. 2.1.2.2-6 |
| Guide Tube ID* | 0.498 | inches | 1.26492 | cm | 0.63246 | - |
| Instrumentation Tube OD | 0.493 | inches | 1.25222 | cm | 0.62611 | 5.7, p. 2.1.2.2-6 |
| Fuel Assembly Envelope | 8.536 | inches | 21.68144 | cm | - | 5.7, p. 2.1.2.2-6 |
| Displaced Volume per Fuel Assembly | 4927 | inches ³ | 0.081 | m ³ | - | 5.9, p. II-3.6-98 |

* The inner diameters (IDs) above are calculated by subtracting 2 × thickness from the outer diameter (OD).

4.1.2 Intact Waste Package Geometry Parameters

The intact waste package geometry parameters used for this analysis are listed in Table 4.1-2 below. These are considered unqualified TBV information, as other WPD QAP-3-9 analyses being performed in parallel may result in design changes not reflected in these parameter values. Minor dimensional revisions from the listed values, if incorporated in the computational models used in this analysis, will have an insignificant effect on results from this analysis.

| Table 4.1-2. Intact WP Dimensions | | |
|---|-----------|-----------------------|
| Component | Dimension | Reference |
| Outer barrier length (skirt edge to skirt edge) | 533.5 cm | 5.11, p. I-18 |
| Outer barrier skirt length (both ends) | 22.5 cm | 5.11, p. I-18 |
| Outer barrier lid thickness | 11.0 cm | 5.11, p. I-18 |
| Outer barrier inner radii | 73.1 cm | 5.12, p. 8 |
| Outer barrier outer radii | 83.1 cm | 5.12, p. 8 |
| Gap between inner and outer lids | 3.0 cm | 5.11, pp. I-18 & I-19 |
| Inner barrier length (overall) | 463.5 cm | 5.11, p. I-19 |
| Inner barrier lid thickness | 2.5 cm | 5.11, p. I-19 |
| Inner barrier inner radii | 71.095 cm | 5.12, p. 8 |
| Inner barrier outer radii | 73.095 cm | 5.12, p. 8 |
| Fuel cell tube thickness | 0.5 cm | 5.11, p. I-21 |
| Fuel cell tube height | 457.5 cm | 5.11, p. I-21 |
| Fuel cell tube outside width | 23.64 cm | 5.11, p. I-21 |

| Table 4.1-2. Intact WP Dimensions | | |
|--|------------------------|------------------------|
| Component | Dimension | Reference |
| Total displaced volume of single fuel cell tube | 0.02117 m ³ | 5.11, p. VI-1 |
| Criticality control plate thickness | 0.7 cm | 5.11, pp. I-29 to I-31 |
| Criticality control plate height | 113.38 cm | 5.11, p. I-20 |
| Total displaced volume of all criticality control plates | 0.243 m ³ | 5.11, p. VI-1 |
| Total displaced volume of guides and supports | 0.259 m ³ | 5.11, p. VI-1 |

4.1.3 Material Properties

The atom densities for the SNF used are taken from a previous criticality analysis (Ref. 5.13, case r58h13f). Case r58h13f is the reference condition on which reactivity calculations are made and the RELAP5 cases are developed. The input for this case is included in Attachment I.

Table 4.1-3. Atom Densities for 4.9% Enriched B&W 15X15 SNF with 34 GWd/MTU and 25,000 Years Burnup (Ref. 5.13)

| Isotope ID | Number Density |
|------------|----------------|
| 8016.50C | 0.046947 |
| 42095.50C | 4.794679E-05 |
| 44101.50C | 4.354501E-05 |
| 43099.50C | 4.284296E-05 |
| 45103.50C | 2.608717E-05 |
| 47109.50C | 3.714096E-06 |
| 60143.50C | 3.74851E-05 |
| 60145.50C | 2.799527E-05 |
| 62147.50C | 1.138963E-05 |
| 62149.50C | 1.455085E-07 |
| 62150.50C | 1.043884E-05 |
| 62152.50C | 4.59594E-06 |
| 63151.55C | 8.136066E-07 |
| 63153.55C | 3.93607E-06 |
| 64155.50C | 1.686186E-07 |
| 92233.50C | 3.326725E-07 |
| 92234.50C | 1.018437E-05 |
| 92235.50C | 5.531404E-04 |
| 92236.50C | 1.774777E-04 |
| 92238.50C | 2.174501E-02 |
| 93237.55C | 4.392789E-05 |
| 94239.55C | 7.906197E-05 |
| 94240.50C | 3.440139E-06 |
| 94241.50C | 2.761636E-12 |
| 94242.50C | 7.012276E-06 |
| 95241.50C | 8.639479E-11 |
| 95243.50C | 1.386765E-07 |

4.2 Criteria

Requirements identified as TBD in the *Engineered Barrier Design Requirements Document* (EBDRD; Ref. 5.7) will not be carried to the conclusions of this analysis based on the rationale that the conclusions are for preliminary design, and will not be used as input in design documents supporting construction, fabrication, or procurement.

The criterion for this analysis is:

- The Engineered Barrier System shall be designed such that the probability and consequences of nuclear criticality provide reasonable assurances that the performance objective of 10CFR60.112 is met [EBDRD 3.7.1.3.A, 3.3.1.G].

In addition, EBDRD 3.3.1.G indicates that "The Engineered Barrier Segment design shall meet all relevant requirements imposed by 10CFR60." The NRC has recently revised several parts of 10CFR60 which relate to the identification and analysis of design basis events (Ref. 5.9) including the criticality control requirement, which was moved to 60.131(h). These changes are not reflected in the current versions of the EBDRD or the CDA. The change to the criticality requirement simply replaces the phrase "criticality safety under normal and accident conditions" with "criticality safety assuming design basis events."

The criterion for this analysis, together with the wording in the current 10CFR60.131(h) can be summarized as: (1) Demonstration of the prevention of criticality, (2) Demonstration that the consequences of criticality (even if one did occur) are insignificant. This analysis is part of a continuing sequence which individually contribute to satisfying the second of these criteria in the following manner:

- The consequences of a criticality, particularly the increase in radionuclide inventory and transient overpressure and temperature, are shown to be insignificant under the range of conditions considered thus far.
- The severity of consequence (particularly increase in radionuclide inventory) will be used as input to the Total System Performance Assessment (TSPA) - Viability Assessment (VA) which, in turn, will demonstrate compliance with the performance objective of §60.112 (as specified in CDA Key assumption 60).

4.3 Assumptions

- 4.3.1 It is assumed that the nuclear reactor type model of a WP developed for RELAP5/MOD3 is an appropriate approximation to the criticality processes involving PWR SNF inside a waste package (TBV). The basis for this assumption is as follows:

RELAP5/MOD3 was developed for the U.S. Nuclear Regulatory Commission for simulations of transient phenomena in PWR systems such as loss of coolant (Ref. 5.4). The physical processes involving material behavior of PWR SNF within a waste package during a criticality event are similar to the situations for which RELAP5/MOD3 was developed to analyze. There is reasonable confidence in the capability of RELAP5/MOD3 to provide conservative results for the applications within this analysis.

Inherent in the assumption that RELAP5 provides an appropriate approximation for WP criticality events is also the assumption that the time dependent neutron population in the WP fuel assemblies can be represented by the point kinetics model. The basis for this assumption is the compact size of the fuel assembly array making the system tightly coupled neutronicly and preventing any spatially localized phase differences in the neutron amplitude.

This assumption is used in Sections 7.4 and 7.5.

4.3.2 It is assumed that the reactivity feedback mechanism for the point kinetics model can be represented by separable effects (TBV). The bases for this assumption are as follows:

- (1) Doppler reactivity depends upon intrinsic fuel parameters with temperature being the only time dependent variable,
- (2) moderator reactivity effects depend only upon the fluid density,
- (3) no soluble poisons are modeled, and
- (4) the settled iron oxide residue is not redistributed in the WP.

This assumption is used throughout Section 7.

4.3.3 The waste package is assumed to be filled with water at the start of the postulated reactivity driven scenarios. The basis for this assumption is that it is conservative and is developed as a scenario in previous probabilistic analyses (Ref. 5.18). This assumption is used in Sections 7.2, 7.3, and 7.4.

4.3.4 CDA assumption EBD RD 3.7.1.3.A has been used to replace TBVs in requirements applicable to this document. The bases for these assumptions are given in the CDA (Ref. 5.15). These assumptions are used in Section 4.2.

4.3.5 Water inflow to the degraded WP is assumed to be 20 m³/year at ambient drift space conditions. The basis for this assumption is that this is the largest design basis flow rate for long term periods (300-20,000 years after emplacement) given by CDA Assumption TDSS

026. Climate models suggest that the long term infiltration rate could possibly increase by as much as a factor of 10. This assumption is used throughout Section 7.

- 4.3.6 The most reactive SNF disposed of in the absorber rod WPs have been excluded from consideration in this analysis since the absorber rod WP design will take credit for the long term presence of neutron absorber control rods (CDA Key 081).

4.4 Codes and Standards

Not Applicable. Neutronic design of the waste package is not controlled by codes and standards.

5. References

- 5.1 *Yucca Mountain Site Characterization Project Q-List*, YMP/90-55Q, REV 4, Yucca Mountain Site Characterization Project.
- 5.2 *QAP-2-0 Activity Evaluations*, ID No. WP-20, Perform Criticality, Thermal, Structural, and Shielding Analyses, Dated 8/3/97, Civilian Radioactive Waste Management System (CRWMS) Management and Operating Contractor (M&O).
- 5.3 *Quality Assurance Requirements and Description*, DOE/RW-0333P REV 7, U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM).
- 5.4 *RELAP5/MOD3 Code Manual*, NUREG/CR-5535, INEL-95/0174, Prepared by Idaho National Engineering Laboratory for the U.S. Nuclear Regulatory Commission, August 1995.
- 5.5 *Software Qualification Report for MCNP4A*, CSCI: 30006 V4A, Document Identifier Number (DI#): 30006-2003 REV 02, CRWMS M&O.
- 5.6 *Software Qualification Report for The SCALE Modular Code System Version 4.3*, CSCI: 30011 V4.3, DI#: 30011-2002 REV 01, CRWMS M&O.
- 5.7 *Preliminary Waste Form Characteristics Report Version 1.0*, UCRL-ID-108314 Rev 1, Lawrence Livermore National Laboratory, December 1994.
- 5.8 *Characteristics of Potential Repository Wastes*, DOE/RW-0184-R1, Volume 1, US DOE OCRWM, July 1992.
- 5.9 *Final Design Package - Babcock & Wilcox BR-100 - 100 Ton Rail/Barge Spent Fuel Shipping Cask*, Document No. 51-1203400-01, B&W Fuel Company, November 1991.
- 5.10 *SCALE 4.3*, RSIC Computer Code Collection, CCC-545, Oak Ridge National Laboratory, October 1995.
- 5.11 *Waste Package Design Basis Events*, DI#: BBA000000-01717-0200-00037 REV 00, CRWMS M&O.
- 5.12 *Probabilistic Criticality Consequence Evaluation*, DI#: BBA000000-01717-0200-00021 REV 00, CRWMS M&O.
- 5.13 *Criticality Evaluation of Degraded Internal Configurations for the PWR AUCF WP Designs*, DI#: BBA000000-01717-0200-00056 REV 00, CRWMS M&O.

Waste Package Development

Design Analysis

Title: Criticality Consequence Analysis Involving Intact PWR SNF in a Degraded 21 PWR Assembly Waste Package

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- 5.14 *Engineered Barrier Design Requirements Document*, YMP/CM-0024, REV 0, ICN 1, Yucca Mountain Site Characterization Project.
- 5.15 *Controlled Design Assumptions Document*, DI#: B00000000-01717-4600-00032 REV 04, ICN 02, CRWMS M&O.
- 5.16 *10 CFR Part 60; Disposal of High-Level Radioactive Wastes in Geologic repositories; Design Basis Events; Final Rule*, U.S. Nuclear Regulatory Commission, Federal Register, volume 61, Number 234, pp. 64257-64270, December 4, 1996.
- 5.17 Jensen, Peter J., et al, *Anticipated Transients Without Scram Analysis for the River Bend Station*, Proceedings: Fourth International RETRAN Conference, EPRI NP-4558-SR, p. 23-1, May 1986.
- 5.18 *Second Waste Package Probabilistic Criticality Analysis: Generation and Evaluation of Internal Criticality Configurations*, DI#: BBA000000-01717-0200-00005 REV 00, CRWMS M&O.
- 5.19 *Determination of WP Design Configurations*, DI#: BBAA00000-01717-0200-00017 REV 00, CRWMS M&O.
- 5.20 Duderstadt, James J., Hamilton, Louis J., *Nuclear Reactor Analysis*, John Wiley & Sons, New York, 1976.
- 5.21 *Third Waste Package Probabilistic Criticality Analysis: Methodology for Basket Degradation with Application to Commercial Spent Nuclear Fuel*, DI#: BBA000000-01717-0200-00049 REV 00, CRWMS M&O.
- 5.22 *Electronic Attachments for: BBA000000-01717-0200-00057 REV 00, Criticality Consequence Analysis Involving Intact PWR SNF in a Degraded 21 PWR Assembly Waste Package*, Colorado Backup Tape, RPC Batch Number MOY-970904-01, CRWMS M&O.
- 5.23 *Final Safety Analysis Report Three Mile Island Nuclear Station - Unit 1*, TMI-1/FSAR, April, 1996.
- 5.24 Idelchik, I. E., *Handbook of Hydraulic Resistance*, The State Scientific Research Institute for Industrial and Sanitary Gas Purification, Second Edition, Moscow, Russia.

6. Use of Computer Software

The calculation of nuclear reactivity of PWR SNF configurations was performed with the MCNP4A computer code, CSCI: 30006 V4A. MCNP4A calculates k_{eff} for a variety of geometric configurations with neutron cross sections for elements and isotopes described in the Evaluated Nuclear Data File version B-V (ENDF-B/V). MCNP4A is appropriate for the fuel geometries and materials required for these analyses. The calculations using the MCNP4A software were executed on Hewlett-Packard (HP) workstations. The software qualification of the MCNP4A software, including problems related to calculation of k_{eff} for fissile systems, is summarized in the Software Qualification Report for the Monte Carlo N-Particle code (Ref. 5.5). The MCNP4A evaluations performed for this design are fully within the range of the validation for the MCNP4A software used. Access to and use of the MCNP4A software for this analysis was granted by Software Configuration Management and performed in accordance with the QAP-SI series procedures. Inputs and outputs for the MCNP4A software are included as attachments (see Tables 9-1 and 9-2) as described in the following design analysis.

The calculation of nuclear reactivity of PWR SNF configurations was also performed with the SAS2H code sequence, which is a part of the SCALE 4.3 code system, CSCI: 30011 V4.3. SAS2H is designed for spent fuel depletion and reactivity calculations to determine spent fuel isotopic content. Thus, SAS2H and ORIGEN-S are appropriate for the fuel geometries and materials required for these analyses. The calculations using the SCALE4.3 software were executed on HP workstations. The software qualification of the SCALE4.3 software, including benchmark problems related to generation of isotope contents, is summarized in the Software Qualification Report for the SCALE Modular Code system (Ref. 5.6). The SAS2H evaluations performed for this design are fully within the range of the validation for the SAS2H software used. The associated 44GROUP cross section library was used for these calculations. Access to and use of the SAS2H software for this analysis was granted by Software Configuration Management and performed in accordance with the QAP-SI series procedures. Inputs and outputs for the SAS2H and ORIGEN-S are included as attachments (see Tables 9-1 and 9-2).

The transient simulation of criticality events is performed using RELAP5/MOD3. RELAP5/MOD3 has been installed on HP workstations and the 10 installation test cases (ans79.p, edhrk.p, edhrkd.p, edhrkn.p, edrst.p, edstrip.p, marpzd4.p, pump2.p, typpwr.p, typpwrn.p) have been run successfully. These installation test cases are included on tape (Ref. 5.22). RELAP5/MOD3 has not been qualified according the QAP-SI-0. RELAP5/MOD3 was developed for the U.S. Nuclear Regulatory Commission for simulations of operational transients in PWR systems such as loss of coolant. The criticality events involving PWR SNF within a waste package are similar to the situations for which RELAP5/MOD3 was developed to analyze. There is reasonable confidence in the capability of RELAP5/MOD3 to provide conservative results for the applications within this analysis (TBV).

7. Design Analysis

7.1 Background

For postclosure, the low probability and consequences of a criticality must provide reasonable assurance that the performance objective of 10CFR60.112 is met. This analysis contributes to satisfying the above requirements for postclosure by determining the consequences of a criticality for PWR SNF within a waste package as measured by the effect on the repository and on the radioisotopic inventory. The probability of criticality events is addressed in a separate analysis.

In a probabilistic analysis (Ref. 5.21, Sections 4.1.2 and 4.1.3) it has been shown that the corrosion rate of the zircaloy cladding of the SNF is much slower than the corrosion rates of the two principal materials which make up the basket (carbon steel and borated stainless steel). Therefore, the basket materials will degrade while the SNF is still mostly intact. What is not known is the exact disposition of the basket material after it has degraded. The iron oxide is very insoluble and will tend to precipitate, but the distribution of the precipitate could range from: (1) collecting equally on all the available surfaces, to (2) settling into the configuration with the lowest gravitational energy, limited only by the maximum density of hydrated iron oxide. The parameters for these two alternatives, called the uniform and settled distributions, respectively, are described in some detail in a previous analysis (Ref. 5.13).

The uniform distribution means that the iron oxide is distributed throughout the waste package wherever there is water. The settled distribution has two different manifestations, depending on whether the basket is partially degraded or fully degraded. The settled distribution for the partial basket will fill the lower portion of each assembly cell with 1/21 of the total oxide formed thus far from the degradation of the carbon steel in the assembly tube basket structure and from the degradation of the borated stainless steel, but not from the carbon steel guides and supports. For the fully degraded basket, the settled distribution will fill the lower portion of the waste package with all of the iron oxide from the complete degradation of the basket, so that some of the assemblies are completely covered by iron oxide while others see no iron oxide at all. These two alternative configurations are described more fully in reference 5.13.

The design basis WP system configuration for 100% coverage of the projected PWR waste stream (Ref. 5.19, Table 8-1) includes five different types of PWR WPs. These types are identified as:

- (1) 21 PWR no absorber WP,
- (2) 21 PWR absorber plate WP,
- (3) 21 PWR absorber rod WP,
- (4) 12 PWR no absorber WP, and

- (5) long 12 PWR absorber plate WP for South Texas fuel.

A previous analysis (Ref. 5.13) investigated the effects on k_{eff} of fuel burnup, enrichment, and decay time, as well as degradation of basket components. The most reactive fuel/WP configuration combination identified was in the 21 PWR absorber plate WP. The fuel designated for disposal in the no absorber plate WP is purposefully of very low reactivity and is subcritical in all configurations. The absorber rod WPs are precluded from criticality even with the otherwise very reactive fuel. The analysis of the absorber plate WP identified the most reactive SNF as ones having the following characteristics:

- (1) an enrichment of 4.9%,
- (2) a burnup of 34 GWd/MTU, and
- (3) a flooded fuel-clad gap.

(Note that as a result of the analysis, the fuels designated for disposal with absorber rods could be adjusted to include all the fuel which can go critical in the absorber plate WP, thereby eliminating these critical configurations from consideration.) The most reactive configuration occurs with the basket fully degraded, the boron removed, the PWR assemblies are stacked together, and the iron oxide from the basket materials has accumulated at its highest reasonable density of 58% leaving one and a half rows of assemblies at the top of the stack in water alone free of oxidation products. This configuration is illustrated in Figure 7.1-1.

09/02/97 15:07:08
 MPCF-21 SNF SNF, Full deg, 50%
 Pw200, modified

probid = 09/02/97 15:04:42
 probid:
 (1.000000, .000000, .000000)
 (.000000, 1.000000, .000000)
 origin:
 (00.00, .00, 0.00)
 extent = (100.00, 100.00)

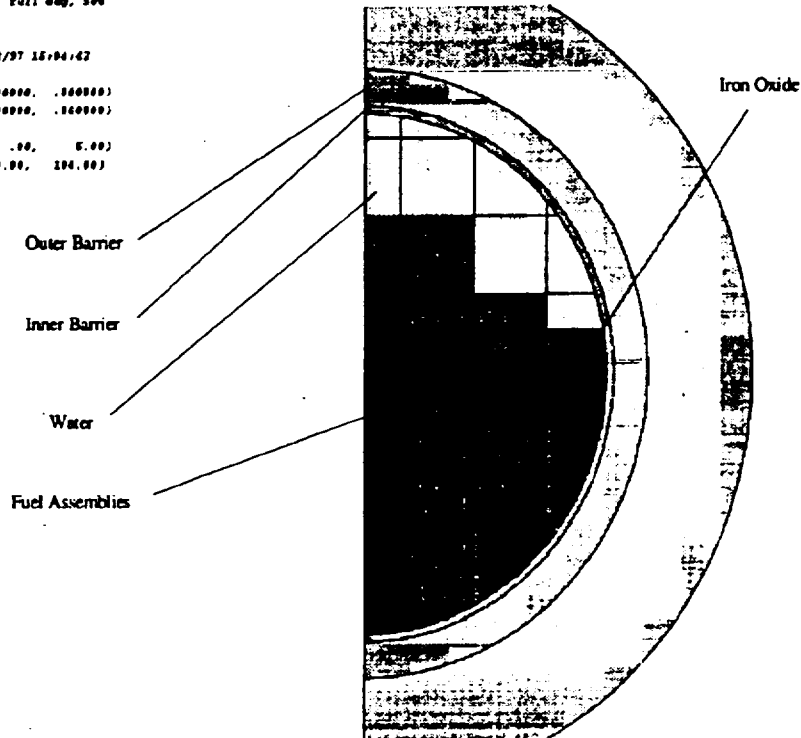


Figure 7.1-1. Base Configuration for Analysis of Stratified Degraded Waste Package

7.2 Neutronics Calculations and Reactivity Coefficients

The effects on reactivity due to changes in the system are shown to be separable into leakage effects and material effects in this section. Leakage effects are primarily dependant on boundary conditions such as water level in the waste package and must be calculated using finite waste package models. Material effects such as changes to fuel temperature, moderator temperature, or moderator density are primarily localized and can be approximated using infinite assembly models with a constant buckling (leakage) term.

Reactivity is defined as (Ref. 5.20, p. 222):

$$\rho = \frac{k_{eff} - 1.0}{k_{eff}}$$

and a change in reactivity ($\Delta\rho$) is defined as (Ref. 5.20, p. 222):

$$\Delta\rho = \rho_{Change} - \rho_{Base} = \frac{1}{k_{eff} - Base} - \frac{1}{k_{eff} - Change}$$

Thus, a positive reactivity change results when ρ_{Change} is greater than ρ_{Base} . In the RELAP5 input, ρ and $\Delta\rho$ are noted in terms of dollars (\$) which is defined as (Ref. 5.20, p. 246):

$$\rho(\$) = \frac{\rho}{\beta_{eff}} \quad \text{and} \quad \Delta\rho(\$) = \frac{\Delta\rho}{\beta_{eff}}$$

where β_{eff} is the effective delayed neutron fraction. The value of the delayed neutron fraction for this analysis is given as (Ref. 5.23)

$$\beta_{eff} = 0.005$$

which is a conservative minimum value.

7.2.1 Reactivity Effect of Water Level in Waste Package

A separate analysis (Ref. 5.13, Table 7.4-10) investigated the effects of different configurations of iron oxide and water in the waste package. Results from that analysis are used here to provide the feedback due to changes in the water level within the waste package. The k_{eff} results for various water levels in the fifth (upper) row of assemblies for the 58% settled oxide case for fuel decayed

for 25,000 years are listed in Table 7.2.1-1 below. For determination of feedback, only the nominal values are used (not adjusted by the standard deviation).

Table 7.2.1-1. Effects of Water Level on k_{eff}

| Case ID | Water Height Relative to Top of Upper Row of Assemblies (cm) | k_{eff} |
|----------|--|-----------|
| r58m13a1 | +21.30 | 0.99656 |
| r58m13a2 | 0.0 | 0.98569 |
| r58m13aw | -12.98 | 0.92672 |
| r58m13bw | -14.43 | 0.91801 |
| r58m13cw | -15.87 | 0.91090 |
| r58m13a3 | -20.30 | 0.85541 |

In order to conservatively calculate the change in reactivity, the reference condition is taken at the water level even with the top of the assemblies (0.0 cm in Table 7.2.1-1). The negative effect of dropping to this level is neglected. The $\Delta\rho$ s resulting from a drop in water level through the upper row of assemblies are listed in Table 7.2.1-2. The reactivity table for the RELAP5 model was extended on to -21.64 cm (lower edge of the assemblies) using the last reactivity value to define a zero level entry. $\Delta\rho$ s for lower water levels are not required because the negative effect of dropping the water level to the bottom of the upper row is great enough to overwhelm the insertion postulated in this analysis.

Table 7.2.1-2. RELAP5 Reactivity Table for WP Water Level

| Water Level Relative to Assembly Top (cm) - MCNP | Water Level Relative to Control Volume Bottom Elevation (ft) - RELAP5 | $\rho = \Delta\rho/\beta_{eff}$ |
|--|---|---------------------------------|
| 0 | 0.71 | 0.0 |
| -12.98 | 0.28415 | -12.911 |
| -14.43 | 0.23657 | -14.959 |
| -15.87 | 0.18933 | -16.660 |
| -20.30 | 0.04399 | -30.902 |
| -21.64 | 0.0 | -30.902 |

7.2.2 Reactivity Effect of Temperature and Density Changes

MCNP4A does not have an associated cross section library with sufficient temperature dependant data to calculate the reactivity changes required for this analysis. The SAS2H sequence of SCALE4.3 does have the necessary cross sections. SAS2H employs a one-dimensional (1-D) assembly-cell discrete-ordinates technique (XSDRNPM) for calculation of the multiplication factor (k_{eff}) for a configuration. A correction for finite dimensions can be made through use of buckling (leakage) correction terms. Initially, infinite MCNP cases were run with which to compare the results from infinite SAS2H cases in order to develop the appropriate SAS2H model to match MCNP results. Corrections were then made to the SAS2H model to account for finite dimensions using the appropriate buckling terms for inclusion in the SAS2H models based on the baseline MCNP finite case. The resulting SAS2H model incorporating the buckling terms is then used for calculating temperature and density reactivity effects.

7.2.2.1 SAS2H Setup and Model Development

The equation for the buckling (B) in the XSDRNPM-S computer software portion of the SAS2H code system is as follows (Ref. 5.10, Vol. 2, pp. F3.2.24-25):

$$B^2 = \left(\frac{\pi}{\text{Axial length} + f (0.710446) \lambda_m} \right)^2 + \left(\frac{\pi}{\text{Radial length} + f (0.710446) \lambda_m} \right)^2$$

This equation for the buckling of the three dimensional waste package models is based on the separability of the geometrical configuration into an axial coordinate and radial plane. The reflector effects are treated by the term:

$$\text{Reflector Effects} = f (0.710446) \lambda_m$$

where f is a factor greater or equal to 0.0, and λ_m is the effective neutron mean free path in the reflector region. The neutron mean free path is determined by the XSDRNPM internal calculations from the properties of the fuel region. The product of f and 0.710446 is a constant input to the SAS2H model to give the reflector effects indicated by the MCNP results. To determine the appropriate reflector effects constant ($f * 0.710446$), MCNP models of the waste package are evaluated. The k_{eff} values from MCNP and the k_{∞} values from the SAS2H models are used to determine the SAS2H buckling values. The buckling values are then used to determine the constant, $f * 0.710446$. This process is performed in an iterative manner with the SAS2H model because the analytic solution of the equation involves multiple unknowns.

The separation of the independent neutron variables into an infinite assembly cell coupled with a buckling correction is assessed by first benchmarking the SAS2H infinite (∞) model (buckling = 0.0)

with three MCNP k_{∞} results. The MCNP k_{∞} represents a fuel region with complete reflection on all finite surfaces. The complete reflection of the MCNP fuel model represents a buckling of 0.0, and a k_{eff} equal to k_{∞} .

The base finite MCNP model represents B&W 15X15 fuel assemblies, 4.9% U-235, 34,000 MWd/MTU burnup, and 25,000 years of isotopic decay. In the degraded state, within a waste package that has been breached by water, that has 58 percent iron oxide by volume settled in the bottom of the waste package, the MCNP k_{eff} is 1.0186 ± 0.0049 (Ref. 5.13, Table 7.4-7).

This MCNP model has two separate fuel regions: (1) the upper region of fuel in the waste package that has no iron oxide in the water, and (2) the lower region of fuel in the waste package that has 58% iron oxide in the water. The SAS2H infinite modeling must be able to produce the same k_{∞} as the MCNP (within an insignificant deviation) for each independent fuel region. Note that the MCNP results are reported $\pm 2\sigma$ (~ 95% confidence interval). Case output filenames which are included on tape (Ref. 5.22) are reported in parentheses beside or below the case results.

| | <u>MCNP-k_{∞}</u> | <u>SAS2H-k_{∞}</u> | <u>$\Delta\rho$ Difference</u> |
|---------|-------------------------------------|--------------------------------------|---|
| No Iron | 1.20780 ± 0.00092 (INFH2O.O) | 1.20693 (out.e49) | -0.00060 |
| Iron | 0.90595 ± 0.000186 (INFOX.O) | 0.905533 (out.fe) | -0.00051 |

The above results show that the reactivity change between SAS2H and the MCNP reference k_{∞} is between $-5/10,000$ and $-6/10,000$. This difference is quite insignificant and indicates that the separability of finite geometrical space and infinite cell - velocity space is generally valid using the SAS2H model with a buckling eigenvalue. A comparison of the SAS2H input with the MCNP input shows that the SAS2H pin cell and assembly cell has the same geometrical and material modeling as the MCNP pin and assembly lattice arrays.

The third SAS2H k_{∞} model evaluation in comparison to MCNP was used to determine the SAS2H neutron flux and volume weighting of the upper fuel region with pure water and the lower fuel region with 58% iron oxide in water. The MCNP model used a square array of 16 fuel assemblies (4 by 4) with 12 containing 58% iron oxide in water and 4 containing pure water. This volume fraction of 0.25 pure water and 0.75 58% iron oxide in water is representative of the volume fraction of the 58 percent settled iron oxide in water model of the degraded waste package. The weighting of upper and lower regions was defined as follows:

$$k_{\infty}(\text{MCNP}) - \Delta\rho \text{ bias} = (x) k_{\infty}(\text{SAS2H pure water}) + (1 - x) k_{\infty}(\text{SAS2H 58\% iron oxide in water})$$

The x is the combined flux and volume weighting factor, and the $\Delta\rho$ bias is defined by the $\Delta\rho$ difference in the table of iron and no iron k_{∞} values. The parameters for the above equation are:

$$\begin{aligned} k_{\infty} (\text{MCNP}) &= 1.12754 \pm 0.00094 (\text{INFLUX2O}) \\ \Delta\rho \text{ bias} &= -0.00055 \\ k_{\infty} (\text{SAS2H pure water}) &= 1.20693 (\text{out.e49}) \\ k_{\infty} (\text{SAS2H 58\% iron oxide in water}) &= 0.905533 (\text{out.fe}) \\ x &= 0.71855 \end{aligned}$$

The comparison of MCNP and SAS2H results are shown in the following table:

| | <u>MCNP - k_{∞}</u> | <u>SAS2H - k_{∞}</u> | <u>$\Delta\rho$ Difference</u> |
|--------------------|---------------------------------------|--|---|
| Inf. Waste Package | 1.12754 ± 0.00094 (INFLUX2O) | 1.12684 (out.wpi) | -0.00055 |

The degraded waste package MCNP model, with a k_{eff} of 1.01860, has a pure water volume fraction of 0.254 and a 58% iron oxide in water volume fraction of 0.746. These volume fractions will only slightly affect the importance of the pure water region and the 58% iron oxide water region in comparison to the MCNP model with 0.25 pure water and 0.75 with 58% iron oxide in water. An increase in the weighting factor of the pure water region to:

$$x = 0.751311$$

was judged to be appropriate. This value is used in the final calculation (wp.out) as a weighting factor for the fraction of water in the moderator and $(1-x)$ is the weighting factor for the fraction of 58% iron oxide/water mix in the moderator.

Axial Leakage Correction

The SAS2H axial buckling equation for the degraded waste package modeling is as follows (Ref. 5.10, Vol. 2, pp. F3.2.24-25):

$$B_{\text{Axial}} (\text{SAS2H}) = \frac{\pi}{\text{Axial length} + f (0.710446) \lambda_m}$$

with the assumption that the axial coordinate and radial plane may be separated by a constant buckling eigenvalue. The infinite cell SAS2H k_{∞} results for the pure water in the upper region of the degraded waste package and the k_{∞} results for the 58% iron oxide in water in the lower region of the degraded waste package indicated that the SAS2H separability modeling is valid. The flux-volume weighting of the upper and lower regions indicated that the importance of the upper region

relative to the lower region is a factor greater than 2 to 1. Therefore, the pure water upper region was used to establish the constants for the theoretical reflector effects.

The pure water axial model of the degraded waste package was computed with MCNP and SAS2H. The MCNP modeling used reflective radial boundary conditions on the radial surfaces of the fuel. Thus, the boundary conditions represented an infinite radial model. The MCNP axial modeling however represented the appropriate geometry and compositions in the degraded waste package with appropriate boundary conditions at the end of the waste package outer metal surfaces. The SAS2H modeling used a radial buckling of zero ($B_{\text{Radial}} = 0.0$) to represent an infinite radial model. The SAS2H axial modeling represented the axial fuel length as 360.172 cm.

The solution of the reflector effects constant, ($f * 0.710446$), was iterative. However, the theoretical solution of $f = 2$ gave a very good comparison between the MCNP and SAS2H k_{eff} results as shown below:

$$\text{Reflector Effects Axial Constant} = f * 0.710446 = 1.420892$$

$$f = 2$$

| | <u>MCNP - k_{eff}</u> | <u>SAS2H - k_{eff}</u> | <u>Δp Difference</u> |
|---------------|---|--|---|
| Waste Package | 1.20489 | 1.20430 | - 0.00041 |
| | ± 0.00096 | (out.fin) | |
| | (INFH2OaO) | | |

The axial constant for the reflector effects on the buckling should be reduced somewhat to increase the axial leakage and reduce k_{eff} such that the Δp difference was closer to - 0.00058 (the weighted bias). However, since the reflection effects constant is a combined axial and radial value, the above results are sufficient. Therefore, no additional correction is needed for the axial buckling other than entering the fuel length (360.172 cm) in the SAS2H input.

Radial Leakage Correction

In the 1-D SAS2H model, the radial leakage from the SNF configuration may be represented by either a cylinder or a square. Both options are investigated to identify the best. There are three theoretical equations that are appropriate to evaluate the radial buckling (Ref. 5.10, pp. F3.2.24-F3.2.25, Ref. 5.20, pp. 205-214) given by:

$$B_{\text{Cylinder}} = \frac{J_0(0) \text{ Bessel Function}}{\text{Radius} + f_C (0.710446) \lambda_m}$$

$$B_{Square} = \frac{\left(\frac{\pi}{2}\right)^2}{Radial\ length + f_s (0.710446) \lambda_m}$$

$$B_{Separable\ Square} = \frac{\sqrt{2} \pi}{(2) Radial\ length + f_{ss} (0.710446) \lambda_m}$$

In the radial buckling for a cylinder, the radial length for the waste package model is the radius of a cylinder which has a planar area equal to the area of the 21 fuel assemblies in the degraded waste package. The width of the fuel lattice in the MCNP baseline degraded case (Attachment I) is 21.3 cm (10.65 X 2). The radius is given by:

$$Radius = \left\{ \frac{(21.3\ cm)^2 \cdot 21}{\pi} \right\}^{1/2} = 55.0699\ cm$$

In the radial buckling for a square, the radial length for the waste package model is either the above radius or one-half the length of a square which has a planar area equal to the area of the fuel assemblies in the degraded waste package. This radial length is given by:

$$Radial\ length = \frac{\left\{ (21.3\ cm)^2 \cdot 21 \right\}^{1/2}}{2} = 48.8044\ cm$$

In the radial buckling for a separable square, the radial length for the waste package model is the above radial length.

Reflector Effects

The three radial buckling equations were evaluated in combination with the axial buckling equation to determine the appropriate constant for the reflector effects on the combined axial and radial leakage for the degraded waste package. The SAS2H radial equation was used to determine the effective radial length with the reflector effects constant set to zero. For example, the effective radial

length in the SAS2H radial buckling equation to reproduce the radial buckling of the separable square equation was determined as follows:

$$\frac{\pi}{\text{Effective Radial Length}} = \frac{\pi}{\sqrt{2} \text{ Radial Length}}$$

where:

$$\text{Effective Radial Length} = 69.01988844 \text{ cm.}$$

Iterations with the radial buckling equations and reflector effects constant in the SAS2H model in comparison to MCNP k_{eff} results indicated that the separable square radial buckling equation gave the more consistent overall results. The effective radial length is that shown above. The combined (axial and radial) reflector effects constant is given by:

$$\text{Reflector Effects Constant} = f * 0.710446 = 0.875108.$$

The comparison of the MCNP and SAS2H k_{eff} values shown below indicates that the iterative solution of the reflector effects constant (0.875108) is appropriately converged.

| | <u>MCNP - k_{eff}</u> | <u>SAS2H - k_{eff}</u> | <u>Δp Difference</u> |
|---------------|---|--|---|
| Waste Package | 1.14053 \pm 0.00052 | 1.13991 | - 0.00048 |
| | (H2OH13FO) | (out.wpn) | |

Based on the results of the axial buckling evaluation of the reflector effects constant, it would be expected that f would be between 1 and 2 for the combined axial and radial reflector effects with a probable value nearer to 1. The above analysis results in an f of 1.23, which is consistent with expectations.

SAS2H Effective Radial Length of Fuel Stack

The last step in the development of a SAS2H model for the waste package reactivity coefficients is to determine the effective radial length. Ideally, the effective radial length for the degraded waste package with pure water and with 58% dense iron oxide and water in separate regions would be the effective radial length for the pure water region. If this were the situation, it would mean that the effects of the spatial flux shape could adequately be defined by the importance weighting of the two water regions. There would be no additional leakage effects. Such a situation would help to theoretically validate the separability model. Unfortunately, the SAS2H k_{eff} results, with an effective radial length of 69.0199 cm and a reflector constant of 0.875108 did not agree with the MCNP k_{eff}

(1.01860 ± 0.00486). To obtain agreement between the MCNP and SAS2H k_{eff} values, the SAS2H effective radial length had to be significantly decreased. The revised value is given by:

$$\text{Effective Radial Length (MCNP } k_{\text{eff}}) = 50.7843927 \text{ cm}$$

The decrease in the effective radial length significantly increased the radial leakage and decreased the k_{eff} . The iteration to determine the effective radial length of 50.7843927 cm gave the following SAS2H k_{eff} in comparison to MCNP:

| | <u>MCNP - k_{eff}</u> | <u>SAS2H - k_{eff}</u> | <u>$\Delta\rho$ Difference</u> |
|---------------|---|--|---|
| Waste Package | 1.01860 (Ref. 5.13) | 1.01801 (out.wp) | - 0.00057 |

This agreement reflects the appropriate bias in the SAS2H k_{eff} results.

Summary

With the buckling corrections developed in this section and the SAS2H assembly model giving the same k_{eff} and k_{eff} results as MCNP, the SAS2H model is appropriate to evaluate reactivity changes in the degraded waste package fuel region. Three values are required for the buckling correction to the SAS2H model: (1) axial length (dz) = 360.172 cm; (2) reflector effects constant (bkl) = 0.875108; and (3) effective radial length (dy) = 50.7843927 cm.

7.2.2.2 SAS2H Reactivity Calculations

The reactivity effects of changes in the fuel temperatures and water densities are calculated with SAS2H to evaluate the RELAP5 functional relations between the thermodynamic state points and the respective reactivity values. The input file for the base SAS2H case (in.wp) is included as Attachment II. The RELAP5 model of reactivity used in this evaluation is based on two reactivity variables: (1) fuel temperature, and (2) water temperature-density. These two reactivity variables are treated as separable entities and combined in the RELAP5 model to define a total reactivity for the waste package.

The development of the RELAP5 reactivity input data included the dependent relationship between the fuel temperature and water temperature-density variables. The dependent effects were modeled using the following constraints and approximations:

- (1) the fuel temperature would lead in time the water temperature-density,
- (2) the water temperature effect on reactivity is insignificant compared to the water density,

- (3) the water pressure effect on reactivity is insignificant compared to the water density,
- (4) the onset of vapor (steam void fraction) formation would occur in the temperature range around 373 K (212°F), and
- (5) the fuel temperature does not exceed 813 K (1004°F).

Steam void fractions in the 10 percent range were assumed to be caused by fuel temperatures of 543 K (518°F). Greater void fractions were assumed to be caused by fuel temperatures of 813 K (1004°F). Table 7.2.2.2-1 provides a case listing of 20 SAS2H calculations which are the bases for the RELAP5 reactivity values.

Table 7.2.2.2-1. SAS2H Reactivity Input for RELAP5

| <u>Case</u> | <u>k_{eff}</u> | <u>Fuel Temperature (K)</u> | <u>Water Density Factor</u> |
|----------------|------------------------|-----------------------------|-----------------------------|
| 1 (out.wp) | 1.01801 | 300 | 1.000 |
| 2 (out~1.122) | 1.01712 | 323 | 1.000 |
| 3 (out~2.122) | 1.01391 | 323 | 0.988 |
| 4 (out~2.212) | 1.01212 | 373 | 0.988 |
| 5 (out~1.212) | 1.00792 | 373 | 0.973 |
| 6 (out~1.320) | 1.00599 | 433 | 0.973 |
| 7 (out~5.518) | 1.00265 | 543 | 0.973 |
| 8 (out~4.518) | 0.998466 | 543 | 0.958 |
| 9 (out~3.518) | 0.993319 | 543 | 0.940 |
| 10 (out~2.518) | 0.987415 | 543 | 0.920 |
| 11 (out~1.518) | 0.981273 | 543 | 0.900 |
| 12 (out~9.100) | 0.974209 | 813 | 0.900 |
| 13 (out~8.100) | 0.966130 | 813 | 0.875 |
| 14 (out~7.100) | 0.957650 | 813 | 0.850 |
| 15 (out~6.100) | 0.948748 | 813 | 0.825 |
| 16 (out~5.100) | 0.939397 | 813 | 0.800 |
| 17 (out~4.100) | 0.929578 | 813 | 0.775 |
| 18 (out~3.100) | 0.919256 | 813 | 0.750 |

| | | | |
|----------------|----------|-----|-------|
| 19 (out-2.100) | 0.908416 | 813 | 0.725 |
| 20 (out-1.100) | 0.897022 | 813 | 0.700 |

7.2.3 Reactivity Insertion Scenario

As previously stated, the base finite MCNP model represents B&W 15X15 fuel assemblies with 4.9% U-235, 34,000 MWd/MTU burnup, and 25,000 years of isotopic decay. In the degraded state where a waste package has been breached by water and where the iron oxide has settled to the bottom of the waste package occupying 58 percent of the space by volume, the MCNP k_{eff} is 1.0186 with a standard deviation of ± 0.0049 (Ref. 5.13, Table 7.4-7). This is the most reactive reasonable configuration possible in the absorber plate waste package. If the critical point is designated as a k_{eff} of 0.95, the maximum reactivity insertion possible is:

$$\frac{\Delta\rho}{\beta_{eff}} = \left[\frac{1}{0.95} - \frac{1}{1.0186} \right] \times \frac{1}{.005} = 14.18\%.$$

A change in reactivity value of this magnitude roughly corresponds to an insertion scenario involving the transition from a homogeneous distribution of iron oxide within the waste package to the stratified base configuration described above (Ref. 5.13, Table 7.4-9) or an increase in water level (Ref. 5.13, Table 7.4-10) for an SNF configuration not already completely submerged.

As will be demonstrated in the RELAP5 results, the magnitude of the insertion is not as important as the reactivity insertion rate. The negative reactivity effects of reduced water level in the package, increased fuel temperature and increased water temperature (decreased density) will eventually overwhelm any conceivable reactivity insertion mechanism. A significant transient criticality event can occur only when the balance of reactivity insertion and these negative counterbalancing effects exceed +1.0\$ (prompt critical). If the insertion rate is sufficiently fast, the power level could be increasing by a factor of 2.7 (exponential period) on a time scale of a millisecond or less while the thermal changes are occurring on a time scale of a second or longer (Ref. 5.20, pp. 233-277). The greater the balance exceeds 1.0\$ and the longer the duration, the greater will be the significance of the transient event in terms of the energy generated and its associated phenomena. This translates into a requirement for a relatively short insertion time (seconds) in order to achieve a prompt critical situation. The transition from a homogeneous to a stratified distribution of iron oxide within the waste package would, in general, be a slow process taking many days, months or years. Low probability events which conceivably could result in an insertion rate on a time scale of a second or minute would include:

- (1) Increasing Ambient Episodic Focused Flow of water of 20 m³ to 100 m³ in one week (Ref. 5.15, CDA Assumption TDSS 026),

- (2) Earthquake resulting in shaking of waste package and redistribution of iron oxide, and
- (3) Rock fall resulting in shaking of waste package and redistribution of iron oxide.

The water level scenario (1) could insert reactivity on a minute time scale and the particle redistribution scenarios (2 and 3) could insert reactivity on a second or minute time scale depending on average particle size. Attachment III contains idealized terminal velocity (free fall, no impediment from other obstacles) calculations for particles sizes of 0.010 mm and 0.063 mm, which would take approximately 1 and 40 minutes, respectively, to fall to the bottom of the waste package. The typical crud particle size from metal oxidation is in the range of 0.0001 to 0.01 mm (Ref. 5.8, p. 2.6-6).

Based on these considerations, insertion times of 30 seconds and 3600 seconds were chosen for the RELAP5 calculations in order to demonstrate transient behavior for the criticality event.

7.3 RELAP5 Model Description

The purpose of this section is to describe the RELAP5 model used for the coupled neutronic-thermal-hydraulic analyses of a criticality event in a WP where the outer barrier has been compromised leading to a fully degraded basket assembly. The RELAP5 model of the WP, illustrated as a block diagram in Figure 7.3-1, consisted of 27 control volumes, 43 junctions, and 35 heat conductors. The spatial orientation of the WP is such that the cylindrical WP axis and long fuel assembly dimension are in the horizontal plane as shown in Figure 7.1-1. The model represents one-half of the WP cross-sectional cylinder since the system has left-right symmetry.

The RELAP5 code is designed to for use with fundamentally one-dimensional hydraulic systems but does include multi-dimensional flow representation under restricted conditions (Ref. 5.4). The RELAP5 model for the degraded WP contains flow connections in the two directions normal to the WP cylinder axis but not parallel to the axis. For this quasi-two dimensional model, the fuel bundles were modeled at one-fifth of the actual fueled length of 141.8 in. (Table 4.1-1) with appropriate adjustments to the model parameters. Fuel bundle and WP end fittings were excluded from the RELAP5 model. The principal elements of the model description include the geometric representation, flow connections, friction factors, and heat conductors. These elements are described in the following sections. Note that RELAP5 input quantities are specified in English units. A representative RELAP5 input file (r5wp2d.03c) is included in Attachment IV.

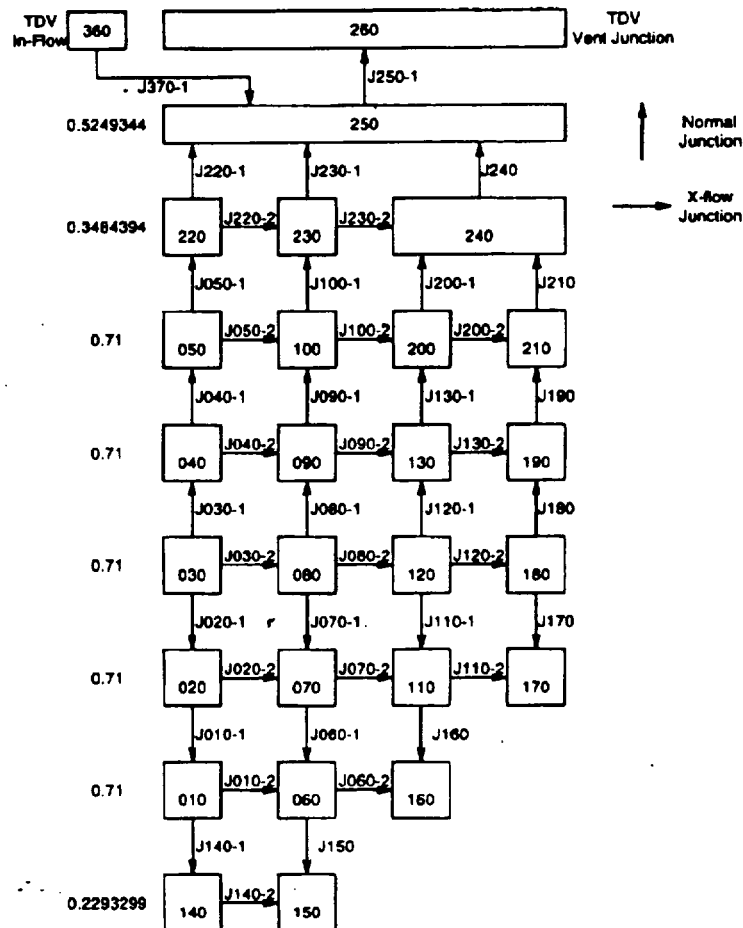


Figure 7.3-1. Block Diagram of RELAP5 Model

7.3.1 RELAP5 Model Geometry

The particular WP configuration modeled for the RELAP5 studies was the fully degraded basket condition with intact fuel assemblies. The iron oxide was assumed to have settled to the bottom of the WP covering the lower 3.5 rows of assemblies. The presence of oxide material was included in the development of the reactivity parameters but not specifically included in the hydrodynamic or thermodynamic modeling. The non-metal volume in each fuel assembly is represented by one RELAP5 control volume and the metal volume (fuel rods, guide tubes, and instrument tubes) modeled by heat conductors connected to the control volume. As stated previously, the WP is designed to hold fuel assemblies in a horizontal arrangement limiting the gravity contributions to volume pressures in the model to elevations of 21.6408 cm (0.568 in. pin cell pitch), the assembly

width (Table 4.1-1). The control volume dimensions were assigned to produce the correct gravity pressure heads and fluid inventory. Dimensions of the water filled control volumes around the WP periphery were derived by subtracting the area of the intersecting rectangular fueled cells from circular sector overlays with a radius of 71.32 cm (Drawing ID# BBAA00000-01717-2700-16004 Rev 00). The control volume dimensions for the model are listed in Table 7.3-1. The total volume contained in the control volumes is 16.051 ft³ resulting in an initial inventory of 990.09 lb_m of water.

Control volumes representing SNF assemblies (heavily shaded rectangular areas in Figure 7.1-1) have IDs from 010010000 through 130010000 where control volumes 010010000-050010000 represent half assemblies. The remaining space in the WP interior (regions around the periphery and above the SNF assemblies in Figure 7.1-1) was described by the control volumes labeled 140010000-250010000. Two time-dependent control volumes (ID 260010000 and ID 360010000), representing the external boundary WP environment, complete the RELAP5 geometry setup. The block diagram of the RELAP5 model displayed in Figure 7.3-1, while not to scale, shows the relative control volume arrangement.

Initial conditions for the RELAP5 control volumes were specified as water filled at 122.0°F and 14.696 psia except for the time-dependent control volume (ID 260010000), representing the external environment, which was initialized as steam at 220.0°F and 14.696 psia to approximate a non-condensing gas environment.

Time-dependent volumes were included in the model to represent the drift space outside the WP where the out-flowing water inventory from the WP accumulates and to provide a low temperature flow path into the WP representing the drift flow leaking into the WP. Time dependent volumes are used as boundary conditions providing sinks and sources for the fluid inventory. Thermodynamic conditions in these control volumes are specified as functions of time and are not dependent upon the mass or enthalpy of connecting volumes.

Table 7.3-1. RELAP5 Control Volumes

| Number ID* | Volume (ft ³) | Vertical Flow Area (ft ²) | Elevation (ft) (Center-line) | Pressure (psia) | Temperature (°F) |
|------------|---------------------------|---------------------------------------|------------------------------|-----------------|------------------|
| 010010000 | 0.3516846 | 0.4953304 | 0.0 | 14.696 | 122.0 |
| 020010000 | 0.3516846 | 0.4953304 | 0.71 | 14.696 | 122.0 |
| 030010000 | 0.3516846 | 0.4953304 | 1.42 | 14.696 | 122.0 |
| 040010000 | 0.3516846 | 0.4953304 | 2.13 | 14.696 | 122.0 |
| 050010000 | 0.3516846 | 0.4953304 | 2.84 | 14.696 | 122.0 |
| 060010000 | 0.7033692 | 0.9906608 | 0.0 | 14.696 | 122.0 |
| 070010000 | 0.7033692 | 0.9906608 | 0.71 | 14.696 | 122.0 |

Table 7.3-1. RELAP5 Control Volumes

| Number ID* | Volume (ft ³) | Vertical Flow Area (ft ²) | Elevation (ft) (Center-line) | Pressure (psia) | Temperature (°F) |
|------------|---------------------------|---------------------------------------|------------------------------|-----------------|------------------|
| 080010000 | 0.7033692 | 0.9906608 | 1.42 | 14.696 | 122.0 |
| 090010000 | 0.7033692 | 0.9906608 | 2.13 | 14.696 | 122.0 |
| 100010000 | 0.7033692 | 0.9906608 | 2.84 | 14.696 | 122.0 |
| 110010000 | 0.7033692 | 0.9906608 | 0.71 | 14.696 | 122.0 |
| 120010000 | 0.7033692 | 0.9906608 | 1.42 | 14.696 | 122.0 |
| 130010000 | 0.7033692 | 0.9906608 | 2.13 | 14.696 | 122.0 |
| 140010000 | 0.2075716 | 0.9051223 | -0.469665 | 14.696 | 122.0 |
| 150010000 | 0.2276341 | 0.9926054 | -0.469665 | 14.696 | 122.0 |
| 160010000 | 0.7989270 | 1.125249 | 0.0 | 14.696 | 122.0 |
| 170010000 | 0.5438773 | 0.7660244 | 0.71 | 14.696 | 122.0 |
| 180010000 | 0.8980821 | 1.264904 | 1.42 | 14.696 | 122.0 |
| 190010000 | 0.8738187 | 1.230731 | 2.13 | 14.696 | 122.0 |
| 200010000 | 0.8633786 | 1.216026 | 2.84 | 14.696 | 122.0 |
| 210010000 | 0.7822260 | 1.101727 | 2.84 | 14.696 | 122.0 |
| 220010000 | 0.8633786 | 2.477844 | 3.36922 | 14.696 | 122.0 |
| 230010000 | 0.8633786 | 2.477844 | 3.36922 | 14.696 | 122.0 |
| 240010000 | 0.4918077 | 1.411458 | 3.36922 | 14.696 | 122.0 |
| 250010000 | 1.2517607 | 2.384604 | 3.80591 | 14.696 | 122.0 |
| 260010000 | 238.468 | 238.468 | 4.06837 | 14.696 | 220.0 |
| 360010000 | 238.468 | 238.468 | 3.54344 | 14.696 | 122.0 |

* First 3 digits correspond to the control volume labels in Figure 7.3-1.

7.3.2 RELAP5 Junction Description

The spatial orientation of the WP cylindrical axis is in the horizontal direction with the fuel assemblies stacked on their sides. The assemblies modeled for the MCNP analyses (Ref. 5.13) were B&W 15X15 assemblies with open pin arrays. This allows cross flow between assemblies since the internal WP structure is assumed to be fully degraded. The "normal" flow direction in the model (normal with respect to the one-dimensional hydraulic characteristic of the RELAP5 code) is vertical

through the assemblies normal to the fuel rod long dimension. RELAP5 junctions define the cross sectional flow area between two control volumes which must intersect both volumes. These junctions are labeled as xxx010000 where xxx is the identifier of all junctions originating in a control volume. (Note that junction label prefixes "xxx" and control volume labels prefixes form independent sets.) A second flow direction was defined horizontally across the assemblies likewise normal to the fuel rod direction. The horizontal flow paths were modeled as junction "branch" components and labeled as xxx020000. Physical constraints on flow paths in the WP are incorporated into the junction flow areas and frictional loss coefficients.

In the development of the RELAP waste package model, form loss coefficients were included to treat the cross-flow between the flow channels. The fundamental expression for the cross-flow form loss coefficients is given by (Ref. 5.24):

$$\zeta = \psi A Re_{av}^m$$

where (ζ) is the loss coefficient,

(ψ) is a function of the angle of the flow (for 90° $\psi = 1$),

(A) is a function of the fuel rod pitch, and the hydraulic diameter,

(Re) is the average (av) Reynolds Number for the fluid conditions, and

(m) is a parameter to provide a best fit of the data.

Framatome has added two other terms, (1) a multiplier for the phase-flow characteristics, and (2) a multiplier for the number of cross-flow bundle-channels that are affected. The coefficient for highly voided regions that best matches data is 72. Sensitivity evaluations suggest that lower values would be appropriate at lower voids and flow velocities. However, for a range of Reynolds numbers (such as $3 \times 10^3 < Re < 10^5$ as noted by Idelchik), the value of 72 gives appropriate results.

All junction flow rates were initialized at zero (0) lb_m/sec except for junction 370000000 at 1.381×10^{-3} lb_m/sec at 122.0°F and 14.696 psia representing a drift inflow source of 20 m³ per year. The junction parameters in the model are listed in Table 7.3-2.

Table 7.3-2. RELAP5 Junction Parameters

| Junction ID* | Area (ft ²) | Orientation W.T. Horizontal (deg) | Connecting Volume IDs | Forward Loss Coefficient | Reverse Loss Coefficient | Choke Flag | Face Position (ft) |
|--------------|-------------------------|--|-----------------------------|--------------------------------|-----------------------------|---------------|--------------------------|
| 010010000 | 0.203838 | 90.0 | 01001000 02001000 | 72.0 | 72.0 | no | 0.355 |

Table 7.3-2. RELAP5 Junction Parameters

| Junction ID* | Area (ft ²) | Orientation W.T. Horizontal (deg) | Connecting Volume IDs | Forward Loss Coefficient | Reverse Loss Coefficient | Choke Flag | Face Position (ft) |
|--------------|-------------------------|--|-----------------------------|--------------------------------|-----------------------------|---------------|--------------------------|
| 010020000 | 0.407675 | 0.0 | 010010000 060010000 | 72.0 | 72.0 | no | 0.355 |
| 020010000 | 0.203883 | 90.0 | 020010000 030010000 | 72.0 | 72.0 | no | 1.065 |
| 020020000 | 0.407675 | 0.0 | 020010000 070010000 | 72.0 | 72.0 | no | 1.065 |
| 030010000 | 0.203883 | 90.0 | 030010000 040010000 | 72.0 | 72.0 | no | 1.775 |
| 030020000 | 0.407675 | 0.0 | 030010000 080010000 | 72.0 | 72.0 | no | 1.065 |
| 040010000 | 0.203838 | 90.0 | 040010000 050010000 | 72.0 | 72.0 | no | 2.485 |
| 040020000 | 0.407675 | 0.0 | 040010000 090010000 | 72.0 | 72.0 | no | 1.775 |
| 050010000 | 0.203838 | 90.0 | 050010000 220010000 | 72.0 | 72.0 | no | 3.195 |
| 050020000 | 0.407675 | 0.0 | 050010000 100010000 | 72.0 | 72.0 | no | 2.485 |
| 060010000 | 0.407675 | 90.0 | 060010000 070010000 | 72.0 | 72.0 | no | 0.355 |
| 060020000 | 0.407675 | 0.0 | 060010000 160010000 | 72.0 | 72.0 | no | 0.355 |
| 070010000 | 0.407675 | 90.0 | 070010000 080010000 | 72.0 | 72.0 | no | 1.065 |
| 070020000 | 0.407675 | 0.0 | 070010000 110010000 | 72.0 | 72.0 | no | 1.065 |
| 080010000 | 0.407675 | 90.0 | 080010000 090010000 | 72.0 | 72.0 | no | 1.775 |
| 080020000 | 0.407675 | 0.0 | 080010000 120010000 | 72.0 | 72.0 | no | 1.065 |
| 090010000 | 0.407675 | 90.0 | 090010000 100010000 | 72.0 | 72.0 | no | 2.485 |

Table 7.3-2. RELAP5 Junction Parameters

| Junction ID* | Area (ft ²) | Orientation W.T. Horizontal (deg) | Connecting Volume IDs | Forward Loss Coefficient | Reverse Loss Coefficient | Choke Flag | Face Position (ft) |
|--------------|-------------------------|--|-----------------------------|--------------------------------|-----------------------------|---------------|--------------------------|
| 090020000 | 0.407675 | 0.0 | 090010000 130010000 | 72.0 | 72.0 | no | 1.775 |
| 100010000 | 0.407675 | 90.0 | 100010000 230010000 | 72.0 | 72.0 | no | 3.195 |
| 100020000 | 0.407675 | 0.0 | 100010000 200010000 | 72.0 | 72.0 | no | 2.485 |
| 110010000 | 0.407675 | 90.0 | 110010000 120010000 | 72.0 | 72.0 | no | 1.065 |
| 110020000 | 0.407675 | 0.0 | 110010000 170010000 | 72.0 | 72.0 | no | 1.065 |
| 120010000 | 0.407675 | 90.0 | 120010000 130010000 | 72.0 | 72.0 | no | 1.775 |
| 120020000 | 0.407675 | 0.0 | 120010000 180010000 | 72.0 | 72.0 | no | 1.065 |
| 130010000 | 0.407675 | 90.0 | 130010000 200010000 | 72.0 | 72.0 | no | 2.485 |
| 130020000 | 0.407675 | 0.0 | 130010000 190010000 | 72.0 | 72.0 | no | 1.775 |
| 140010000 | 0.203838 | 90.0 | 140010000 010010000 | 72.0 | 72.0 | no | -0.355 |
| 140020000 | 0.541983 | 0.0 | 140010000 150010000 | 0.0 | 0.0 | no | -0.355 |
| 150010000 | 0.407675 | 90.0 | 150010000 060010000 | 72.0 | 72.0 | no | -0.355 |
| 160010000 | 0.407675 | 90.0 | 160010000 110010000 | 72.0 | 72.0 | no | 0.355 |
| 170010000 | 1.10807 | 90.0 | 170010000 180010000 | 0.0 | 0.0 | no | 1.065 |
| 180010000 | 1.33394 | 90.0 | 180010000 190010000 | 0.0 | 0.0 | no | 1.775 |
| 190010000 | 1.03803 | 90.0 | 190010000 210010000 | 0.0 | 0.0 | no | 2.485 |

Table 7.3-2. RELAP5 Junction Parameters

| Junction ID* | Area (ft ²) | Orientation W.T. Horizontal (deg) | Connecting Volume IDs | Forward Loss Coefficient | Reverse Loss Coefficient | Choke Flag | Face Position (ft) |
|--------------|-------------------------|--|-----------------------------|--------------------------------|-----------------------------|---------------|--------------------------|
| 200010000 | 0.754086 | 90.0 | 200010000 240010000 | 0.0 | 0.0 | yes | 3.195 |
| 200020000 | 1.79585 | 0.0 | 200010000 210010000 | 0.0 | 0.0 | yes | 2.485 |
| 210010000 | 1.03803 | 90.0 | 210010000 240010000 | 0.0 | 0.0 | yes | 3.195 |
| 220010000 | 0.203838 | 90.0 | 220010000 250010000 | 0.0 | 0.0 | yes | 3.54344 |
| 220020000 | 0.823478 | 0.0 | 220010000 230010000 | 0.0 | 0.0 | yes | 3.195 |
| 230010000 | 0.407675 | 90.0 | 230010000 250010000 | 0.0 | 0.0 | yes | 3.54344 |
| 230020000 | 0.823478 | 0.0 | 230010000 240010000 | 0.0 | 0.0 | yes | 3.195 |
| 240010000 | 0.973291 | 90.0 | 240010000 250010000 | 0.0 | 0.0 | yes | 3.54344 |
| 250010000 | 0.107639 | 90.0 | 250010000 260010000 | 0.0 | 0.0 | yes | 4.06837 |
| 370010000 | 1.0 | 0.0 | 360010000 250010000 | 0.0 | 0.0 | no | 3.54344 |

* Digits 1-3 and 5 correspond to the "J" IDs in Figure 7.3-1.

7.3.3 RELAP5 Heat Conductor Description

Energy sources in RELAP5 models must be modeled with powered heat conductors connected to control volumes. In addition, non-powered heat conductors may be used to transport energy between disjoint fluid paths and/or into heat sinks. In order to properly model the thermal characteristics of conductors, the geometry is normally representative of individual components such as fuel rods. The overall fuel assembly energy balance is modeled by assigning the proper heat transfer area to the conductor. For the RELAP5 model of the WP, two sets of conductors describing the fuel pins and guide tubes were defined, one powered set representing the UO₂ fuel pellets (IDs 3301001 through 3301013) and one passive set representing the fuel rod cladding and guide tubes (IDs 3481001 through 3481013).

The conductor series 3301 and 3481 were connected respectively to control volumes 01001000 through 130010000 where the SNF assemblies are located. The fuel rods were modeled with independent pellet and clad conductors to simulate breached conditions with no gas gap between the fuel pellets and cladding and water is in contact with the UO_2 pellets. In this model, the fuel rod cladding was dissociated from the fuel pellet-to-water heat conduction path placing the pellets directly in contact with the control volume water mass. The cladding and guide tubes were in turn heated from secondary contact with the control volume water mass.

The outer containment shell of the WP was modeled with a set of nine passive heat conductors (IDs 3121001 through 3121009) representing large carbon steel heat sinks connected to the peripheral water filled control volumes (IDs 140010000 through 220010000).

Initial conditions for all heat conductors were 122.0°F.

Global energy sources in the RELAP5 program are defined by the time-dependent solution of point kinetics equations for the fission contribution to the energy generation coupled with (optionally) fission product and actinide radioactive decay energy. The global energy sources are distributed locally to powered heat conductors (IDs 3301001 through 3301013) through power factors which consist of nodal weights within conductors and overall weight factors among the conductors. For the RELAP5 WP model, the time-dependent power history represented one fuel assembly and the power factors were specified accordingly; 0.2 for one-fifth length full area assemblies and 0.1 for one-fifth length half area assemblies. Nodal power factors within conductors were given equal weighing.

The heat conductor descriptions for the RELAP5 model are listed in Table 7.3-3.

Table 7.3-3. RELAP5 Heat Conductor Specifications

| Conductor ID | Geometry | Composition | Coordinate (ft) Left Right | Volume Connection | Initial Temperature (°F) | Heat Transfer Area (ft ²) | Power Factor |
|--------------|----------|---------------|----------------------------------|----------------------|-----------------------------|---|-----------------|
| 3301001 | Cylinder | UO_2 | 0.0 1.535833e-02 | 0 010010000 | 122.0 | 245.78667 | 0.1 |
| 3301002 | Cylinder | UO_2 | 0.0 1.535833e-02 | 0 020010000 | 122.0 | 245.78667 | 0.1 |
| 3301003 | Cylinder | UO_2 | 0.0 1.535833e-02 | 0 030010000 | 122.0 | 245.78667 | 0.1 |
| 3301004 | Cylinder | UO_2 | 0.0 1.535833e-02 | 0 040010000 | 122.0 | 245.78667 | 0.1 |
| 3301005 | Cylinder | UO_2 | 0.0 1.535833e-02 | 0 050010000 | 122.0 | 245.78667 | 0.1 |

Waste Package Development**Design Analysis**

Title: Criticality Consequence Analysis Involving Intact PWR SNF in a Degraded 21 PWR Assembly Waste Package

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Table 7.3-3. RELAP5 Heat Conductor Specifications

| Conductor ID | Geometry | Composition | Coordinate (ft) Left Right | Volume Connection | Initial Temperature (°F) | Heat Transfer Area (ft ²) | Power Factor |
|--------------|----------|-----------------|----------------------------------|------------------------|-----------------------------|--|-----------------|
| 3301006 | Cylinder | UO ₂ | 0.0 1.535833e-02 | 0 060010000 | 122.0 | 491.57333 | 0.2 |
| 3301007 | Cylinder | UO ₂ | 0.0 1.535833e-02 | 0 070010000 | 122.0 | 491.57333 | 0.2 |
| 3301008 | Cylinder | UO ₂ | 0.0 1.535833e-02 | 0 080010000 | 122.0 | 491.57333 | 0.2 |
| 3301009 | Cylinder | UO ₂ | 0.0 1.535833e-02 | 0 090010000 | 122.0 | 491.57333 | 0.2 |
| 3301010 | Cylinder | UO ₂ | 0.0 1.535833e-02 | 0 100010000 | 122.0 | 491.57333 | 0.2 |
| 3301011 | Cylinder | UO ₂ | 0.0 1.535833e-02 | 0 110010000 | 122.0 | 491.57333 | 0.2 |
| 3301012 | Cylinder | UO ₂ | 0.0 1.535833e-02 | 0 120010000 | 122.0 | 491.57333 | 0.2 |
| 3301013 | Cylinder | UO ₂ | 0.0 1.535833e-02 | 0 130010000 | 122.0 | 491.57333 | 0.2 |
| 3481001 | Cylinder | Zr-4 | 1.570833e-02 1.791112e-02 | 010010000 010010000 | 122.0 | 265.875 531.750 | 0.0 |
| 3481002 | Cylinder | Zr-4 | 1.570833e-02 1.791112e-02 | 020010000 020010000 | 122.0 | 265.875 531.750 | 0.0 |
| 3481003 | Cylinder | Zr-4 | 1.570833e-02 1.791112e-02 | 030010000 030010000 | 122.0 | 265.875 531.750 | 0.0 |
| 3481004 | Cylinder | Zr-4 | 1.570833e-02 1.791112e-02 | 040010000 040010000 | 122.0 | 265.875 531.750 | 0.0 |
| 3481005 | Cylinder | Zr-4 | 1.570833e-02 1.791112e-02 | 050010000 050010000 | 122.0 | 265.875 531.750 | 0.0 |
| 3481006 | Cylinder | Zr-4 | 1.570833e-02 1.791112e-02 | 060010000 060010000 | 122.0 | 265.875 531.750 | 0.0 |
| 3481007 | Cylinder | Zr-4 | 1.570833e-02 1.791112e-02 | 070010000 070010000 | 122.0 | 265.875 531.750 | 0.0 |
| 3481008 | Cylinder | Zr-4 | 1.570833e-02 1.791112e-02 | 080010000 080010000 | 122.0 | 265.875 531.750 | 0.0 |

Table 7.3-3. RELAP5 Heat Conductor Specifications

| Conductor ID | Geometry | Composition | Coordinate (ft) Left Right | Volume Connection | Initial Temperature (°F) | Heat Transfer Area (ft ²) | Power Factor |
|--------------|-------------|--------------|----------------------------------|------------------------|-----------------------------|---|-----------------|
| 3481009 | Cylinder | Zr-4 | 1.570833e-02 1.791112e-02 | 090010000 090010000 | 122.0 | 265.875 531.750 | 0.0 |
| 3481010 | Cylinder | Zr-4 | 1.570833e-02 1.791112e-02 | 100010000 100010000 | 122.0 | 265.875 531.750 | 0.0 |
| 3481011 | Cylinder | Zr-4 | 1.570833e-02 1.791112e-02 | 110010000 110010000 | 122.0 | 265.875 531.750 | 0.0 |
| 3481012 | Cylinder | Zr-4 | 1.570833e-02 1.791112e-02 | 120010000 120010000 | 122.0 | 265.875 531.750 | 0.0 |
| 3481013 | Cylinder | Zr-4 | 1.570833e-02 1.791112e-02 | 130010000 130010000 | 122.0 | 265.875 531.750 | 0.0 |
| 3121001 | Rectangular | Carbon Steel | 0.0 190.0 | 140010000 0 | 122.0 | 1.73 0.0 | 0.0 |
| 3121002 | Rectangular | Carbon Steel | 0.0 190.0 | 150010000 0 | 122.0 | 1.73 0.0 | 0.0 |
| 3121003 | Rectangular | Carbon Steel | 0.0 190.0 | 160010000 0 | 122.0 | 1.73 0.0 | 0.0 |
| 3121004 | Rectangular | Carbon Steel | 0.0 190.0 | 170010000 0 | 122.0 | 1.73 0.0 | 0.0 |
| 3121005 | Rectangular | Carbon Steel | 0.0 190.0 | 180010000 0 | 122.0 | 1.73 0.0 | 0.0 |
| 3121006 | Rectangular | Carbon Steel | 0.0 190.0 | 190010000 0 | 122.0 | 1.73 0.0 | 0.0 |
| 3121007 | Rectangular | Carbon Steel | 0.0 190.0 | 200010000 0 | 122.0 | 1.73 0.0 | 0.0 |
| 3121008 | Rectangular | Carbon Steel | 0.0 190.0 | 210010000 0 | 122.0 | 1.73 0.0 | 0.0 |
| 3121009 | Rectangular | Carbon Steel | 0.0 190.0 | 220010000 0 | 122.0 | 1.73 0.0 | 0.0 |

7.3.4 RELAP5 Reactivity Tables

The feedback reactivity in the RELAP5 point kinetics model can be specified as direct time dependent tables (labeled as scram tables), weighted tables of fluid density vs reactivity, or through

control system variables. The control system allows reactivity values to be more generally specified as functions of model variables.

The RELAP5 reactivity changes for fuel and moderator temperature effects are shown in Tables 7.3-4 and 7.3-5. The first parameter shown on Tables 7.3-4 and 7.3-5 is the 8 digit input line number beginning with the number 3 (30000000). The last 3 digits on these input lines identify the fuel temperature variables, 30000601 through 30000607, moderator density variables, 30000501 through 30000516, and the respective reactivities. The English units used here reflect the values used in the RELAP5 input.

The formulation of the reactivities for each input line is denoted as:

$$\rho(603) = \Delta\rho_{CB} + \rho(\text{sum})$$

where $\rho(603)$ is the input line number (603 for example), $\rho(\text{sum})$ is the summation of reactivities from the initial state point (122 °F), and:

$$\Delta\rho_{CB} = \frac{1}{k_{\text{eff}} - \text{Base}} - \frac{1}{k_{\text{eff}} - \text{Change}}$$

where C represents the change case number from Table 7.2.2.2-1 and B represents the base case number from the same table. Note that the cases listed in Table 7.2.2.2-1 include a number of branch cases (fuel temperature varied at constant density and density varied at constant fuel temperature). The constant parameter is listed the last column in Table 7.3-4 and Table 7.3-5.

• Table 7.3-4. Average Fuel Temperature Versus Reactivity

| RELAP5 Input Line # | Fuel Temperature (°F) | $\Delta\rho(\%)$ | Density (lb _m /ft ³) |
|---------------------|-----------------------|------------------|---|
| 30000601 | 32.0 | +0.1719079 | 62.4279606 |
| 30000602 | 80.33 | +0.1719079 | 62.4279606 |
| 30000603 | 122.0 | +0.0 | 61.6903146 |
| 30000604 | 212.0 | -0.3488604 | 61.6903146 |
| 30000605 | 320.0 | -0.7295469 | 60.7424057 |
| 30000606 | 518.0 | -1.3918144 | 60.7424057 |
| 30000607 | 1004.0 | -2.8696928 | 56.1851645 |

Table 7.3-5. Moderator Density Versus Reactivity

| RELAP5 Input Line # | Density (lb _m /ft ³) | Δρ(\$) | Fuel Temperature (°F) |
|---------------------|---|--------------|-----------------------|
| 30000501 | 43.6995724 | - 22.8341124 | 1004 |
| 30000502 | 45.2602714 | -20.0375898 | 1004 |
| 30000503 | 46.8209705 | -17.4413905 | 1004 |
| 30000504 | 48.3816695 | -15.0255317 | 1004 |
| 30000505 | 49.9423685 | -12.7766726 | 1004 |
| 30000506 | 51.5030675 | -10.6782739 | 1004 |
| 30000507 | 53.0637665 | -8.7187079 | 1004 |
| 30000508 | 54.6244655 | -6.8856192 | 1004 |
| 30000509 | 56.1851645 | -5.1688975 | 518 |
| 30000510 | 57.4337238 | -3.9010990 | 518 |
| 30000511 | 58.6822830 | -3.9010990 | 518 |
| 30000512 | 59.8121897 | -1.6592902 | 518 |
| 30000513 | 60.7424057 | -0.8234196 | 212 |
| 30000514 | 61.6903146 | 0.00 | 122 |
| 30000515 | 62.4279606 | +0.6225345 | 122 |
| 30000516 | 65.0000000 | +0.6225345 | 80.33 |

The initial state point is represented by fuel temperatures of 122°F and a corresponding density of 61.6903146 lb/ft³. There are interpolation control reactivity lines for ρ (601) and ρ (516). Temperatures less than 80.33°F (ρ (602)) cannot be attained. Therefore, 32°F is a dead-ended interpolation point:

$$\rho(601)_{32^{\circ}\text{F}} = \rho(602)_{80.33^{\circ}\text{F}}$$

Likewise, water densities greater than 1.0 gm/cm³ or 62.4 lb/ft³ cannot be attained. Therefore, 65.0 lb/ft³ is a dead-ended interpolation point:

$$\rho(516)_{65.0\text{ lb/ft}^3} = \rho(515)_{62.4\text{ lb/ft}^3}$$

The reactivity summation, ρ (sum), begins with the base reactivity for the initial state points and proceeds in the direction of increasing positive values or decreasing negative ones.

The formulations for the fuel temperature reactivity values are shown below. These expressions are straightforward. For example, if a positive reactivity increase is considered to have resulted from a fuel temperature decrease from 122°F to 80.33°F, the base case in Table 7.2.2.2-1 is #2 and the change case is #1. Consequently, the change in reactivity is $\Delta\rho_{1,2}$. The sum of all previous reactivities is zero because this is the first change from the base reactivity, which is zero at 122°F.

$$\begin{aligned}\rho(601) &= \rho(602) \\ \rho(602) &= \Delta\rho_{1,2} + \rho(603) \\ \rho(603) &= 0.0 = \Delta\rho = \rho(603) \\ \rho(604) &= \Delta\rho_{4,3} + \rho(603) \\ \rho(605) &= \Delta\rho_{6,5} + \rho(\text{sum}) \\ \rho(\text{sum}) &= \rho(604) + \rho(603) \\ \\ \rho(606) &= \Delta\rho_{7,6} + \rho(\text{sum}) \\ \rho(\text{sum}) &= \rho(605) + \dots \\ \\ \rho(607) &= \Delta\rho_{12,11} + \rho(\text{sum}) \\ \rho(\text{sum}) &= \rho(606) + \dots\end{aligned}$$

The formulations for the moderator density reactivity values are shown below. The format and evaluation follow the same pattern as that for the fuel temperatures discussed above.

$$\begin{aligned}\rho(516) &= \rho(515) \\ \rho(515) &= \Delta\rho_{2,3} + \rho(514) \\ \rho(514) &= 0 = \Delta\rho = \rho(\text{sum}) \\ \rho(513) &= \Delta\rho_{5,4} + \rho(514) \\ \rho(512) &= \Delta\rho_{8,7} + \rho(\text{sum}) \\ \rho(\text{sum}) &= \rho(513) + \rho(514) \\ \\ \rho(511) &= \Delta\rho_{9,8} + \rho(\text{sum}) \\ \rho(\text{sum}) &= \rho(512) + \dots \\ \\ \rho(510) &= \Delta\rho_{10,9} + \rho(\text{sum}) \\ \rho(\text{sum}) &= \rho(511) + \dots \\ \\ \rho(509) &= \Delta\rho_{11,10} + \rho(\text{sum}) \\ \rho(\text{sum}) &= \rho(510) + \dots \\ \\ \rho(508) &= \Delta\rho_{13,12} + \rho(\text{sum})\end{aligned}$$

ρ (sum) = Sum of previous ρ values

$$\rho(507) = \Delta\rho_{14,13} + \rho(\text{sum})$$

$$\rho(506) = \Delta\rho_{15,14} + \rho(\text{sum})$$

$$\rho(505) = \Delta\rho_{16,15} + \rho(\text{sum})$$

$$\rho(504) = \Delta\rho_{17,16} + \rho(\text{sum})$$

$$\rho(503) = \Delta\rho_{18,17} + \rho(\text{sum})$$

$$\rho(502) = \Delta\rho_{19,18} + \rho(\text{sum})$$

$$\rho(501) = \Delta\rho_{20,19} + \rho(\text{sum})$$

During the development of the model, it was noted that the reactivity was remaining high during the transient when the water level was decreasing down through the upper row of assemblies. Based on the results in Section 7.2.1 that this was a very large negative effect, it was recognized that this effect needed to be included. The control system input option was used to incorporate the results in Table 7.2.1-2 into the RELAP5 model. A control block was added to the input file to compute an average liquid level in the top row of fueled assemblies and adjacent fluid volumes having the same elevation. Reactivity is calculated from the table at the current liquid level using linear interpolation procedures based on the results in Section 7.2.1. The MCNP analyses for the sequence of water levels in the WP were evaluated from the top of the fuel assembly to -20.30 cm as indicated in Section 7.2.1. The reactivity table for the RELAP5 model was extended to -21.64 cm (lower edges of the assemblies) using the last reactivity value to define a zero level entry. This is a conservative approach since the k_{eff} of the system is strongly correlated with the water level at these conditions.

The inclusion of the control block for water level necessitated that the moderator density table be overridden. Note that this is conservative since the drop in moderator density is shown in Table 7.3-5 to always result in a negative change in reactivity.

7.4 Results of RELAP5 Analysis

All results in this section from RELAP5 calculations are TBV because the RELAP5/MOD3 code has not been qualified according QAP-SI-0 as indicated in Section 6.

The consequences of a large reactivity insertion in the WP, one where the insertion rate was on the order of minutes and the second where the rate was on the order hours, were investigated with the RELAP5 model. In particular, the scenarios investigated were a positive reactivity insertion of 14.18\$ at a constant rate over 30 seconds and over 3600 seconds. These cases are labeled as r5wp2d.sht for the 30 second scenario and r5wp2d.lng for the 3600 second scenario. The short term (initial power excursion) transient responses in both cases were qualitatively similar, being dominated by the positive ramp reactivity insertion and negative Doppler feedback reactivity which terminated the initial power rise in each case prior to the introduction of significant negative void reactivity. The transient response of the WP system following termination of the initial power rise was controlled by the rate of energy addition affecting the rate and magnitude of the void formation

and thus the time evolution of the void reactivity component. Ultimately, sufficient fluid inventory was lost from the WP (> 225 kg in either case) to sustain a large negative void reactivity component, keeping the system in a subcritical condition.

Maximum pressures in the WP system remained below $2.55\text{e}+05$ Pa and maximum center line fuel rod temperatures remained below 570 K. Sufficient fluid inventory remained in the WP at the problem termination to redistribute the energy in the system and reducing the fuel rod temperatures to less than 373 K. Values of several key parameters from the RELAP5 analyses are summarized in Table 7.4-1.

Table 7.4-1. Summary of 14.18\$ Ramp Reactivity Insertion Cases

| Variable | 30 second reactivity insertion case r5wp2d.sht | 3600 second reactivity insertion case r5wp2d.lng |
|--|--|--|
| Peak fission power/assembly | $9.47\text{e}+07$ watts | $8.76\text{e}+05$ watts |
| Time of peak fission power | 2.52 seconds | 176.0 seconds |
| Total fission and decay heat power per assembly at time of fission power maximum | $9.48\text{e}+07$ watts | $9.00\text{e} + 05$ watts |
| Total energy into WP/assembly at termination time | $5.16\text{e}+07$ joules | $8.15\text{e}+07$ joules |
| Maximum volume pressure | $2.544\text{e}+05$ Pa | $2.258\text{e}+05$ Pa |
| Control volume where maximum pressure monitored | 150010000 | 150010000 |
| Peak mean fuel rod temperature | 497.5 K | 438.4 K |
| Time of peak pin temperature | 4.18 seconds | 633 seconds |
| Water inventory - Initial | 450.04 kg | 450.04 kg |
| Water inventory - Final | 209.02 kg | 219.29 kg |
| Incremental Burnup | $1.6\text{e}-03$ MWd/MTU | 1.8 MWd/MTU |
| Termination time | 1200 seconds | 1800 seconds |

The consequences of each reactivity insertion scenario were directly related in severity to the reactivity insertion rate in the flooded WP which is typical of transient reactivity events analyzed in

reactor systems such as during Anticipated Transients Without Scram (ATWS) (Ref. 5.17), supporting the assumption that the RELAP5 code can adequately model the WP system. The total energy generated may be larger for slower insertion rate events as shown in Table 7.4-1 but is distributed over longer time periods than the more rapid insertion rate events. Within an essentially closed system such as the WP being analyzed, the energy generation can be considered as an adiabatic process since the time scales are too short for significant amounts of energy to be transferred into the WP barriers as heat sinks. Thus, although the detailed histories differ markedly, preliminary analysis indicates that the final state of the system is, at most, only weakly dependent upon reactivity insertion rates since the fission reaction terminates as soon as the WP is sufficiently voided. In this state, sufficient fluid inventory has been converted to steam (or a two-phase fluid) and expelled from the WP to preclude any short term return to criticality.

The time evolution of key parameters from the 30 second scenario are shown in Figure 7.4-1 through Figure 7.4-10, respectively, for assembly power, reactivity components, control volume pressures, WP fluid inventory, junction flow rates, and average fuel temperature. Two ranges are shown for several of the parameters, one showing a panoramic view of the parameter value over the total time period, and the second providing a higher resolution study over a limited time scale. In this scenario, the energy generation rate was sufficiently rapid during the initial power excursion to raise fuel temperatures (Figure 7.4-10) well into the range where void formation occurs generating the sharp pressure rise (Figure 7.4-5) and inventory loss (Figure 7.4-7). As shown in Figure 7.4-3, the large negative void reactivity component prevented any possible return to criticality in the WP system and the fission power level (Figure 7.4-1) asymptotically approaches the characteristic 79 second decay period of the longest lived delayed neutron precursor group (standard 6-group model).

The total system reactivity and its three components (positive ramp insertion, negative Doppler and void feedback) are given in Figure 7.4-3. This figure shows the early Doppler feedback reactivity which terminated the initial power excursion followed by the larger negative void reactivity which ultimately terminates the event. All values of the reactivity components have reached their asymptotic values by 30 seconds.

Maximum pressures in the WP system reach approximately 2.5×10^5 Pa during the initial phases of the event as shown in Figure 7.4-4 and Figure 7.4-5, then return to near initial values. The lower final values reflect the gravity head from the reduced final fluid inventory as shown in Figure 7.4-6 and Figure 7.4-7.

The flow rate in the exit junction, ID 250010000, and junction IDs 230010000 and 230020000 are shown in Figure 7.4-8 over the total event period and in Figure 7.4-9 for an initial phase. The flow rate in the exit junction, ID 250010000, is limited by the choking model which controls the rate of inventory loss and pressure relief. The direction of flow for the exit junction is predominately outward

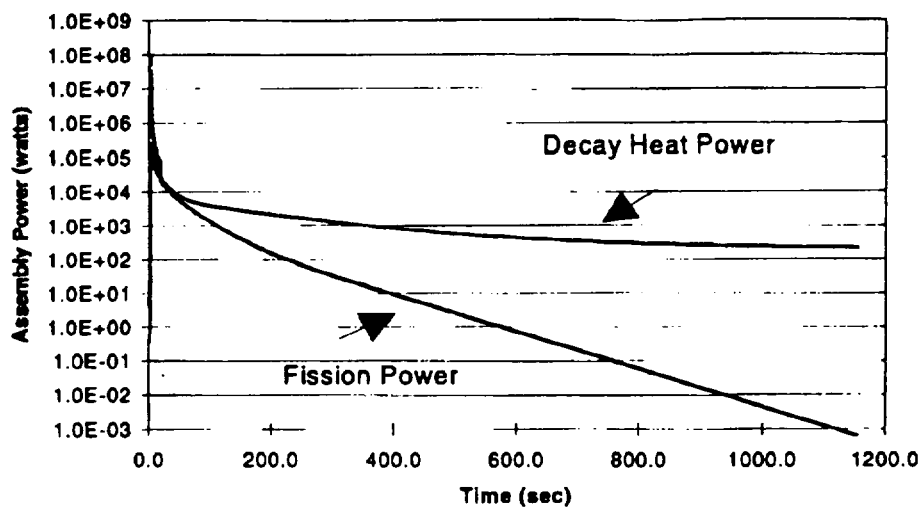


Figure 7.4-1. Assembly Power - 30 second Reactivity Insertion Scenario

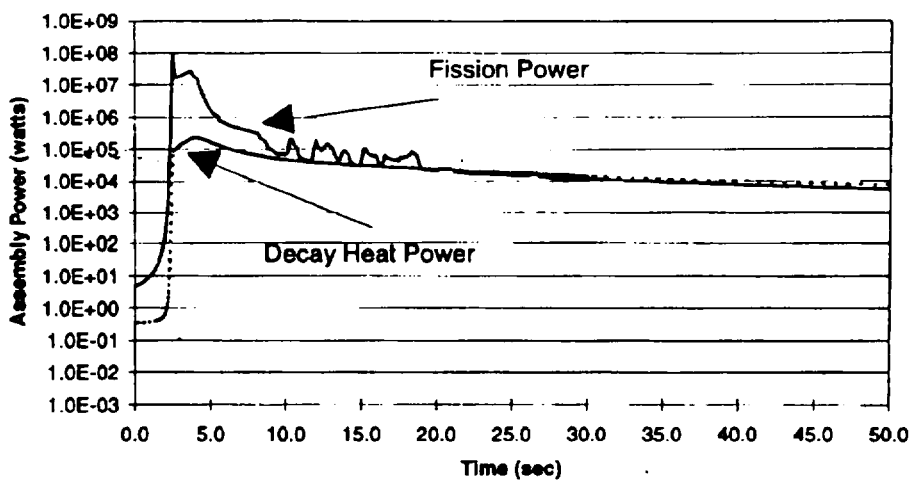


Figure 7.4-2. Assembly Power - 30 second Reactivity Insertion Scenario

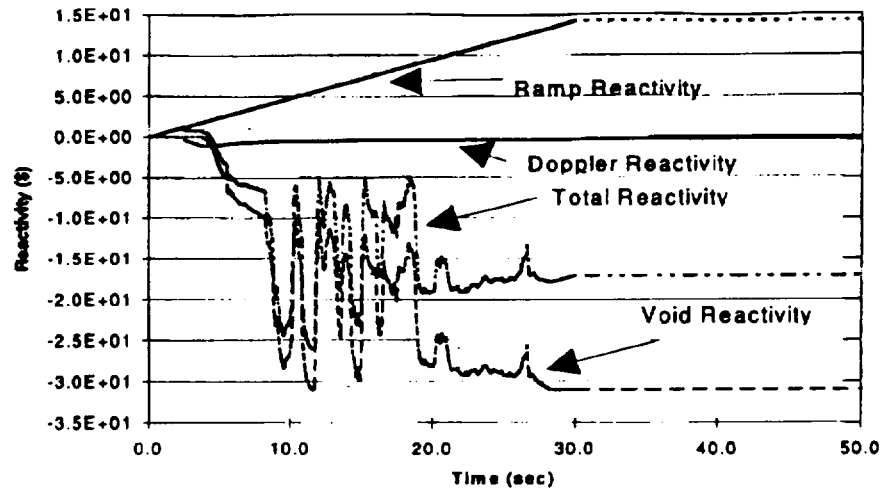


Figure 7.4-3. Reactivity Components - 30 second Reactivity Insertion Scenario

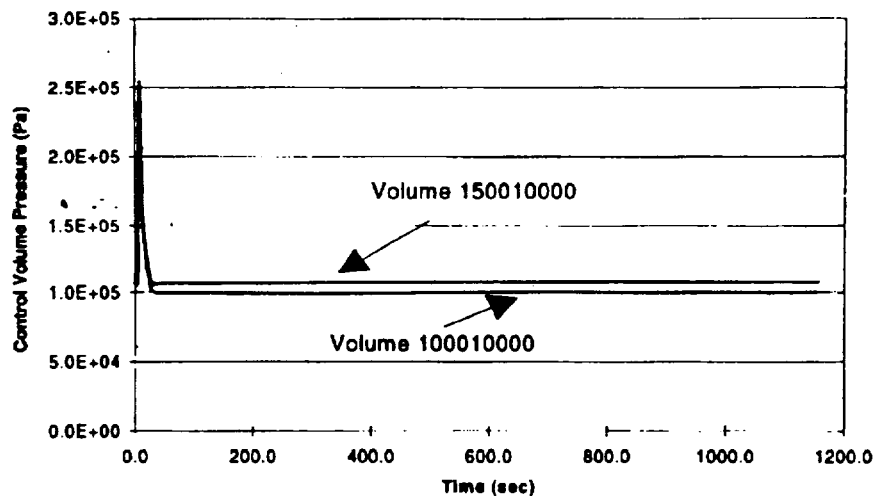


Figure 7.4-4. Volume Pressures - 30 second Reactivity Insertion Scenario

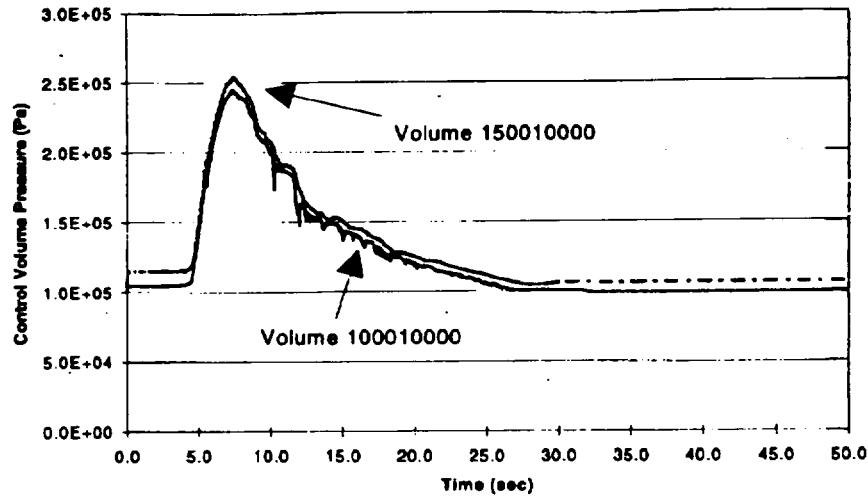


Figure 7.4-5. Volume Pressures - 30 second Reactivity Insertion Scenario

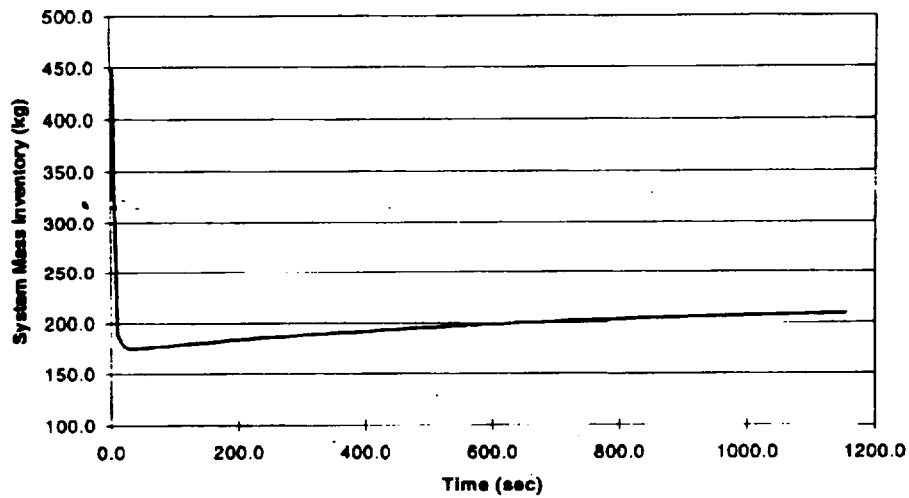


Figure 7.4-6. Waste Package Fluid Inventory - 30 second Reactivity Insertion Scenario

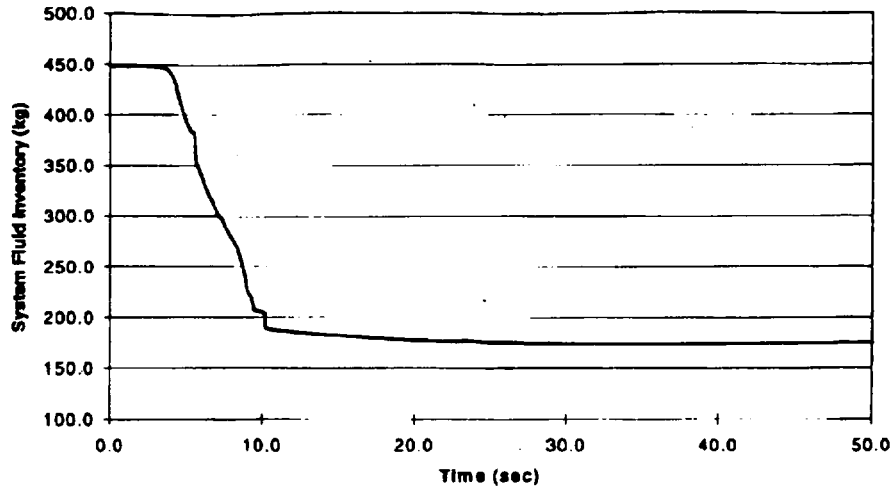


Figure 7.4-7. Waste Package Fluid Inventory - 30 second Reactivity Insertion Scenario

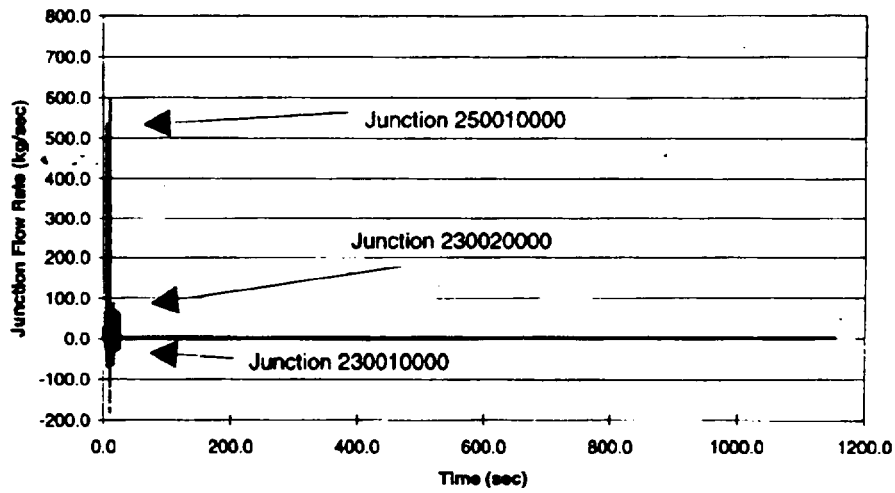


Figure 7.4-8. Junction Flow Rates - 30 second Reactivity Insertion Scenario

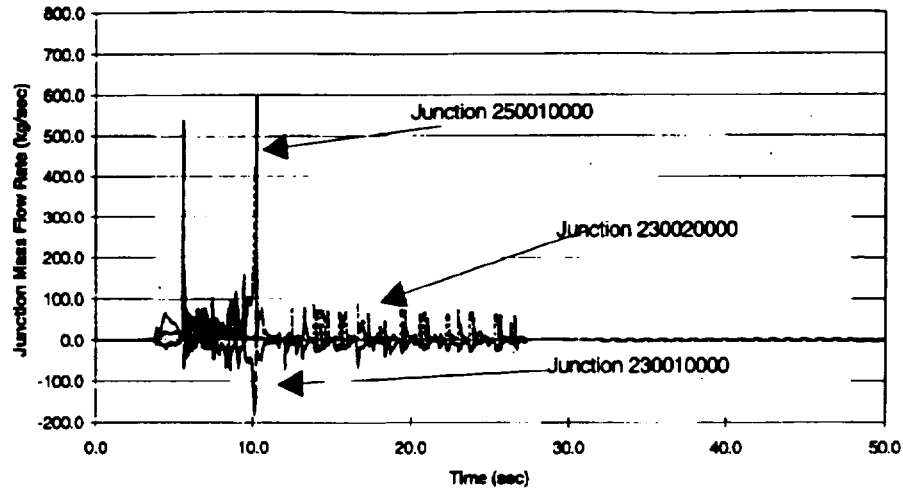


Figure 7.4-9. Junction Flow Rates - 30 second Reactivity Insertion Scenario

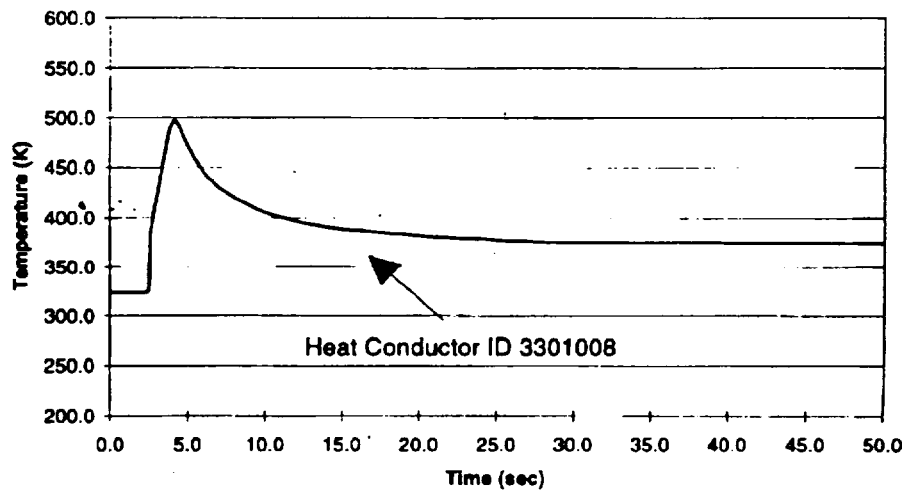


Figure 7.4-10. Average Metal Temperature - 30 second Reactivity Insertion Scenario

(inventory loss) with very low reverse mass flow rates since the external environment (Control Volume 260010000) was specified as water vapor. Interior junctions, as shown in these figures, may experience either positive or negative flow rates as the pressure distribution dictates. As stated previously, the system returns to a stable sub-critical configuration following the initial activity.

The much lower reactivity insertion rate in the 3600 second reactivity insertion scenario, and thus the energy generation rate, resulted in a less severe transient response than for the 30 second reactivity insertion scenario as listed in Table 7.4-1. The time evolution of key parameters from this scenario is shown in Figure 7.4-11 through Figure 7.4-20, respectively, for assembly power, reactivity components, control volume pressures, WP fluid inventory, junction flow rates, and average fuel temperature. Two ranges are shown, as above, for several of the parameters, one showing a panoramic view of the parameter value over the total time period, and the second providing a higher resolution study over a limited time scale. In the 3600 second reactivity insertion scenario, the power excursion is terminated by the negative Doppler reactivity (Figure 7.4-13) with fuel pin metal temperatures (Figure 7.4-20) at values where subcooled boiling can be initiated. The initial vapor generation was coincident with the initial WP inventory loss (Figure 7.4-15) but did not result in a prominent pressure surge as shown in Figure 7.4-16. During the 200-600 second time period in the scenario, negative reactivity from the void and Doppler effects was nearly equal to the positive ramp insertion reactivity, maintaining the power level (Figure 7.4-12). An increase in the vapor generation rate around 600 seconds into the scenario resulted in a pressure surge (Figure 7.4-16) and further inventory loss. As shown in Figure 7.4-13, the large negative void reactivity component prevents any possible return to criticality in the WP system and the fission power level (Figure 7.4-11) asymptotically approaches the characteristic 80 second decay profile. The inventory loss at this point is sufficient to prevent any possible return to critical conditions until the WP refills with water which has a time scale of years.

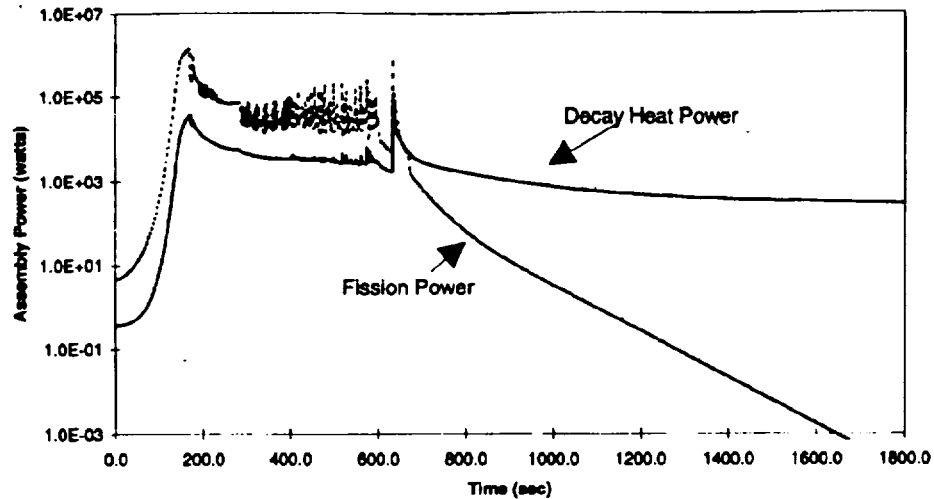


Figure 7.4-11. Assembly Power - 3600 second Reactivity Insertion Scenario

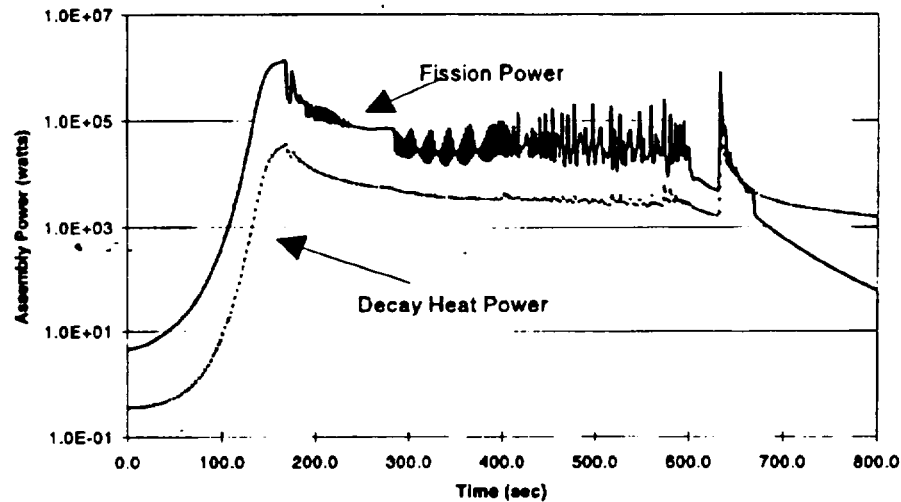


Figure 7.4-12. Assembly Power - 3600 second Reactivity Insertion Scenario

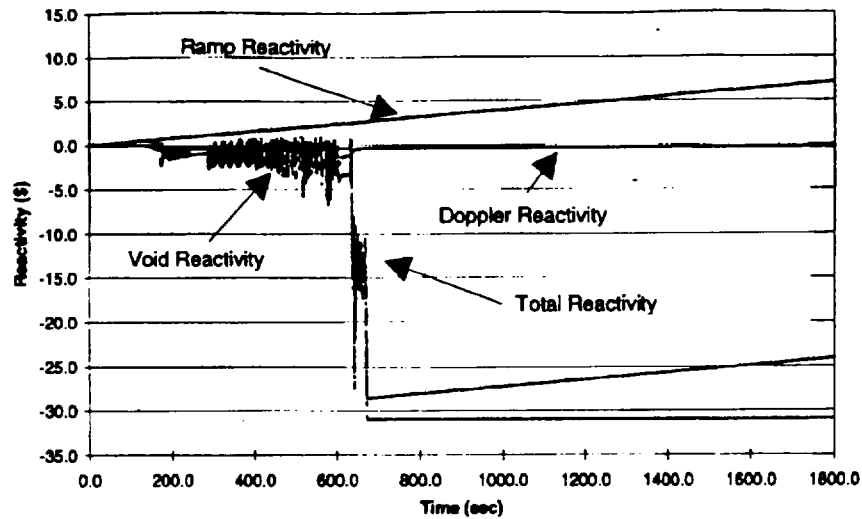


Figure 7.4-13. Component Reactivity - 3600 second Reactivity Insertion Scenario

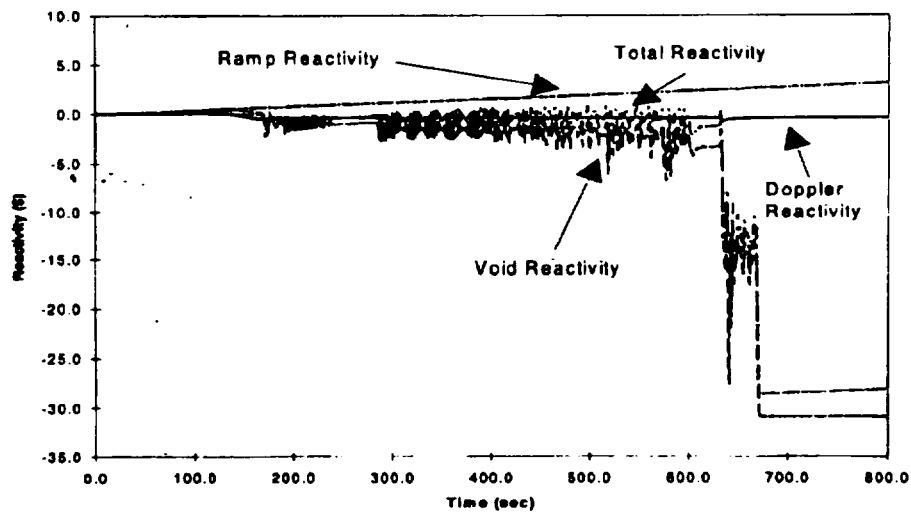


Figure 7.4-13. Component Reactivity - 3600 second Reactivity Insertion Scenario

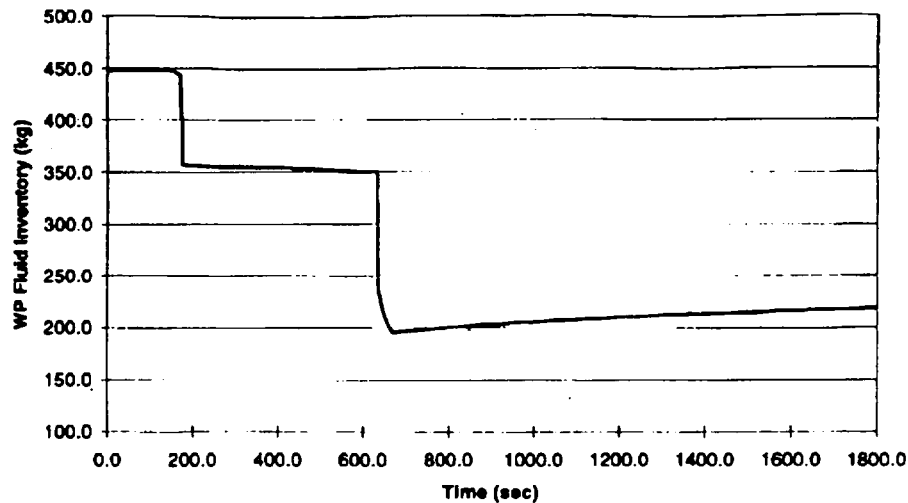


Figure 7.4-15. Waste Package Fluid Inventory - 3600 second Reactivity Insertion Scenario

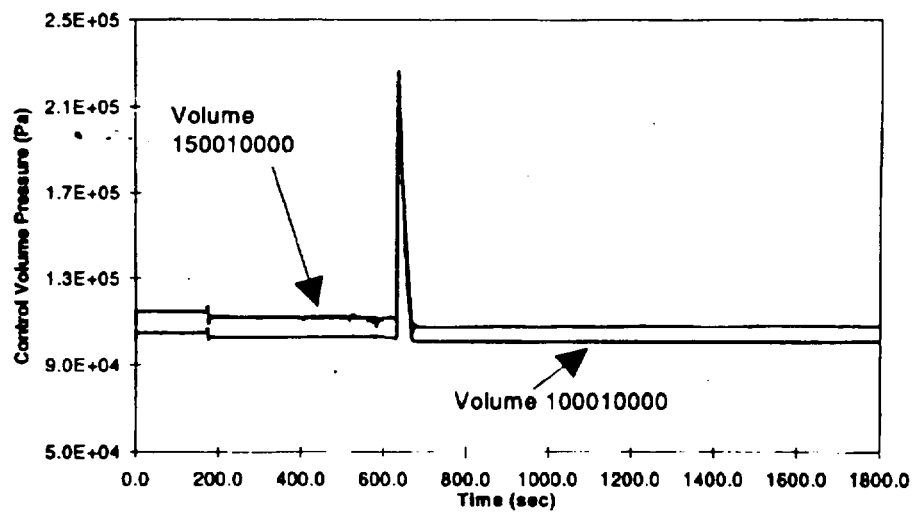


Figure 7.4-16. Volume Pressures - 3600 second Reactivity Insertion Scenario

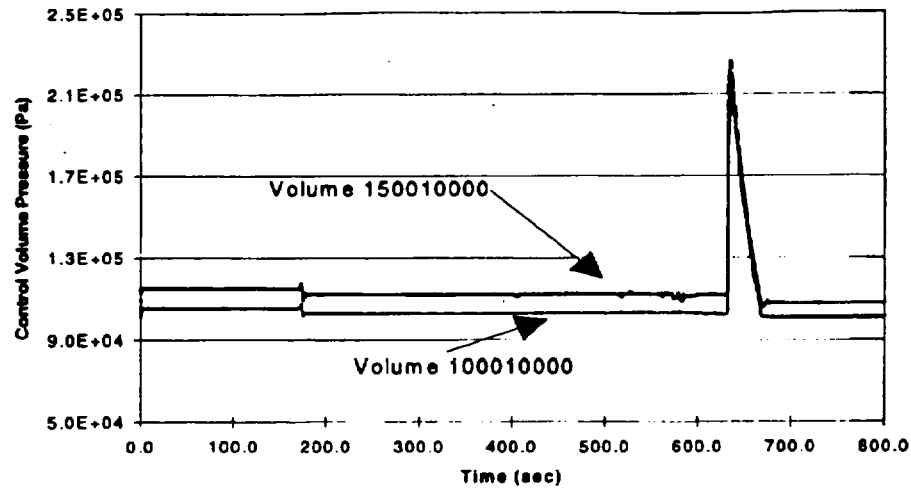


Figure 7.4-17. Volume Pressures - 3600 second Reactivity Insertion Scenario

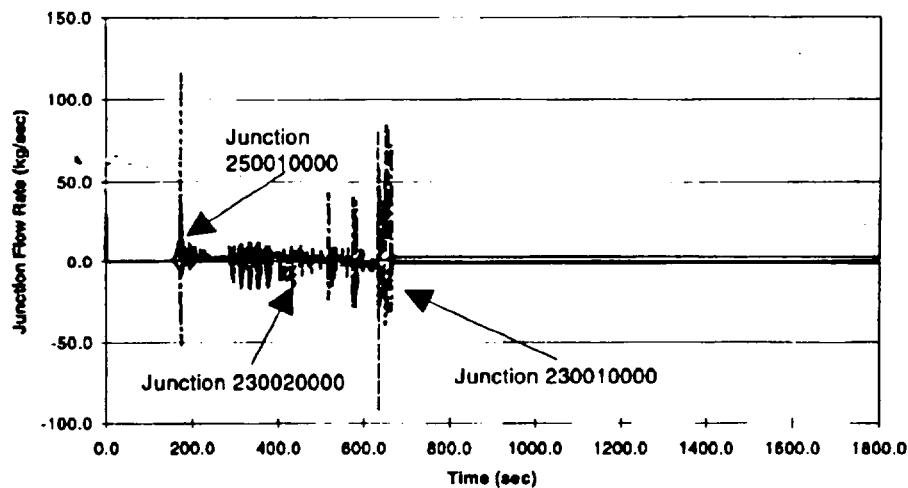


Figure 7.4-18. Junction Flow Rates - 3600 second Reactivity Insertion Scenario

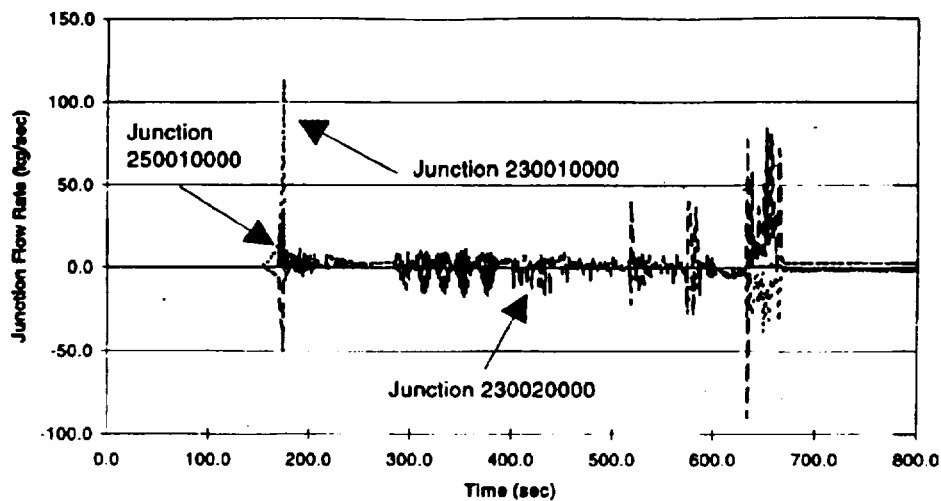


Figure 7.4-19. Junction Flow Rates - 3600 second Reactivity Insertion Scenario

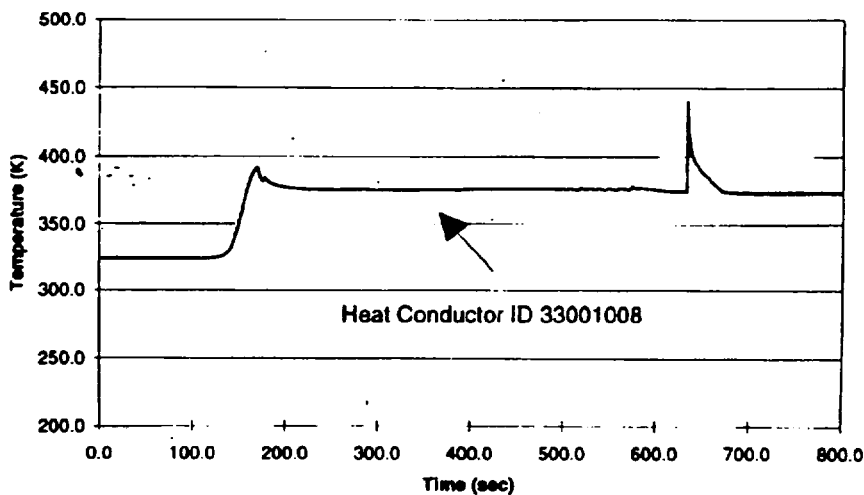


Figure 7.4-20. Average Metal Temperature - 3600 second Reactivity Insertion Scenario

7.5 Changes to the Radionuclide Inventory Due to Transient Criticality Event

To evaluate the effects of a criticality on the radionuclide inventory of a waste package, the code sequence SAS2H was run using the PWR criticality design basis fuel, power histories from the RELAP5 analyses, and a decay period of one year. The maximum decay period of one year was based on the short operating time of the criticality event which precludes formation of significant inventories of long lived isotopes. The transient fission power history and fuel temperature, listed in Table 7.5-1, for the SAS2H input files (short.inp, long.inp) were approximated by histograms derived from the graphical data shown in Section 7.4. Figure 7.4-1 and Figure 7.4-10 were the basis for the 30 second reactivity scenario histograms. Figure 7.4-11 and Figure 7.4-20 were the basis for the 3600 second reactivity insertion scenario histograms. The burnup calculated from these histograms (summation of time steps in days multiplied by power in MW and divided by 0.464 MTU) are only $1.6\text{E-}3$ MWd/MTU and 1.8 MWd/MTU for the short and the long cases, respectively. The output of the SAS2H runs (short.out and long.out) list the radionuclide inventories in curies for the 30 second and 3600 second reactivity insertion scenarios, respectively. These values are compared in Table 7.5-2 to the initial radionuclide inventory for a 25,000 year decay period generated as part of a previous analysis (Ref. 5.13). The initial analysis contained 36 isotopes in the radionuclide inventory. For this analysis, only those isotopes whose inventories after one year decay differed from the original values by a minimum cutoff value ($\sim 10^{-20}$) are listed. As shown, small differences appear in the fission product activity but the principal radioactivity is due to the actinide decay which is not significantly altered by the criticality events.

Note that the input compositions for the short and long SAS2H runs are based on the MCNP criticality compositions which have been adjusted up to 96% of 10.96 g/cm^3 (theoretical density of natural UO_2). The 25,000 year decay case to which the results are compared has compositions based on a UO_2 density of 10.206. Therefore, the activities for the isotopes for which a composition was specified in the inputs for the long and short cases must be multiplied by 0.97 ($10.206/10.5216$) to be compared on the same basis.

Table 7.5-1. ORIGEN-S Input Parameters

| Case | Power (MW) | Burn Time (days) | Fuel Temperature (K) |
|--|------------|------------------|----------------------|
| 30 second Reactivity Scenario (short.out) | | | |
| | 9.0 | 0.0000023 | 326.5 |
| | 50.0 | 0.0000023 | 383.2 |
| | 25.0 | 0.000015 | 469.3 |
| | 2.0 | 0.000023 | 455.4 |
| | 0.5 | 0.000069 | 422.1 |
| | 0.3 | 0.00046 | 388.8 |
| 3600 second Reactivity Scenario (long.out) | * | * | * |
| | 0.5 | 0.00046 | 327.6 |
| | 1.0 | 0.00023 | 374.8 |
| | 0.5 | 0.00035 | 380.4 |
| | 0.07 | 0.0093 | 376.5 |
| | 0.03 | 0.0035 | 376.5 |
| | 0.01 | 0.001 | 373.2 |

Table 7.5-2. Radionuclide Inventory after One Year Decay Period

| Isotope | Initial Activity (Ci) (Ref. 5.13) | 30 second Reactivity Scenario (short.out) Increase (Ci) | 3600 sec Reactivity Scenario (long.out) Increase (Ci) |
|------------------|--------------------------------------|---|---|
| Actinides | - | - | - |
| th229 | 3.71e-02 | 5.63e-06 | 5.63e-06 |
| th230 | 2.60e-01 | 1.17e-05 | 1.17e-05 |
| pa231 | 9.01e-03 | 5.20e-07 | 5.20e-07 |
| u233 | 6.20e-02 | - | - |
| u234 | 1.23e+00 | - | - |
| u235 | 2.33e-02 | - | - |
| u236 | 2.25e-01 | - | - |
| u238 | 1.45e-01 | - | - |
| np237 | 6.10e-01 | - | - |
| pu238 | 0.00e+00 | 5.65e-04 | 6.27e-04 |
| pu239 | 9.74e+01 | - | - |
| pu240 | 1.56e+01 | - | - |
| pu241 | 5.72e-03 | - | - |
| pu242 | 5.57e-01 | - | - |
| am241 | 5.95e-03 | - | - |
| am243 | 5.59e-01 | - | - |
| cm244 | 0.00e+00 | 1.22e-05 | 1.34e-05 |
| Fission Products | - | - | - |
| tc99 | 6.02e+00 | 1.34e-02* | 1.34e-02* |
| sm151 | 0.00e+00 | 1.22e-04 | 1.36e-04 |

* These values may be significantly overestimated as a result of roundoff to 3 digits in SAS2H.

8. Conclusions

All conclusions in this section from RELAP5 calculations are TBV because the RELAP5/MOD3 code has not been qualified according QAP-SI-0 as indicated in Section 6.

The criticality consequence analyses performed for the fully degraded internal structure of a 21 PWR WP loaded with 15X15 B&W SNF demonstrated that, based upon conservative assumptions, the system remains in a safe configuration following scenarios where 14.18\$ of positive reactivity is added to the WP system over time scales of 30 to 3600 seconds. The 14.18\$ reactivity value represents the maximum possible reactivity attainable in the WP designs as discussed in Section 7.2.3. The probability of these criticality scenarios will be addressed in separate analyses (TBD). The results of the preliminary analysis in Section 7.4 show that the PWR SNF WP system returns to a subcritical configuration with the fuel rod temperatures and WP internal pressures remaining well below levels which could melt fuel or generate more than minor effects on adjacent WP systems (e.g. humidity levels will temporarily increase in the drift environment). The results discussed in Section 7.4 also show that consequences of a reactivity insertion event decrease in severity as the insertion rate decreases. However, the final state of the system, where sufficient water is lost from the WP to maintain a subcritical state, depends primarily on the energy generated rather than the rate, since steam formation is the primary energy dissipation mechanism in the WP.

Consequently, criticality events in a WP will be restricted to localized incidents and not involve additional WPs or affect the overall integrity of the repository. The principal impact on the environment external to the WP experiencing a criticality event is the return of water in vapor form to the drift environment increasing the ambient humidity. This should not significantly impact the WP environment in an adverse manner since the presence of water in the environment is assumed initially. Although not considered in the RELAP5 model, condensation of the water vapor will prevent any significant over pressurization of adjacent WP modules since the drift environment is assumed to be 326.2 K. The criticality analysis of the WP (Ref. 5.13) showed that the system is subcritical unless the SNF in the WP is submerged in water. This criticality consequence analysis shows that sufficient water inventory is expelled from the WP to preclude any immediate return to a critical configuration. Flooding the WP to levels where criticality is again possible would require several years even at the most conservative flow rates forecast for the drift region.

Burnup from the transient reactivity scenarios was less than 2.0e-03 Mwd/MTU per scenario. The ORIGEN-S analysis of the scenarios showed that the radionuclide inventories in a WP had a negligible increase after a one year decay period which will have no significant effects on the WP or repository.

9. Attachments

The hardcopy attachments are listed in Table 9-1 below. Electronic attachments are provided on Colorado Trakker® tapes (Ref. 5.22) and are listed in Table 9-2 below for REV 00 Cases.

Table 9-1. Attachments of Supporting Documentation for Criticality Consequence Analysis Involving Intact PWR SNF in a Degraded 21 PWR Assembly Waste Package

| Attachment Number | Description | Pages |
|-------------------|--------------------------------|-------|
| I | Base MCNP Case (R58H13F) | 4 |
| II | Base SAS2H Case (IN.WP) | 3 |
| III | Terminal Velocity Calculation | 1 |
| IV | RELAP5 Input File (R5WP2D.03C) | 17 |

Table 9-2. Attachments of Computer Outputs for Criticality Consequence Analysis

| File Name | File Size (Bytes) | File Date | File Time of Day |
|-----------|----------------------|-----------|---------------------|
| ANS79.P | 95,956 | 9/2/97 | 4:42p |
| EDHTRK.P | 610,033 | 9/2/97 | 4:42p |
| EDHTRKD.P | 605,830 | 9/2/97 | 4:42p |
| EDHTRKN.P | 605,649 | 9/2/97 | 4:42p |
| EDRST.P | 699,984 | 9/2/97 | 4:42p |
| EDSTRIP.P | 7,743 | 9/2/97 | 4:42p |
| MARPZD4.P | 693,794 | 9/2/97 | 4:42p |
| PUMP2.P | 1,362,805 | 9/2/97 | 4:42p |
| TYPPWR.P | 1,677,913 | 9/2/97 | 4:42p |
| TYPPWRN.P | 1,679,245 | 9/2/97 | 4:43p |
| INFH2O.O | 547,580 | 8/29/97 | 1:31p |
| INFOX.O | 234,872 | 8/29/97 | 1:31p |
| OUT.E49 | 2,694,284 | 7/22/97 | 7:23p |
| OUT.FE | 2,730,022 | 7/22/97 | 7:23p |

Table 9-2. Attachments of Computer Outputs
for Criticality Consequence Analysis

| File Name | File Size (Bytes) | File Date | File Time of Day |
|------------|----------------------|-----------|---------------------|
| INFLUX2O | 556,209 | 8/29/97 | 1:31p |
| OUT.WP | 2,738,210 | 8/29/97 | 1:23p |
| INFH2OaO | 544,337 | 8/29/97 | 1:31p |
| OUT.FIN | 2,694,880 | 8/19/97 | 7:46p |
| H2OH13FO | 579,852 | 8/29/97 | 1:28p |
| OUT.WPN | 2,694,372 | 7/22/97 | 7:59p |
| OUT.WP | 2,738,210 | 8/29/97 | 1:23p |
| OUT~1.122 | 2,740,086 | 8/29/97 | 1:23p |
| OUT~2.122 | 2,740,107 | 8/29/97 | 1:23p |
| OUT~2.212 | 2,740,122 | 8/29/97 | 1:24p |
| OUT~1.212 | 2,740,122 | 8/29/97 | 1:23p |
| OUT~1.320 | 2,740,236 | 8/29/97 | 1:23p |
| OUT~5.518 | 2,740,464 | 8/29/97 | 1:24p |
| OUT~4.518 | 2,740,443 | 8/29/97 | 1:24p |
| OUT~3.518 | 2,738,807 | 8/29/97 | 1:24p |
| OUT~2.518 | 2,738,828 | 8/29/97 | 1:24p |
| OUT~1.518 | 2,738,828 | 8/29/97 | 1:23p |
| OUT~9.100 | 2,739,362 | 8/29/97 | 1:25p |
| OUT~8.100 | 2,739,341 | 8/29/97 | 1:25p |
| OUT~7.100 | 2,737,726 | 8/29/97 | 1:25p |
| OUT~6.100 | 2,737,684 | 8/29/97 | 1:25p |
| OUT~5.100 | 2,740,464 | 8/29/97 | 1:24p |
| OUT~4.100 | 2,737,726 | 8/29/97 | 1:24p |
| OUT~3.100 | 2,736,174 | 8/29/97 | 1:24p |
| OUT~2.100 | 2,736,153 | 8/29/97 | 1:23p |
| OUT~1.100 | 2,736,216 | 8/29/97 | 1:23p |
| R5WP2D.SHT | 18,830,566 | 9/2/97 | 4:24p |
| R5WP2D.LNG | 18,839,913 | 9/2/97 | 4:23p |
| SHORT.OUT | 22,131,092 | 9/2/97 | 3:52p |
| LONG.OUT | 22,136,053 | 9/2/97 | 3:46p |

AUCF-21 BW15x15, full deg, 58% Fe2O3, settled

C CELL SPECIFICATIONS

C Assembly Sub-lattices - 1/2 Model

1 0 1 3 -13 -20 FILL=1 (0 -74 0) IMP:N=1

C ASSEMBLY LATTICE

5 1 -3.4592 -61 60 -63 62 IMP:N=1 LAT=1 U=1
FILL=0:3 0:7 0:0 1 3R 56 56 1 1 56 56 56 1
56 56 56 1 59 59 59 60 57 57 58 58
58 3R 58 3R \$ 1/2 model

C BARRIER CELLS

C Basket Material-Lid Gap

76 8 -1.0000 1 -20 13 -14 IMP:N=1 \$ 1/2 model

C Inner Barrier

77 5 -8.4425 1 3 20 -21 -14 IMP:N=1 \$ 1/2 model

C Inner Lid

78 5 -8.4425 1 14 -15 -21 IMP:N=1 \$ 1/2 model

C Gap between Inner and Outer Barrier Lids

79 8 -1.0000 1 15 -16 -21 IMP:N=1 \$ 1/2 model

C Gap between Inner and Outer Barriers

80 8 -1.0000 21 -22 1 3 -16 IMP:N=1 \$ 1/2 model

C Outer Barrier

81 7 -7.8320 22 -24 1 3 -16 IMP:N=1 \$ 1/2 model

C Outer Barrier Lid

82 7 -7.8320 1 -24 16 -17 IMP:N=1 \$ 1/2 model

C 12" of Water around Container

83 8 -1.0000 24 -25 1 3 -17 IMP:N=1 \$ 1/2 model

C 12" of Water above Container

84 8 -1.0000 17 -19 1 -25 IMP:N=1 \$ 1/2 model

C OUTSIDE WORLD

85 0 -1:-3:19:25 IMP:N=0 \$ 1/2 model

C WET w/ Fe2O3 PIN LATTICE

86 1 -3.4592 -26 27 -28 29 IMP:N=1 LAT=1 U=56
FILL -8:8 -8:8 0:0 56 16R 56 2 14R 56 56 2 14R 56
56 2 4R 4 2 2R 4 2 4R 56
56 2 2R 4 2 6R 4 2 2R 56 56 2 14R 56
56 2 2 4 2 2 4 2 2R 4 2 2 4 2 2 56
56 2 14R 56
56 2 6R 6 2 6R 56
56 2 14R 56
56 2 2 4 2 2 4 2 2R 4 2 2 4 2 2 56
56 2 14R 56 56 2 2R 4 2 6R 4 2 2R 56
56 2 4R 4 2 2R 4 2 4R 56
56 2 14R 56 56 2 14R 56 56 16R

C Water LATTICE

87 8 -1.0000 -58 56 -59 57 IMP:N=1 U=58

C WET PIN LATTICE

88 8 -1.0000 -26 27 -28 29 IMP:N=1 LAT=1 U=57
FILL -8:8 -8:8 0:0 57 16R 57 3 14R 57 57 3 14R 57
57 3 4R 5 3 2R 5 3 4R 57
57 3 2R 5 3 6R 5 3 2R 57 57 3 14R 57
57 3 3 5 3 3 5 3 2R 5 3 3 5 3 3 57
57 3 14R 57
57 3 6R 7 3 6R 57
57 3 14R 57
57 3 3 5 3 3 5 3 2R 5 3 3 5 3 3 57
57 3 14R 57 57 3 2R 5 3 6R 5 3 2R 57
57 3 4R 5 3 2R 5 3 4R 57
57 3 14R 57 57 3 14R 57 57 16R

C WET W/ Fe2O3 FUEL ROD

89 2 6.982783E-02 -30 -10 IMP:N=1 U=2

90 4 -6.5600 -30 10 -11 IMP:N=1 U=2

91 1 -3.4592 -30 11 IMP:N=1 U=2

92 8 -1.0000 30 -31 -11 IMP:N=1 U=2

93 1 -3.4592 30 -31 11 IMP:N=1 U=2

94 4 -6.5600 31 -32 -11 IMP:N=1 U=2

95 1 -3.4592 31 -32 11 IMP:N=1 U=2

96 1 -3.4592 32 IMP:N=1 U=2

C Wet FUEL ROD

97 2 6.982783E-02 -30 -10 IMP:N=1 U=3

98 4 -6.5600 -30 10 -11 IMP:N=1 U=3

```

99  8 -1.0000 -30 11 IMP:N=1 U=3
100 8 -1.0000 30 -31 -11 IMP:N=1 U=3
101 8 -1.0000 30 -31 11 IMP:N=1 U=3
102 4 -6.5600 31 -32 -11 IMP:N=1 U=3
103 8 -1.0000 31 -32 11 IMP:N=1 U=3
104 8 -1.0000 32 IMP:N=1 U=3
C WET w/ Fe203 CONTROL ROD/GUIDE TUBE
105 8 -1.0000 -33 IMP:N=1 U=4 $ No DCRA Rod
C 105 9 -7.8300 -33 IMP:N=1 U=4 $ DCRA Rod
106 1 -3.4592 33 -34 IMP:N=1 U=4
107 1 -3.4592 34 -35 IMP:N=1 U=4 $ No DCRA Cladding
C 107 4 -6.5600 34 -35 IMP:N=1 U=4 $ DCRA Cladding
108 1 -3.4592 35 -36 IMP:N=1 U=4
109 4 -6.5600 36 -37 IMP:N=1 U=4
110 1 -3.4592 37 IMP:N=1 U=4
C Wet CONTROL ROD/GUIDE TUBE
111 8 -1.0000 -33 IMP:N=1 U=5 $ No DCRA Rod
C 111 9 -7.8300 -33 IMP:N=1 U=5 $ DCRA Rod
112 8 -1.0000 33 -34 IMP:N=1 U=5
113 8 -1.0000 34 -35 IMP:N=1 U=5 $ No DCRA Cladding
C 113 4 -6.5600 34 -35 IMP:N=1 U=5 $ DCRA Cladding
114 8 -1.0000 35 -36 IMP:N=1 U=5
115 4 -6.5600 36 -37 IMP:N=1 U=5
116 8 -1.0000 37 IMP:N=1 U=5
C WET w/ Fe203 INSTRUMENTATION TUBE
117 8 -1.0000 -38 IMP:N=1 U=6
118 4 -6.5600 38 -39 IMP:N=1 U=6
119 1 -3.4592 39 IMP:N=1 U=6
C Wet INSTRUMENTATION TUBE
120 8 -1.0000 -38 IMP:N=1 U=7
121 4 -6.5600 38 -39 IMP:N=1 U=7
122 8 -1.0000 39 IMP:N=1 U=7
C WET w/ Partial Fe203 PIN LATTICE
123 1 -3.4592 -26 27 -28 29 IMP:N=1 LAT=1 U=59
FILL -8:8 -8:8 0:0 59 16R 59 2 14R 59 59 2 14R 59
59 2 4R 4 2 2R 4 2 4R 59
59 2 2R 4 2 6R 4 2 2R 59 59 2 14R 59
59 2 2 4 2 2 4 2 2R 4 2 2 4 2 2 59
59 2 14R 59
59 2 6R 6 2 6R 59
59 3 14R 59
59 3 3 5 3 3 5 3 2R 5 3 3 5 3 3 59
59 3 14R 59 59 3 2R 5 3 6R 5 3 2R 59
59 3 4R 5 3 2R 5 3 4R 59
59 3 14R 59 59 3 14R 59 59 16R
C Half Water/Half Fe203 LATTICE
124 8 -1.0000 -58 56 -59 66 IMP:N=1 U=60
125 1 -3.4592 -58 56 -66 57 IMP:N=1 U=60
C SURFACE SPECIFICATIONS
1* PX 0.0
3* PZ 0.00
10 PZ 180.0860 $ TOP ACTIVE FUEL
11 PZ 201.2360 $ TOP FUEL HARDWARE
C 12 PZ 226.75 $ TOP TUBE - (Shielding Model)
13 PZ 228.75 $ TOP OF BASKET MATERIAL
14 PZ 229.25 $ TOP RING/WATER GAP
15 PZ 231.75 $ TOP INNER LID
16 PZ 234.75 $ TOP LID GAP
17 PZ 245.75 $ TOP OUTER LID
C 18 PZ 268.25 $ TOP SKIRT - (Shielding Model)
19 PZ 298.75 $ TOP REFLECTOR REGION
20 CZ 71.095 $ ID OF INNER BARRIER
21 CZ 73.095 $ OD OF INNER BARRIER
22 CZ 73.10 $ ID OF OUTER BARRIER
C 23 CZ 76.45 $ ID OF SKIRT LIP - (Shielding Model)
24 CZ 83.10 $ OD OF OUTER BARRIER
25 CZ 113.60 $ OD OF REFLECTOR REGION
C PIN LATTICE BOUNDS
26 PX 0.72136

```



```

27 PX -0.72136
28 PY 0.72136
29 PY -0.72136
C FUEL ROD
30 CZ 0.468122
31 CZ 0.478790
32 CZ 0.546100
C CONTROL ROD/GUIDE TUBE
33 CZ 0.45340 $ 0.49022
34 CZ 0.46990 $ 0.50292
35 CZ 0.54610 $ 0.56007
36 CZ 0.62230 $ 0.63246
37 CZ 0.67310
C INSTRUMENTATION TUBE
38 CZ 0.56007
39 CZ 0.62611
C ASSEMBLY LATTICE BOUNDS Actual
56 PX -11.95 $ UCF Intact Outside Tube ID
57 PY -11.95
58 PX 11.95
59 PY 11.95
C FUEL CELL LATTICE BOUNDS
60 PX -10.65 $ ACTUAL 12.30
61 PX 10.65
62 PY -10.65
63 PY 10.65
C plane for half water/half oxide lattice cell
66 PY 0.72136

MODE N
C VOL 88J
KCODE 4000 1.01 10 400
C MATERIAL SPECIFICATIONS
C WATER AT 300 K d=3.4592 g/cc w/ 58% Fe2O3
M1 1001.50C 2.8089-2 8016.50C 4.8430-2 26000.55C 2.2924-2
MT1 LWTR.01T
C e49b34.sum 25000 years decay
M2 8016.50C .046947
42095.50C 4.794679E-05
44101.50C 4.354501E-05
43099.50C 4.284296E-05
45103.50C 2.608717E-05
47109.50C 3.714096E-06
60143.50C 3.74851E-05
60145.50C 2.799527E-05
62147.50C 1.138963E-05
62149.50C 1.455085E-07
62150.50C 1.043884E-05
62152.50C 4.59594E-06
63151.55C 8.136066E-07
63153.55C 3.93607E-06
64155.50C 1.686186E-07
92233.50C 3.326725E-07
92234.50C 1.018437E-05
92235.50C 5.531404E-04
92236.50C 1.774777E-04
92238.50C 2.174501E-02
93237.55C 4.392789E-05
94239.55C 7.906197E-05
94240.50C 3.440139E-06
94241.50C 2.761636E-12
94242.50C 7.012276E-06
95241.50C 8.639479E-11
95243.50C 1.386765E-07
C Air d=0.001225 g/cc
M3 7014.50C -0.80 8016.50C -0.20
C ZIRCALOY-4 d=6.56 g/cc
M4 8016.50C -0.0012 24000.50C -0.0010 26000.55C -0.0020
40000.50C -0.9818 50000.35C -0.0140
C ALLOY 625 d=8.4425 g/cc

```

M5 6000.50C -0.1000 13027.50C -0.4000 14000.50C -0.5000
16032.50C -0.0150 22000.50C -0.4000 24000.50C -21.500
25055.50C -0.5000 26000.55C -5.0000 28000.50C -58.000
41093.50C -1.8200 42000.50C -9.0000 73181.50C -1.8200
15031.50C -0.0150 27059.50C -0.9300
C A516 CARBON STEEL $\rho=7.832$ g/cc
M7 6000.50C -0.00220 14000.50C -0.002750 15031.50C -0.00035
16032.50C -0.00035 25055.50C -0.0090
26000.55C -0.98535
C WATER AT 300 K $\rho=1.0000$ g/cc
M8 1001.50C 2. 8016.50C 1.
MT8 LWTR.01T
C TALLIES
PRINT

1 primary module access and input record (scale driver - 95/03/29 - 09:06:37)
 - module sas2h will be called

SAS2H: 4.9wt%, 346WD/MTU, 25000yr, Waste-Pack Buckling Model

Iron (Fe2O3) rust in the water around the fuel pins 58 vol. %

Blending from MCNP = 0.751311 water + .248689 rusty water

B & W 15x15 fuel assembly, high temp burnup

44group latticell

MCNP input mixtures for fuel-pin-cell, assembly-cell, and waste package

| | |
|--------|----------------------------|
| o | 1 0 4.694700-02 300.00 end |
| u-233 | 1 0 3.326725-07 300.00 end |
| u-234 | 1 0 1.018437-05 300.00 end |
| u-235 | 1 0 5.531404-04 300.00 end |
| u-236 | 1 0 1.774777-04 300.00 end |
| u-238 | 1 0 2.174501-02 300.00 end |
| np-237 | 1 0 4.392789-05 300.00 end |
| pu-239 | 1 0 7.906197-05 300.00 end |
| pu-240 | 1 0 3.440139-06 300.00 end |
| pu-241 | 1 0 2.761636-12 300.00 end |
| pu-242 | 1 0 7.012276-06 300.00 end |
| am-241 | 1 0 8.639479-11 300.00 end |
| am-243 | 1 0 1.386765-07 300.00 end |
| mo-95 | 1 0 4.794679-05 300.00 end |
| tc-99 | 1 0 4.284296-05 300.00 end |
| ru-101 | 1 0 4.354501-05 300.00 end |
| rh-103 | 1 0 2.608717-05 300.00 end |
| ag-109 | 1 0 3.714096-06 300.00 end |
| nd-143 | 1 0 3.748510-05 300.00 end |
| nd-145 | 1 0 2.799527-05 300.00 end |
| sm-147 | 1 0 1.138963-05 300.00 end |
| sm-149 | 1 0 1.455085-07 300.00 end |
| sm-150 | 1 0 1.043884-05 300.00 end |
| sm-152 | 1 0 4.595940-06 300.00 end |
| eu-151 | 1 0 8.136066-07 300.00 end |
| eu-153 | 1 0 3.936070-06 300.00 end |
| gd-155 | 1 0 1.686186-07 300.00 end |
| kr-83 | 1 0 1-20 300.00 end |
| kr-85 | 1 0 1-20 300.00 end |
| y-89 | 1 0 1-20 300.00 end |
| sr-90 | 1 0 1-20 300.00 end |
| zr-93 | 1 0 1-20 300.00 end |
| zr-94 | 1 0 1-20 300.00 end |
| zr-95 | 1 0 1-20 300.00 end |
| nb-94 | 1 0 1-20 300.00 end |
| ru-106 | 1 0 1-20 300.00 end |
| rh-105 | 1 0 1-20 300.00 end |
| pd-105 | 1 0 1-20 300.00 end |
| pd-108 | 1 0 1-20 300.00 end |
| sb-124 | 1 0 1-20 300.00 end |
| xe-131 | 1 0 1-20 300.00 end |
| xe-132 | 1 0 1-20 300.00 end |
| xe-135 | 1 0 1-20 300.00 end |
| xe-136 | 1 0 1-20 300.00 end |
| cs-134 | 1 0 1-20 300.00 end |
| cs-135 | 1 0 1-20 300.00 end |
| cs-137 | 1 0 1-20 300.00 end |
| ba-136 | 1 0 1-20 300.00 end |
| la-139 | 1 0 1-20 300.00 end |
| pr-141 | 1 0 1-20 300.00 end |
| pr-143 | 1 0 1-20 300.00 end |
| nd-147 | 1 0 1-20 300.00 end |
| ce-144 | 1 0 1-20 300.00 end |
| pm-147 | 1 0 1-20 300.00 end |
| pm-148 | 1 0 1-20 300.00 end |
| eu-154 | 1 0 1-20 300.00 end |

```

eu-155      1 0 1-20      300.00 end
-----
/
/ Homogenized zirc-4 clad and water gap
/
/ water - o 2 0 4.27077-03 300.00 end
/ zirc4 - o 2 0 2.602667-04 300.00 end
/
/ h      2 0 8.54154-03 300.00 end
/ o      2 0 4.52929-03 300.00 end
/ cr     2 0 6.62716-05 300.00 end
/ fe     2 0 1.23407-04 300.00 end
/ zr     2 0 3.70866-02 300.00 end
/ arbm-sn 5.7221016 1 0 0 0 50000 100.0
/         2 0 0.013999775 300.00 end
/
/ sn      2 0 4.06386-04 300.00 end
-----
/
/ Moderator around fuel pins and guide tubes
/
/ Assembly with iron
/
/ h      3 0 2.8089-02 300.00 end
/ o      3 0 4.8430-02 300.00 end
/ fe     3 0 2.2924-02 300.00 end
/
/ MCNP K-inf blended iron assembly
/
/ Contains (1-x) 58 vol% Fe2O3 water and x pure water
/ with x=0.734106 from blending equation
/
/ h      3 0 5.72276-02 300.00 end
/ o      3 0 3.71651-02 300.00 end
/ fe     3 0 5.70095-03 300.00 end
/
/ 0 ppm boron
-----
/
/ Zirc-4
/
/ o      4 0 2.98378-04 300.00 end
/ cr     4 0 7.59759-05 300.00 end
/ fe     4 0 1.41478-04 300.00 end
/ zr     4 0 4.25173-02 300.00 end
/ arbm-sn 6.5600 1 0 0 0 50000 100.0
/         4 0 0.013999775 300.00 end
/
/ sn      4 0 4.65894-04 300.00 end
-----
/
/ Water region inside of the guide tubes
/
/ o      5 0 3.34363-02 300.00 end
/ h      5 0 6.68727-02 300.00 end
/
/ 0 ppm boron
-----
/
end comp
-----
/
/ fuel - pin - cell geometry:
/
/ Water - Zirc-4 homogenized for water in gap
/
/ MCNP assembly pitch = 10.65 + 10.65 = 21.30
/
/ 21.30/15(pin-cells) = 1.42 pin-cell pitch
/

```

```
squarepitch 1.42000 0.936244 1 3 1.0922 2 0.936245 0 end
/
/ Standard pin-cell pitch = 1.44272
/
squarepitch 1.44272 0.936244 1 3 1.0922 2 0.936245 0 end
/
/ Standard gap with gas and standard clad
/
squarepitch 1.44272 0.936244 1 3 1.0922 2 0.95758 0 end
/-----/
/
/ Pin-cell buckling
/
more data bkl=0.875108 dy=50.7843927
dz=360.172 end
/-----/
/
/ assembly and cycle parameters
/
/ guide tube region is different
/
npin/assm=208 fuelngth=360.172 ncycles=1 nlib/cyc=1
printlevel=7 inplevel=3 numxtotal=6 end
5 0.453400 2 0.453401 3 0.622300
4 0.6736472448 3 0.8011492 500 2.9146084
/
/ Assembly buckling
/
bon end
nit end
xsd
SAS2H: 4.9wt%, 34GWD/MTU, 25000yr, Inf-Assem, No iron
x5= 1.0-4 1.0-4 1.0 0.0 0.0 0.875108
50.7843927 360.172 0.0 1.0 1.0-3 0.75
end
power=7.25 burn=1.0-20 down=1.0-20
end
```

Size of small spherical particle required to fall 1 meter in 1 minute in water

$$\text{Density of water at } 120^{\circ}\text{F} \quad \rho_f = 988.8 \frac{\text{kg}}{\text{m}^3}$$

$$\text{Viscosity of water at } 120^{\circ}\text{F} \quad \mu = 5.62 \cdot 10^{-4} \frac{\text{kg}}{\text{m} \cdot \text{sec}}$$

$$\text{Density of } \text{Fe}_2\text{O}_3 \quad \rho_s = 5240 \frac{\text{kg}}{\text{m}^3}$$

Terminal velocity as a function of diameter for small sphere's using Stoke's law ($Re \leq 1$)

$$F_d = m \cdot g - F_b$$

$$3 \cdot \pi \cdot \mu \cdot v \cdot D = \rho_s \cdot \frac{4}{3} \cdot \pi \cdot \left(\frac{D}{2}\right)^3 \cdot g - \rho_f \cdot g \cdot \frac{4}{3} \cdot \pi \cdot \left(\frac{D}{2}\right)^3$$

From Fox, R.W., McDonald, A.T., *Introduction to Fluid Mechanics*, 3rd Edition, John Wiley & Sons, 1985, p. 461

Solving for v yields

$$v(D) := \frac{1}{18} \cdot D^2 \cdot g \cdot \frac{(\rho_s - \rho_f)}{\mu}$$

$$Re(D) = \frac{v(D) \cdot D \cdot \rho_f}{\mu}$$

$$\frac{1 \cdot \text{m}}{v(.063 \cdot \text{mm})} = 1.019 \cdot \text{min}$$

$$Re(.063 \cdot \text{mm}) = 1.813$$

However, a 0.063 mm diameter sphere at terminal velocity slightly outside of the range of Stoke's law (drag will be slightly higher and particle will fall slightly slower than indicated).

Note that typical crud particle sizes are in the range of 0.1 to 10 microns per *Characteristics of Repository Wastes*, DOE/RW-0184 vol. 1, p. 2.6-6

$$\frac{1 \cdot \text{m}}{v(.010 \cdot \text{mm})} = 40.441 \cdot \text{min}$$

$$Re(.010 \cdot \text{mm}) = 7.251 \cdot 10^{-3}$$

```
= relap5/mod2 waste package (b & w 15 by 15 21 fa)
*-----
*
*
* ( this is /kappa/jrw/lv/relap/r5wp2d.in
*
* the input is a transition from tmi-1 power uprate lbloca
* to waste package (near field) criticality excursion consequences
* with 4.90 wt.% u-235 , 34,000 mwd/mtu burnup and 25,000 year decay
*
* b & w heavy isotope actinide contribution )
*
*----- base model description -----
*
* fti document 32-124460-00
* by: ks pacheco
*
* the base deck for the tmi-1 model was taken from 2772base1.in
* contained in 32-1234886-00. /kappa/ksp/tmipug/base/tmibase.in
*
* 21fa, 208-pins/fa, 16-guide tubes/fa, 1-instrument tube/fa
* one-fifth length model - Power into Assembly is 5 Watts
* for Full Length assemblies
*
*-----
*
* deck obtained from tuck w. (lynchburg) 07/31/97
* 07/31/97 modification - jam (lv)
* delete most of the $$$ cards from deck
* convert to mod3 format
* junction control flag - change from 3xxxx to 0xxxx
* no horizontal stratification
* heat structure cards ...8xx and ...9xx - CHF Changes
* MOD2 - 5 wds, MOD3 - 9 wds
* add Time-Dependent Vol and Time-Dependent Junction to input
* Inflow Conditions
* Add Minor Edits
*
* Case 001 Using small time steps to make sure case runs ok
* Case 002 Match Tuck Worsham's data (Fax memo - 08/04/97)
* Case 003 Use short time steps through power peak
* Case 004 Add Doppler Weight Factors to activate Fuel Temp Feedback
* B&W Relap5 has been modified to compute Doppler Weights
* internally if none supplied.
* Add Avg-Fuel Temp To Minor Edits
* Add variable Void Weight Factors proportional to Control
* Volume relative size
* Case 005 Rerun Case C003 with Doppler Weights
* Case 006 Add Reactivity Control Blocks to Edit Components to Case 004
* Case 101 Switch to Implicit Numerics
* Shorten time steps to avoid zero mass in control volumes
* around 5.8 sec, turn on the choking model for junctions in
* non-fuelled volumes.
* Case 111 Similar to Case 101: reduce reactivity ramp by 50%;
* increase refill rate by 50%;
* change minor edits;
* adjust minor edit frequencies to 0.05 sec
*
* Case 102 Try Case 101 with automatic T.S. control to cut down on
* number of minor edit points
* Redo case 102 to include fission and decay heat power,
* add reactivity table vs mixture level
* Case 102a review short T.S. case again
* 102b check for T.S. convergence (more stable than case 102a)
* 102c check further for T.S. convergence
* 103a actually add mixture level calc - limit to top fuelled row
* delete void reactivity table
* 103b 08/20/97 - revise case c103a and rerun
* revise MCNP void reactivity table to use delta rho
* and include all restart time steps, remove mixture level flgs
* 103c reinstate the mixture level model in vols 21001, 05001, 10001,
```

```

*          20001
*
*-----*
*
100 new transnt
101 run
* 101 inp-chk
102 british british
105 150. 160.
*
* noncondensable gas
110 "nitrogen"
*
*-----*
*
* time step control
*   end   min   max   time minor major restart
*   time delt time step edit edit point
*   (sec) (sec) step optn freq freq freq
*
* Case 103a time steps
201 0.1      1.0-8 1.0-4 07 100 1000 1000
202 1.5      1.0-8 1.0-3 07 100 100 100
203 4.0      1.0-8 5.0-5 07 1000 10000 10000
204 20.0     1.0-8 5.0-5 07 10000 20000 20000
*
* Case c103a.rst01 time steps
205 30.0     1.0-8 5.0-5 07 10000 20000 20000
*
* Case c103a.rst02 time steps
206 40.0     1.0-8 1.0-4 07 1000 10000 10000
*
* Case c103a.rst03 time steps
207 80.0     1.0-8 1.0-4 07 1000 10000 10000
*
* Case c103a.rst04 time steps
208 360.0    1.0-8 1.0-3 07 1000 10000 10000
*
* Case c103a.rst05 time steps
209 1800.0   1.0-8 1.0-2 07 200 1000 1000
*
*-----*
*
*          general tables
*
*-----*
*
* reactivity insertion
*
20200100 reac-t
20200101 0.0 0.0 30.0 14.18 1.0+10 14.18
* 20200101 0.0 0.0 30.0 7.09 1.0+10 7.09
*
*
* average fuel temperature vs. reactivity
*
20200200 reac-t
*
*          fuel temp. K          reactivity, dollars          density lb/ft**3
*
20200201 273.16          +0.1719079
20200202 300.01          +0.1719079
20200203 323.16          0.0
20200204 373.16          -0.3488604
20200205 433.16          -0.7295469
20200206 543.16          -1.3918144

```


20200207 813.16 -2.8696928

*
* moderator density reactivity feedback
*

20200500 reac-t

| | density kg/m**3 | reactivity, dollars | fuel temp. f |
|----------|-----------------|---------------------|--------------|
| 20200501 | 701.470834 | -22.8341124 | * 1004 |
| 20200502 | 726.523364 | -20.0375898 | * 1004 |
| 20200503 | 751.575895 | -17.4413905 | * 1004 |
| 20200504 | 776.628425 | -15.0255317 | * 1004 |
| 20200505 | 801.680954 | -12.7766726 | * 1004 |
| 20200506 | 826.733484 | -10.6782739 | * 1004 |
| 20200507 | 851.786013 | -08.7187079 | * 1004 |
| 20200508 | 876.838543 | -06.8856192 | * 1004 |
| 20200509 | 901.891072 | -05.1688975 | * 518 |
| 20200510 | 921.933098 | -03.9010990 | * 518 |
| 20200511 | 941.975121 | -02.6972060 | * 518 |
| 20200512 | 960.112521 | -01.6592902 | * 518 |
| 20200513 | 975.044461 | -00.8234196 | * 212 |
| 20200514 | 990.260409 | 00.00 | * 122 |
| 20200515 | 1002.101192 | +00.6225345 | * 122 |
| 20200516 | 1043.387881 | +00.6225345 | * 80.33 |

*
* MCNP mixture level reactivity table (beta = 0.005)
* Row 5 of fueled assemblies
* Ref: W.D. reactor physics book + J. Massari Doc
*

| | Mixture level (ft) | Reactivity (\$) |
|--|--------------------|-----------------|
|--|--------------------|-----------------|

20201000 reac-t

| | | |
|----------|---------|---------|
| 20201001 | 0.0 | -30.902 |
| 20201002 | 0.04399 | -30.902 |
| 20201003 | 0.18933 | -16.660 |
| 20201004 | 0.23657 | -14.959 |
| 20201005 | 0.28415 | -12.911 |
| 20201006 | 0.71 | 0.0 |

*
* minor edits
*

*
* pressure
*

| | | | |
|-----|-----|-----------|----------------|
| 301 | "p" | 150010000 | * Vol Pressure |
| 302 | "p" | 060010000 | * Vol Pressure |
| 303 | "p" | 070010000 | * Vol Pressure |
| 304 | "p" | 080010000 | * Vol Pressure |
| 305 | "p" | 090010000 | * Vol Pressure |
| 306 | "p" | 100010000 | * Vol Pressure |
| 307 | "p" | 250010000 | * Vol Pressure |

*
* enthalpy
*

| | | | |
|-----|---------|-----------|----------------|
| 315 | "hvmix" | 090010000 | * Vol Enthalpy |
| 317 | "hvmix" | 250010000 | * Vol Enthalpy |

*
* volume vapor generation/unit vol
*

| | | | |
|-----|----------|-----------|----------------------|
| 321 | "vapgen" | 150010000 | * Vol vapor gen rate |
| 322 | "vapgen" | 060010000 | * Vol vapor gen rate |

```

323 "vapgen" 070010000 * Vol vapor gen rate
324 "vapgen" 080010000 * Vol vapor gen rate
325 "vapgen" 090010000 * Vol vapor gen rate
326 "vapgen" 100010000 * Vol vapor gen rate
*
*
* Volume Mass
*
329 "tmass" 0 * Fluid Inventory
330 "tmassv" 260010000 * Vol Mass
331 "tmassv" 150010000 * Vol Mass
332 "tmassv" 060010000 * Vol Mass
333 "tmassv" 070010000 * Vol Mass
334 "tmassv" 080010000 * Vol Mass
335 "tmassv" 090010000 * Vol Mass
336 "tmassv" 100010000 * Vol Mass
337 "tmassv" 220010000 * Vol Mass
338 "tmassv" 230010000 * Vol Mass
339 "tmassv" 240010000 * Vol Mass
340 "tmassv" 250010000 * Vol Mass
*
* mass flow
*
341 "mflowj" 080010000 * Jun Flow
342 "mflowj" 080020000 * Jun Flow
343 "mflowj" 070010000 * Jun Flow
344 "mflowj" 070020000 * Jun Flow
345 "mflowj" 240010000 * Jun Flow
346 "mflowj" 230010000 * Jun Flow
347 "mflowj" 230020000 * Jun Flow
348 "mflowj" 250010000 * Jun Flow
349 "mflowj" 220010000 * Jun Flow
351 "mflowj" 220020000 * Jun Flow
352 "mflowj" 020010000 * Jun Flow
353 "mflowj" 020020000 * Jun Flow
*
*
* average fuel temperature
*
361 "htvat" 3301008 * Avg Metal Temp
*
* control variables
*
* kinetics parameters
*
389 "rkfipow" 0 * "fission" "power"
390 "rkgapow" 0 * "decay heat" "power"
391 "rkreac" 0 * "total" "reactivi"
392 "cntrlvar" 081 * "MCNP void Reactivity"
393 "cntrlvar" 014 * "doppler reac"
394 "cntrlvar" 056 * "void reactivity"
395 "cntrlvar" 060 * "ramp reactivity"
396 "cntrlvar" 065 * "total calc reac"
397 "cntrlvar" 070 * "assembly energy"
398 "cntrlvar" 075 * "Sum (Heat slab vapor gen rate)"
*
*
*-----*
*
* waste package
*
* modeling begins with central planar region
*
*-----*
*
* bottom of cylinder
*

```

```

1400000 "bot-watr" "branch"
* no. of jun jun cntrl
1400001 2 0
* aflow(norm) len vol angle(az) inclin elev change
1400101 0.00 .2293299 .2075716 0.0 -90.0 -.2293299
* wall rough hyd dia cntrl
1400102 4.1667-5 1.0+10 00
* vol cntrl press temp
1400200 003 14.696 122.00
* from vol to vol a(jun) k(f) k(r) jun cntrl
1401101 140000000 010010000 .2038375 72.0 72.0 01000
* liq vel vap vel interface vel
1401201 0.0 0.0 0.0
* from vol to jun a(jun) k(f) k(r) jun cntrl
1402101 140000000 150000000 .5419829 0.0 0.0 01003
* liq vel vap vel interface vel
1402201 0.0 0.0 0.0
*
* bottom side of cylinder
*
1500000 "bos-watr" "branch"
1500001 1 0
1500101 0.00 .2293299 .2276341 0.0 -90.0 -.2293299
* cntrl (therm-off, mix-off, pack-on,
* vert strat-on, interphase fric-pipe,
* wall-xdir, non-eq)
1500102 4.1667-5 1.0+10 0000000
1500200 003 14.696 122.00
1501101 150000000 060010000 .4076750 72.0 72.0 01000
1501201 0.0 0.0 0.0
*
* side of cylinder fuel level 1
*
1600000 "s1-watr" "branch"
1600001 1 0
1600101 0.00 .71 .7989270 0.0 -90.0 -.71
1600102 4.1667-5 1.0+10 00
1600200 003 14.696 122.00
1601101 160000000 110010000 .4076750 72.0 72.0 01000
1601201 0.0 0.0 0.0
*
* side of cylinder fuel level 2
*
1700000 "s2-watr" "branch"
1700001 1 0
1700101 0.00 .71 .5438773 0.0 -90.0 -.71
1700102 4.1667-5 1.0602200 00
1700200 003 14.696 122.00
1701101 170000000 180000000 1.1080708 0.0 0.0 01000
1701201 0.0 0.0 0.0
*
* side of cylinder fuel level 3
*
1800000 "s3-watr" "branch"
1800001 1 0
1800101 0.00 .71 .8980821 0.0 90.0 .71
1800102 4.1667-5 2.1134025 00
1800200 003 14.696 122.00
1801101 180010000 190000000 1.3339422 0.0 0.0 01000
1801201 0.0 0.0 0.0
*
* side of cylinder fuel level 4
*
1900000 "s4-watr" "branch"
1900001 1 0
1900101 0.00 .71 .8738187 0.0 90.0 .71
1900102 4.1667-5 2.0432176 00
1900200 003 14.696 122.00
1901101 190010000 210000000 1.0380308 0.0 0.0 01000
1901201 0.0 0.0 0.0

```

```

*
* side of cylinder - fuel level 5
*
2100000 "s5-watr" "branch"
2100001 1 0
2100101 0.00 .71 .7822260 0.0 90.0 .71
2100102 4.1667-5 1.6252320 0100000
2100200 003 14.696 122.00
* 2101101 210010000 240000000 1.0380308 0.0 0.0 01000
  2101101 210010000 240000000 1.0380308 0.0 0.0 00000
2101201 0.0 0.0 0.0
*
* 21 fuel assemblies
*
* half symmetry gives 13 planar fuel areas
*
* modeling begins with central fuel length,
*
* center fuel column, at the cylinder bottom
*
* hydraulic dia. based on flow around fuel-clad, guide tubes, inst. tube
*
*-----*
*
* column 1
*
0100000 "fuel-010" "branch"
0100001 2 0
0100101 0.00 .71 .3516846 0.0 -90.0 -.71
0100102 3.133-6 .04168514 00
0100200 003 14.696 122.00
0101101 010000000 020010000 .2038375 72.0 72.0 01000
0101201 0.0 0.0 0.0
0102101 010000000 060000000 .4076750 72.0 72.0 01003
0102201 0.0 0.0 0.0
*
0200000 "fuel-020" "branch"
0200001 2 0
0200101 0.00 .71 .3516846 0.0 -90.0 -.71
0200102 3.133-6 .04168514 00
0200200 003 14.696 122.00
0201101 020000000 030000000 .2038375 72.0 72.0 01000
0201201 0.0 0.0 0.0
0202101 020000000 070000000 .4076750 72.0 72.0 01003
0202201 0.0 0.0 0.0
*
0300000 "fuel-030" "branch"
0300001 2 0
0300101 0.00 .71 .3516846 0.0 90.0 .71
0300102 3.133-6 .04168514 00
0300200 003 14.696 122.00
0301101 030010000 040000000 .2038375 72.0 72.0 01000
0301201 0.0 0.0 0.0
0302101 030000000 080000000 .4076750 72.0 72.0 01003
0302201 0.0 0.0 0.0
*
0400000 "fuel-040" "branch"
0400001 2 0
0400101 0.00 .71 .3516846 0.0 90.0 .71
0400102 3.133-6 .04168514 00
0400200 003 14.696 122.00
0401101 040010000 050000000 .2038375 72.0 72.0 01000
0401201 0.0 0.0 0.0
0402101 040000000 090000000 .4076750 72.0 72.0 01003
0402201 0.0 0.0 0.0
*
0500000 "fuel-050" "branch"
0500001 2 0
0500101 0.00 .71 .3516846 0.0 90.0 .71
*
cntrl (therm-off, mix-on, pack-on,

```

```

*
*
*      vert strat-on, interphase fric-pipe,
*      wall-xdir, non-eq)
0500102  3.133-6  .04168514  0100000
0500200  003      14.696      122.00
0501101  050010000 220000000  .2038375  72.0  72.0  01000
0501201  0.0      0.0      0.0
0502101  050000000 100000000  .4076750  72.0  72.0  01003
0502201  0.0      0.0      0.0

```

* column 2

```

*
0600000  "fuel-060" "branch"
0600001  2      0
0600101  0.00    .71      .7033692  0.0  -90.0  -.71
0600102  3.133-6  .04168514  00
0600200  003      14.696      122.00
0601101  060000000 070010000  .4076750  72.0  72.0  01000
0601201  0.0      0.0      0.0
0602101  060000000 160000000  .4076750  72.0  72.0  01003
0602201  0.0      0.0      0.0

```

```

*
0700000  "fuel-070" "branch"
0700001  2      0
0700101  0.00    .71      .7033692  0.0  -90.0  -.71
0700102  3.133-6  .04168514  00
0700200  003      14.696      122.00
0701101  070000000 080000000  .4076750  72.0  72.0  01000
0701201  0.0      0.0      0.0
0702101  070000000 110000000  .4076750  72.0  72.0  01003
0702201  0.0      0.0      0.0

```

```

*
0800000  "fuel-080" "branch"
0800001  2      0
0800101  0.00    .71      .7033692  0.0   90.0   .71
0800102  3.133-6  .04168514  00
0800200  003      14.696      122.00
0801101  080010000 090000000  .4076750  72.0  72.0  01000
0801201  0.0      0.0      0.0
0802101  080000000 120000000  .4076750  72.0  72.0  01003
0802201  0.0      0.0      0.0

```

```

*
0900000  "fuel-090" "branch"
0900001  2      0
0900101  0.00    .71      .7033692  0.0   90.0   .71
0900102  3.133-6  .04168514  00
0900200  003      14.696      122.00
0901101  090010000 100000000  .4076750  72.0  72.0  01000
0901201  0.0      0.0      0.0
0902101  090000000 130000000  .4076750  72.0  72.0  01003
0902201  0.0      0.0      0.0

```

```

*
1000000  "fuel-100" "branch"
1000001  2      0
1000101  0.00    .71      .7033692  0.0   90.0   .71
1000102  3.133-6  .04168514  0100000
1000200  003      14.696      122.00
1001101  100010000 230000000  .4076750  72.0  72.0  01000
1001201  0.0      0.0      0.0
1002101  100000000 200000000  .4076750  72.0  72.0  01003
1002201  0.0      0.0      0.0

```

* column 3

```

*
1100000  "fuel-110" "branch"
1100001  2      0
1100101  0.00    .71      .7033692  0.0  -90.0  -.71

```

```

1100102 3.133-6 .04168514 00
1100200 003 14.696 122.00
1101101 110000000 120000000 .4076750 72.0 72.0 01000
1101201 0.0 0.0 0.0
1102101 110000000 170000000 .4076750 72.0 72.0 01003
1102201 0.0 0.0 0.0
*
1200000 "fuel-120" "branch"
1200001 2 0
1200101 0.00 .71 .7033692 0.0 90.0 .71
1200102 3.133-6 .04168514 00
1200200 003 14.696 122.00
1201101 120010000 130000000 .4076750 72.0 72.0 01000
1201201 0.0 0.0 0.0
1202101 120000000 180000000 .4076750 72.0 72.0 01003
1202201 0.0 0.0 0.0
*
1300000 "fuel-130" "branch"
1300001 2 0
1300101 0.00 .71 .7033692 0.0 90.0 .71
1300102 3.133-6 .04168514 00
1300200 003 14.696 122.00
1301101 130010000 200000000 .4076750 72.0 72.0 01000
1301201 0.0 0.0 0.0
1302101 130000000 190000000 .4076750 72.0 72.0 01003
1302201 0.0 0.0 0.0
*
* water - column 3
*
*-----*
*
2000000 "ts-watr" "branch"
2000001 2 0
2000101 0.00 .71 .8633786 0.0 90.0 .71
2000102 4.1667-5 1.0+10 0100000
2000200 003 14.696 122.00
* 2001101 200010000 240000000 .7540857 0.0 0.0 01000
  2001101 200010000 240000000 .7540857 0.0 0.0 00000
2001201 0.0 0.0 0.0
* 2002101 200000000 210000000 1.7958536 0.0 0.0 01003
  2002101 200000000 210000000 1.7958536 0.0 0.0 00003
2002201 0.0 0.0 0.0
*
* top of cylinder
*
*
* three water columns
*
*
2200000 "c1-watr" "branch"
2200001 2 0
2200101 0.00 .3484394 .8633786 0.0 90.0 .3484394
2200102 4.1667-5 1.0+10 00
2200200 003 14.696 122.00
* 2201101 220010000 250000000 .2038375 0.0 0.0 01000
  2201101 220010000 250000000 .2038375 0.0 0.0 00000
2201201 0.0 0.0 0.0
* 2202101 220000000 230000000 .8234784 0.0 0.0 01003
  2202101 220000000 230000000 .8234784 0.0 0.0 00003
2202201 0.0 0.0 0.0
*
2300000 "c2-watr" "branch"
2300001 2 0
2300101 0.00 .3484394 .8633786 0.0 90.0 .3484394
2300102 4.1667-5 1.0+10 00
2300200 003 14.696 122.00
* 2301101 230010000 250000000 .4076750 0.0 0.0 01000
  2301101 230010000 250000000 .4076750 0.0 0.0 00000
2301201 0.0 0.0 0.0
* 2302101 230000000 240000000 .8234784 0.0 0.0 01003

```

```

2302101 230000000 240000000 .8234784 0.0 0.0 00003
2302201 0.0 0.0 0.0
*
2400000 "c3-watr" "branch"
2400001 1 0
2400101 0.00 .3484394 .4918077 0.0 90.0 .3484394
2400102 4.1667-5 1.6908844 00
2400200 003 14.696 122.00
* 2401101 240010000 250000000 .9732914 0.0 0.0 01000
  2401101 240010000 250000000 .9732914 0.0 0.0 00000
2401201 0.0 0.0 0.0
*
* top plenum
*
2500000 "tp-watr" "branch"
2500001 1 0
2500101 0.00 .5249344 1.2517607 0.0 90.0 .5249344
2500102 4.1667-5 1.3256083 00
2500200 003 14.696 122.00
* 2501101 250010000 260000000 .1076391 0.0 0.0 01000
  2501101 250010000 260000000 .1076391 0.0 0.0 00000
2501201 0.0 0.0 0.0
*
* outside of waste package,
*
* drift at 14.696 psia
*
2600000 "drift" "tmdpv01"
2600101 238.46 1.0 0.0 0.0 90.0 1.0 1.0e-6 0.0 0010
2600200 003
2600201 0.0 14.696 220.00
*
* drift inflow volume
*
3600000 "gnd-watr" "tmdpv01"
3600101 238.46 1.0 0.0 0.0 90.0 1.0 1.0e-6 0.0 0010
3600200 103
3600201 0.0 14.696 122.0
*
* Time-Dependent Junction for inflow
*
3700000 "in-flow" "tmdpj01"
3700101 360010000 250000000 1.0
3700200 1 0
3700201 0.0 1.381e-3 0.0 0.0
* 3700201 0.0 2.762e-3 0.0 0.0
*
*****
***
***
*** heat structure input
***
***
*****
*
* waste package wall
*
13121000 9 20 1 1 0.0
13121100 0 2
13121101 10.0 19
13121201 6 19
13121301 0.0 19
13121400 0
13121401 122. 20
13121501 140010000 10000000 1 1 1.73 9
13121601 0 0 0 1 1.73 9
13121701 0 0.0 0.0 0.0 9
* 13121801 0 0.0 0.0 0.0 9
* 13121901 0 0.0 0.0 0.0 9

```

13121801 0.0 10.0 10.0 0.0 0.0 0.0 0.0 1.0 9
 13121901 0.0 10.0 10.0 0.0 0.0 0.0 0.0 1.0 9

* fuel assembly clad, guide tubes, & inst-tube in fuel region

*
 13481000 13 3 2 1 0.01570833
 13481100 0 1
 13481101 2 0.01791112
 13481201 5 2
 13481301 0.0 2
 13481400 0
 13481401 122. 3
 *
 225 *2.3633333 = 531.75 ft
 112.5*2.3633333 = 265.875 ft
 13481501 010010000 10000000 1 1 265.8750 5
 13481502 060010000 10000000 1 1 531.7500 13
 13481601 010010000 10000000 1 1 265.8750 5
 13481602 060010000 10000000 1 1 531.7500 13
 13481701 0 0.0 0.0 0.0 13
 * 13481801 0 0.0 0.0 0.0 13
 * 13481901 0 0.0 0.0 0.0 13
 13481801 0.0 10.0 10.0 0.0 0.0 0.0 0.0 1.0 13
 13481901 0.0 10.0 10.0 0.0 0.0 0.0 0.0 1.0 13
 * 13481801 0 0.05360754 0.05360754 0.0 13
 * 13481901 0 0.04701465 0.04701465 0.0 13
 *

* fuel assembly pellets - water in gap region

*
 13301000 13 10 2 1 0.0
 13301100 0 1
 * 13301101 6 0.01535833 1 0.01570833 2 0.01791667
 13301101 9 0.01535833
 * 13301201 3 6 -4 7 -5 9
 13301201 3 9
 * 13301301 1.0 6 0.0 7 0.0 9
 13301301 1.0 9
 13301400 -1
 13301401 122. 122. 122. 122. 122. 122. 122. 122. 122.
 13301402 122. 122. 122. 122. 122. 122. 122. 122. 122.
 13301403 122. 122. 122. 122. 122. 122. 122. 122. 122.
 13301404 122. 122. 122. 122. 122. 122. 122. 122. 122.
 13301405 122. 122. 122. 122. 122. 122. 122. 122. 122.
 13301406 122. 122. 122. 122. 122. 122. 122. 122. 122.
 13301407 122. 122. 122. 122. 122. 122. 122. 122. 122.
 13301408 122. 122. 122. 122. 122. 122. 122. 122. 122.
 13301409 122. 122. 122. 122. 122. 122. 122. 122. 122.
 13301410 122. 122. 122. 122. 122. 122. 122. 122. 122.
 13301411 122. 122. 122. 122. 122. 122. 122. 122. 122.
 13301412 122. 122. 122. 122. 122. 122. 122. 122. 122.
 13301413 122. 122. 122. 122. 122. 122. 122. 122. 122.
 13301501 0 0 0 0 0.0 13

* length of fuel pin = #pins/ass'y * 141.8/(5 * 12)
 = 208 * 2.363 = 491.57333

*
 13301601 010010000 10000000 1 1 245.78667 5
 13301602 060010000 10000000 1 1 491.57333 13
 13301701 1000 0.1 0.0 0.0 5
 13301702 1000 0.2 0.0 0.0 13
 * 13301801 0 0.0 0.0 0.0 13
 * 13301901 0 0.05492351 0.05492351 0.0 13
 13301801 0.0 10.0 10.0 0.0 0.0 0.0 0.0 1.0 13
 13301901 0.0 10.0 10.0 0.0 0.0 0.0 0.0 1.0 13
 *

*


```

***
***
*** reactor vessel heat structures
***
*
*
* lower plenum of reactor vessel
*
*
*-----*
*
* heat structure composition type
*
*-----*
*
* fuel (uo2)
*
20100300 "tbl/fctn" 1 1
*-----*
*
* gap (hot channel)
*
20100400 "tbl/fctn" 3 1
*-----*
*
* clad (zr-4)
*
20100500 "tbl/fctn" 1 1
*-----*
*
* base metal (carbon steel)
*
20100600 "tbl/fctn" 1 1
*-----*
*
* cladding (stainless steel)
*
20100700 "tbl/fctn" 1 1
*-----*
*
*$$$ *$$$ *
*$$$ *$$$ * gap (avg channel)
*$$$ *$$$ *
*$$$ *$$$ 20100900 "tbl/fctn" 3 1
*$$$ *
*-----*
*
*
* heat structure thermal conductivities
*
*-----*
*
* fuel (uo2)
*
20100301 70.0 1.237e-3 200.0 1.237e-3
20100302 400.0 1.022e-3 800.0 0.745e-3
20100303 1200.0 0.592e-3 1600.0 0.492e-3
20100304 2000.0 0.430e-3 2400.0 0.395e-3
20100305 2800.0 0.383e-3 3200.0 0.367e-3
20100306 3600.0 0.370e-3 4000.0 0.380e-3
20100307 4400.0 0.405e-3 5000.0 0.470e-3
*
* gap (bol)
*
20100401 "helium" 0.989748

```

```

20100402 "nitrogen" 0.008098
20100403 "oxygen" 0.002153
20100404 "krypton" 0.000000
20100405 "xenon" 0.000002
*
* clad (zr-4)
*
20100501 70.0 2.333e-3 200.0 2.333e-3 400.0 2.458e-3
20100502 800.0 2.805e-3 1200.0 3.278e-3 1600.0 3.805e-3
20100503 1800.0 4.112e-3 2000.0 4.445e-3 2100.0 4.667e-3
20100504 2200.0 4.945e-3 2800.0 7.000e-3
*
* thermal conductivity base metal ( carbon steel )
*
20100601 0.0 .00728 2000.0 .00728
*
* thermal conductivity cladding ( stainless steel )
*
20100701 0.0 .00311 2000.0 .00311
*
*-----*
*
* heat structure volumetric heat capacities
*
*-----*
*
* volumetric heat capacity fuel ( uo2 )
*
20100351 77.0 33.8 200.0 40.62 400.0 43.87
20100352 600.0 45.82 800.0 47.12 1000.0 48.10
20100353 1200.0 48.88 1600.0 49.92 2000.0 50.37
20100354 2400.0 51.35 2800.0 53.62 3200.0 58.17
20100355 3600.0 66.30 4000.0 78.97 4400.0 90.80
20100356 4800.0 99.12 5100.0 101.40
*
* volumetric heat capacity gap (hot channel)
*
20100451 32.0 0.000075 5400.0 0.000075
*
* volumetric heat capacity clad
*
20100551 32.0 28.346 1062.0 33.232 1140.0 35.432
20100552 1480.0 35.432 1510.0 49.440 1530.0 56.440
20100553 1560.0 58.916 1590.0 61.800 1610.0 66.332
20100554 1620.0 76.220 1650.0 80.340 1680.0 78.28
20100555 1700.0 74.16 1780.0 35.432 3000.0 35.432
*
* volumetric heat capacity base metal (carbon steel)
*
20100651 0.0 64.4 2000.0 64.4
*
* volumetric heat capacity cladding (stainless steel)
*
20100751 0.0 64.4 2000.0 64.4
*
*-----*
*
* general tables
*
*-----*
*
* test power insertion
*
* 20200100 power
* 20200101 0.0 0.0 5.0 0.0 25.0 1.0-2
*

```

```

*-----*
*
*
*   control variables
*
*-----*
*
* 20547400 "hcopwr"   "constant" 3.15e6
* 20547400 "hcopwr"   "function" 3.15e4 0.0 0
* 20547401 time 0 1
*
*-----*
***
***
***   reactor kinetics
***
*-----*
*
* power in watts per assembly
*
30000000 "point"   "separabl"
30000001 "gamma-ac" 5.00000 .00000 .28637e+03 1.0 1.0
30000002 "ans73"   0.0 1.0
30000301 0.3230 0.000491 0.2910 0.00000341
*
*-----*
*
* general table for waste package reactivity insertion ttt = 1
*
30000011 1
30000012 10081
*
*-----*
*
* moderator density reactivity feedback
*
* beff = 0.005
*
*
*   density lf/ft**3   reactivity, dollars   fuel temp. f
*
30000501 43.6995724 -22.8341124 * 1004
30000502 45.2602714 -20.0375898 * 1004
30000503 46.8209705 -17.4413905 * 1004
30000504 48.3816695 -15.0255317 * 1004
30000505 49.9423685 -12.7766726 * 1004
30000506 51.5030675 -10.6782739 * 1004
30000507 53.0637665 -08.7187079 * 1004
30000508 54.6244655 -06.8856192 * 1004
30000509 56.1851645 -05.1688975 * 518
30000510 57.4337238 -03.9010990 * 518
30000511 58.6822830 -02.6972060 * 518
30000512 59.8121897 -01.6592902 * 518
30000513 60.7424057 -00.8234196 * 212
30000514 61.6903146 00.00 * 122
30000515 62.4279606 +00.6225345 * 122
30000516 65.0000000 +00.6225345 * 80.33
*
* control volume weighting - modified from Original deck with uniform weights
*
30000701 010010000 0 .02191015 0.0
30000702 020010000 0 .02191015 0.0
30000703 030010000 0 .02191015 0.0
30000704 040010000 0 .02191015 0.0
30000705 050010000 0 .02191015 0.0
30000706 060010000 0 .04382030 0.0
30000707 070010000 0 .04382030 0.0
30000708 080010000 0 .04382030 0.0
30000709 090010000 0 .04382030 0.0

```

| | | | | |
|----------|-----------|---|-----------|-----|
| 30000710 | 100010000 | 0 | .04382030 | 0.0 |
| 30000711 | 110010000 | 0 | .04382030 | 0.0 |
| 30000712 | 120010000 | 0 | .04382030 | 0.0 |
| 30000713 | 130010000 | 0 | .04382030 | 0.0 |
| 30000714 | 140010000 | 0 | .01293183 | 0.0 |
| 30000715 | 150010000 | 0 | .01418173 | 0.0 |
| 30000716 | 160010000 | 0 | .04977361 | 0.0 |
| 30000717 | 170010000 | 0 | .03388387 | 0.0 |
| 30000718 | 180010000 | 0 | .05595103 | 0.0 |
| 30000719 | 190010000 | 0 | .05443940 | 0.0 |
| 30000720 | 200010000 | 0 | .05378898 | 0.0 |
| 30000721 | 210010000 | 0 | .04873313 | 0.0 |
| 30000722 | 220010000 | 0 | .05378898 | 0.0 |
| 30000723 | 230010000 | 0 | .05378898 | 0.0 |
| 30000724 | 240010000 | 0 | .03063990 | 0.0 |
| 30000725 | 250010000 | 0 | .07798541 | 0.0 |

*

30000501
30000502
30000503
30000504
30000505
30000506
30000507
30000508
30000509
30000510
30000511
30000512
30000513
30000514
30000515
30000516
30000701
30000702
30000703
30000704
30000705
30000706
30000707
30000708
30000709
30000710
30000711
30000712
30000713
30000714
30000715
30000716
30000717
30000718
30000719
30000720
30000721
30000722
30000723
30000724
30000725

*

* average fuel temperature vs. reactivity

*

*

| | fuel temp. f | reactivity, dollars | density lb/ft**3 |
|----------|--------------|---------------------|------------------|
| 30000601 | 32.0 | +0.1719079 | * 62.4279606 |
| 30000602 | 80.33 | +0.1719079 | * 62.4279606 |
| 30000603 | 122.0 | 0.0 | * 61.6903146 |
| 30000604 | 212.0 | -0.3488604 | * 61.6903146 |
| 30000605 | 320.0 | -0.7295469 | * 60.7424057 |

★ 60.7424057
★ 56.1851645

•

★

| | | | | |
|----------|---------|---|-----------|-----|
| 30000801 | 3301001 | 0 | .04762000 | 0.0 |
| 30000802 | 3301002 | 0 | .04761900 | 0.0 |
| 30000803 | 3301003 | 0 | .04761900 | 0.0 |
| 30000804 | 3301004 | 0 | .04761900 | 0.0 |
| 30000805 | 3301005 | 0 | .04761900 | 0.0 |
| 30000806 | 3301006 | 0 | .09523800 | 0.0 |
| 30000807 | 3301007 | 0 | .09523800 | 0.0 |
| 30000808 | 3301008 | 0 | .09523800 | 0.0 |
| 30000809 | 3301009 | 0 | .09523800 | 0.0 |
| 30000810 | 3301010 | 0 | .09523800 | 0.0 |
| 30000811 | 3301011 | 0 | .09523800 | 0.0 |
| 30000812 | 3301012 | 0 | .09523800 | 0.0 |
| 30000813 | 3301013 | 0 | .09523800 | 0.0 |

★

```

20500000 999
20500100 cntrlvar function 0.04762 0.0 0
20500101 htvat 3301001 002
20500200 cntrlvar function 0.04761 0.0 0
20500201 htvat 3301002 002
20500300 cntrlvar function 0.04761 0.0 0
20500301 htvat 3301003 002
20500400 cntrlvar function 0.04761 0.0 0
20500401 htvat 3301004 002
20500500 cntrlvar function 0.04761 0.0 0
20500501 htvat 3301005 002
20500600 cntrlvar function 0.095238 0.0 0
20500601 htvat 3301006 002
20500700 cntrlvar function 0.095238 0.0 0
20500701 htvat 3301007 002
20500800 cntrlvar function 0.095238 0.0 0
20500801 htvat 3301008 002
20500900 cntrlvar function 0.095238 0.0 0
20500901 htvat 3301009 002
20501000 cntrlvar function 0.095238 0.0 0
20501001 htvat 3301010 002
20501100 cntrlvar function 0.095238 0.0 0
20501101 htvat 3301011 002
20501200 cntrlvar function 0.095238 0.0 0
20501201 htvat 3301012 002
20501300 cntrlvar function 0.095238 0.0 0
20501301 htvat 3301013 002
20501400 cntrlvar sum 1.0 0.0 0
20501401 -6.63322e-5 1.0 cntrlvar 1 1.0 cntrlvar 2 1.0 cntrlvar 3
20501402 1.0 cntrlvar 4 1.0 cntrlvar 5 1.0 cntrlvar 6
20501403 1.0 cntrlvar 7 1.0 cntrlvar 8 1.0 cntrlvar 9
20501404 1.0 cntrlvar 10 1.0 cntrlvar 11 1.0 cntrlvar 12
20501405 1.0 cntrlvar 13

```

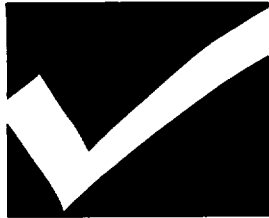
| | | | | | |
|----------|----------|-----------|------------|-----|---|
| 20502000 | cntrlvar | function | 0.02191015 | 0.0 | 0 |
| 20502001 | "rho" | 010010000 | 005 | | |
| 20502100 | cntrlvar | function | 0.02191015 | 0.0 | 0 |
| 20502101 | "rho" | 020010000 | 005 | | |
| 20502200 | cntrlvar | function | 0.02191015 | 0.0 | 0 |
| 20502201 | rho | 030010000 | 005 | | |
| 20502300 | cntrlvar | function | 0.02191015 | 0.0 | 0 |
| 20502301 | rho | 040010000 | 005 | | |
| 20502400 | cntrlvar | function | 0.02191015 | 0.0 | 0 |
| 20502401 | rho | 050010000 | 005 | | |
| 20502500 | cntrlvar | function | 0.0438203 | 0.0 | 0 |

```

20502501 rho 060010000 005
20502600 cntrlvar function 0.0438203 0.0 0
20502601 rho 070010000 005
20502700 cntrlvar function 0.0438203 0.0 0
20502701 rho 080010000 005
20502800 cntrlvar function 0.0438203 0.0 0
20502801 rho 090010000 005
20502900 cntrlvar function 0.0438203 0.0 0
20502901 rho 100010000 005
20503000 cntrlvar function 0.0438203 0.0 0
20503001 rho 110010000 005
20503100 cntrlvar function 0.0438203 0.0 0
20503101 rho 120010000 005
20503200 cntrlvar function 0.0438203 0.0 0
20503201 rho 130010000 005
20503300 cntrlvar function 0.01293183 0.0 0
20503301 rho 140010000 005
20503400 cntrlvar function 0.01418173 0.0 0
20503401 rho 150010000 005
20503500 cntrlvar function 0.04977361 0.0 0
20503501 rho 160010000 005
20503600 cntrlvar function 0.03388387 0.0 0
20503601 rho 170010000 005
20503700 cntrlvar function 0.05595103 0.0 0
20503701 rho 180010000 005
20503800 cntrlvar function 0.05443940 0.0 0
20503801 rho 190010000 005
20503900 cntrlvar function 0.05378898 0.0 0
20503901 rho 200010000 005
20504000 cntrlvar function 0.04873313 0.0 0
20504001 rho 210010000 005
20504100 cntrlvar function 0.05378898 0.0 0
20504101 rho 220010000 005
20504200 cntrlvar function 0.05378898 0.0 0
20504201 rho 230010000 005
20504300 cntrlvar function 0.03063990 0.0 0
20504301 rho 240010000 005
20504400 cntrlvar function 0.07798541 0.0 0
20504401 rho 250010000 005
*
20505000 cntrlvar sum 1.0 0.0 0
20505001 0.0 1.0 cntrlvar 20 1.0 cntrlvar 21 1.0 cntrlvar 22
20505002 1.0 cntrlvar 23 1.0 cntrlvar 24 1.0 cntrlvar 25
20505003 1.0 cntrlvar 26 1.0 cntrlvar 27 1.0 cntrlvar 28
20505004 1.0 cntrlvar 29 1.0 cntrlvar 30 1.0 cntrlvar 31
*
20505500 cntrlvar sum 1.0 0.0 0
20505501 0.0 1.0 cntrlvar 32 1.0 cntrlvar 33 1.0 cntrlvar 34
20505502 1.0 cntrlvar 35 1.0 cntrlvar 36 1.0 cntrlvar 37
20505503 1.0 cntrlvar 38 1.0 cntrlvar 39 1.0 cntrlvar 40
20505504 1.0 cntrlvar 41 1.0 cntrlvar 42 1.0 cntrlvar 43
20505505 1.0 cntrlvar 44
*
20505600 cntrlvar sum 1.0 0.0 0
20505601 0.1185681 1.0 cntrlvar 50 1.0 cntrlvar 55
*
20506000 cntrlvar function 1.0 0.0 0
20506001 time 0 001
20506500 cntrlvar sum 1.0 0.0 0
20506501 0.0 1.0 cntrlvar 14 1.0 cntrlvar 56 1.0 cntrlvar 60
*
20507000 cntrlvar integral 1.0 0.0 0
20507001 rktpow 0
*
20507500 cntrlvar sum 6.22971e-2 0.0 0
20507501 0.0 1.0 htgamw 312100100 1.0 htgamw 312100200
20507502 1.0 htgamw 312100300 1.0 htgamw 312100400
20507503 1.0 htgamw 312100500 1.0 htgamw 312100600
20507504 1.0 htgamw 312100700 1.0 htgamw 312100700
20507505 1.0 htgamw 312100900

```

```
*
*          scale factor = 1/area sum
20508000  cntrlvar sum 0.26289886 0.0 0
20508001  0.0 0.3516846 voidf 050010000 0.7033692 voidf 100010000
20508002  0.8633786 voidf 200010000 0.7822260 voidf 210010000
*
20508100  cntrlvar function 1.0 0.0 0
20508101  cntrlvar 80 010
. * end of data
```



RPC Staff Meeting Minutes

12/04/98

The next staff meeting will be held on 12/18

Vic:

- **Staff Updates** – Kelly Ross is now longer with the project. Judy and Kim Q. are on vacation today and Judy will also be out on Monday. Sharon is on AWW today. Kim will be on an extended leave starting 12/11 for about six weeks. Dorothy will be leaving us on 12/14 to become part of the Document Control staff.
- **Lead Integration** – The Leads are going to be crossing the boundaries of their previously designated functions in order to keep a handle on all aspects of records processing. Kelly will now be overseeing scanning and Kim will do the same with the daily QC function. Judy and Sharon are overlapping on Media and exclusionary records. Charlene will be updating her daily processing, QC, scanning and IQC skills. This cross training will help to enable the Leads to answer questions from any staff member regardless of function.
- **Staff Flexibility** – Not only Leads, but all the staff will be required to switch functions as the need arises. Due to extra projects, work flow requirements, etc., flexibility is needed to increase production in a particular function in order to keep up with the work. It is critical that we have a staff who can change functions rapidly at these times.

Terri:

- **Backlog** – Because of our growing backlog, we are still a long way off from reaching out twenty-four hour record completion turn around time. Part of this is due to an overall increase in record's receipts, but it is also the result of low staff production.
- **Staff Performance** - Performance is still a main issue, and the expectation that everyone will perform to the best of their ability has not changed. If you are not sure of where you stand concerning performance, ask a Lead. the Leads are well aware of the quality of your work, and it is their feedback that Terri and Vic will rely on for your quarterly reviews. So, if you don't know, ask.
- **Electronic Sampling** – During a recent PLA audit, the PLA controlled environment temperature was found to be deficient. They received a Deficiency Report, and because of that report, we must perform a sampling to see if there was any damage to our electronic media.
- **100% Verification** – Since all CD's will be re-cut, 100% verification has been discontinued. Presently each CD contains information from numerous boxes; but when they are re-cut, each CD will reflect the information in one box.
- **IQC Meeting** – Monday at 10:00 a.m. (Canceled).

Kelly:

- **Retrieval Backup** – Kenneth Hannon will start back up retrieval training three days a week (Mon., Wed., & Fri.) for 1 hour each day. This will help when a large retrieval is needed or one of our retrieval staff is absent.
- **Addition to QC Function** - Sharon Racine will now be performing daily QC.
- **Daily Quotas** – Kelly will reevaluate the daily records processing quotas and will give out new quotas shortly.
- **Miscellaneous** – If you are dupe checking a record, do not go any farther than RDMS Render. Do not look all through the QC drawers to find a dupe.

Charlene:

- **Schedule Changes** – If you wish to make any changes to your schedules, see Charlene first. She will forward you message/request to the appropriate Supervisor/Lead. If Charlene is not available, be sure you send your message/request via a Lotus Note addressed to both Supervisors and all Leads.
- **Back Door Problems** – There is a sign on the outside of the back door to our stating that it is not to be used as an entrance. This door is to be used as an exit only (except by Media personnel), In the past, someone placed tape on the door causing it not to lock. That tape has been removed and it is not to be replaced.
- **Christmas Tree** – Thank you to everyone who helped decorate our tree especially Pam and Kim B. It looks great! We are also going to decorate the tree with group Christmas cards. If you would like to send you coworkers a group card, just hang it on the tree.
- **Christmas Week** – We are going to have an all day potluck on Tuesday, December 22. Record Services, Mail Services, and the TIC have all been invited to join us. Tables will be set up early in the morning for your breakfast/snack items. They will be changed again before our scheduled 11:30 lunch. We will all have lunch starting at 11:30 that day. A sheet will be passed around for you to fill out with the item(s) you will be bringing to the potluck so that we can have some idea of the menu.
- **Birthday Celebrations for 1999** – It was decided that we will continue the birthday club as it is now during 1999.
- **Miscellaneous** - Give the name of your Secret Santa person to Shirley Smith

Miscellaneous:

- **Reprocessing Task** - Dave Keller tasked us with performing a 1-day reprocessing representation in order to get an idea of how many Vienna records we can reprocess in one month.
- **RPC Moves**
 - Dave Keller will be moving into the office where Judy and Kim are now located.
 - Mike will be moving to station 1106D and there will be privacy panels installed on the South and West sides of this station.
 - Ed Worfolk will move to the station opposite John Cox (#1110Q).
 - Judy and Kim will have stations added somewhere in the room, probably in the back where the OQA staff are now located.