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Calculation Cover Sheet

Complete only applicable items.

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CRC Reactivity Calculations for Three Mile Island Unit 1			
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8. Checker	John M. Scaglione	John M. Scaglione	6/4/98
9. Lead Design Engineer	Daniel A. Thomas	D A Thomas	06/04/98

10. Remarks

Attachments I through IV include electronic files which are contained on an attachment tape. The number of pages shown in Box 6 for each of the attachments refers to the hard-copy listing of the file content on the attachment tape.

PCG compliance review by WE Wallin 6/4/98

The electronic attachments have been checked. JOHN M. SCAGLIONE

John M. Scaglione 6/4/98

Revision History

11. Revision No.	12. Date Approved	13. Description of Revision
00		Initial Issuance

Table of Contents

1. Purpose

The purpose of this calculation is to document the Three Mile Island Unit 1 pressurized water reactor (PWR) reactivity calculations performed as part of the commercial reactor critical (CRC) evaluation program. CRC evaluation reactivity calculations are performed at a number of statepoints, representing reactor start-up critical conditions at either beginning of life (BOL), beginning of cycle (BOC), or mid-cycle when the reactor resumed operation after a shutdown. The CRC evaluations support the development and validation of the neutronics models used for criticality analyses involving commercial spent nuclear fuel in a geologic repository.

2. Method

The calculational method used to perform the Three Mile Island Unit 1 core reactivity calculations consisted of using the MCNP code (Ref. 7.1) to calculate the effective neutron multiplication factor (k_{eff}) for the various critical core configurations. Each of the critical core configurations were modeled in detail using measured critical conditions. The various fuel assemblies were modeled explicitly in the critical core configurations. The SAS2H code of the SCALE 4.3 modular code system (Ref. 7.2) was used to deplete the various fuel assemblies as necessary to obtain the burned fuel isotopics for use in the reactivity calculations documented herein. These fuel assembly depletion calculations are documented in Reference 7.3. The Three Mile Island Unit 1 CRC configurations are actual PWR cores which contained fuel loadings that varied from all fresh fuel (BOL) to a mixture of fresh and burned fuel (BOC) to a mixture of all burned fuel (mid-cycle restart).

3. Assumptions

Not Used

4. Use of Computer Software

4.1. Software Approved for QA Work

4.1.1. MCNP

The MCNP code was used to calculate the k_{eff} of the Three Mile Island Unit 1 critical reactor configurations. The software specifications are as follow:

- Program Name: MCNP
- Version/Revision Number: Version 4B2
- CSCI Number: 30033 V4BLV
- Computer Type: HP 9000 Series Workstations

The input and output files for the various MCNP calculations are documented in the attachments to this calculation file as described in Sections 5 and 8, such that an independent repetition of the software use may be performed. The MCNP software used was: (a) appropriate for the application of commercial

reactor k_{eff} calculations, (b) used only within the range of validation as documented throughout References 7.1 and 7.4, (c) obtained from the Software Configuration Manager in accordance with appropriate procedures.

4.2. Software Routines

4.2.1. MACE

- Title: MCNP Accessory for CRC Evaluations (MACE)
- Version/Revision Number: Version 3

The MACE code automates the production of MCNP input decks to calculate the k_{eff} of the critical reactor configurations in the CRC evaluations. The input and output for the various MACE calculations are documented in Sections 5 and 8, such that an independent repetition of the software routine use may be performed. The description of the MACE software routine is provided in Attachment I of Reference 7.14. This description documentation contains the following information:

- Descriptions and equations of mathematical algorithms
- Description of software routine including execution environment
- Range of input parameter values for which results were verified
- Identification of any limitations on software routine applications or validity
- Reference list of all documentation relevant to the qualification
- Directory listing of executable and data files
- Computer listing of source code

The MCNP input decks that were produced for the Three Mile Island Unit 1 CRC evaluations and presented in this calculation file serve as the test cases for MACE. These input decks were thoroughly reviewed to verify that MACE was performing correctly.

4.2.2. Excel

- Title: Excel
- Version/Revision Number: Microsoft® Excel 97

The Excel spreadsheet program was used for simple numeric calculations as documented in Section 5 of this calculation file. The user-defined formulas, inputs, and results were documented in sufficient detail in Section 5 to allow an independent repetition of the various computations.

5. Calculation

The Three Mile Island Unit 1 CRC reactivity calculations are detailed calculations of the neutron multiplication factor for actual critical reactor configurations. This analysis provides the geometry, material, core loading, and calculational control descriptions for each CRC reactivity calculation performed with MCNP. The MCNP input decks for each CRC reactivity calculation documented in this analysis were created with the MACE software routine. Complete documentation of the MACE software routine and MACE input deck preparation instructions are provided in Attachment I of

Reference 7.14. The MACE input decks used to create each of the MCNP input decks are presented in Attachment I (this attachment has been moved to Reference 7.15). The MACE generated MCNP input decks are presented in Attachment II (this attachment has been moved to Reference 7.15). The MCNP output decks are presented in Attachment III (this attachment has been moved to Reference 7.15). The k_{eff} results for each CRC reactivity calculation are presented in Section 6.

5.1. Three Mile Island Unit 1 CRC Reactivity Calculations

The Three Mile Island Unit 1 CRC reactivity calculations represent three critical statepoints at which either BOL, BOC, or mid-cycle reactor start-ups were performed. Table 5.1-1 presents a listing of these three statepoints by reactor cycle and effective full-power day (EFPD) time.

Table 5.1-1. McGuire Unit 1 CRC Reactivity Calculations

Cycle	Critical Statepoint EFPD Time
1	0.0
5	0.0
5	114.4

5.2. Three Mile Island Unit 1 MCNP Geometrical Descriptions

The MCNP models for the Three Mile Island Unit 1 PWR incorporated detailed and explicit representations of the fuel assemblies and reactor core components. Extensive fuel assembly and core modeling was incorporated for regions beyond the extent of the active fuel in the axial direction to ensure that neutron leakage was correctly simulated. Actual core loading patterns were utilized in all of the critical configuration models. Core symmetry was used wherever possible to minimize the number of unique fuel assembly descriptions that were required. The use of core symmetry also served to expedite the k_{eff} calculations. The depleted fuel in each assembly was composed of eighteen unique, axially delineated, fuel compositions. These depleted fuel compositions were calculated with SAS2H as documented throughout Reference 7.3. Burnable poison rod assemblies (BPRAs), rod cluster control assemblies (RCCAs), and axial power shaping rod assemblies (APSRAs) were modeled explicitly in the core locations corresponding to the measured critical conditions at the various statepoints. The average system temperature and soluble boron concentration that was measured at each critical statepoint was utilized in the MCNP models. Sections 5.2.1 through 5.2.8 discuss the MCNP geometric modeling details for the various components of the Three Mile Island Unit 1 CRC configurations.

5.2.1. Three Mile Island Unit 1 Reactor Core Geometric Description

The Three Mile Island Unit 1 PWR is a B&W reactor core design consisting of 177, 15x15 cell lattice, fuel assemblies (p. 5, Ref. 7.11). A core liner surrounds the periphery fuel assemblies in the core. The periphery of the reactor consists of the core barrel, the thermal shield, the pressure vessel liner, and the pressure vessel. These peripheral components are separated by a regions of moderator (borated water). A radial view of the reactor internals is shown in Figure 5.2.1-1. The height of the active fuel region in the core is 360.172 cm (p. 5, Ref. 7.11). The assembly pitch in the core is 21.81098 cm (p. 5, Ref. 7.11). Table 5.2.1-1 presents the dimensions from the center of the core to the outside surface of the pressure vessel. An axial view of the reactor core internals is shown in Figure 5.2.1-2. Due to their geometric complexity and low neutronic importance, the components in the reactor regions above and below the

upper and lower end-fittings of the fuel assemblies are homogenized for each region. Four homogenized regions are modeled above the assembly upper end-fitting: Upper Plenum Region, CRGT Flange Region, Upper Core Grid Region, and Upper Pad Region. Three homogenized regions are modeled below the assembly lower end-fitting: Lower Pad Region, Lower Core Grid Region, and Region Between the Lower Grid and Vessel Plate. These reactor regions above and below the fuel assembly end-fittings are modeled as uniform geometric cells, each containing the appropriately homogenized material composition. The homogenization of these components will allow MCNP to simulate the average axial leakage from the system.

Table 5.2.1-1. Dimensions from Core Center to Outside Surface of Pressure Vessel

Description	Thickness (cm)	Outer Dimension (cm)
Core Center	---	0.00000
Half of FA-1	10.84072	10.84072
Water	0.12954	10.97026
FA-2	21.68144	32.65170
Water	0.12954	32.78124
FA-3	21.68144	54.46268
Water	0.12954	54.59222
FA-4	21.68144	76.27366
Water	0.12954	76.40320
FA-5	21.68144	98.08464
Water	0.12954	98.21418
FA-6	21.68144	119.89562
Water	0.12954	120.02516
FA-7	21.68144	141.70660
Water	0.12954	141.83614
FA-8	21.68144	163.51758
Water	0.27442	163.79200
Core Liner	1.905	165.697
Water	13.373	179.070
Core Barrel	5.080	184.150
Water	2.540	186.690
Thermal Shield	5.080	191.770
Water	24.925	216.695
Pressure Vessel Clad	0.478	217.173
Pressure Vessel	21.433	238.606

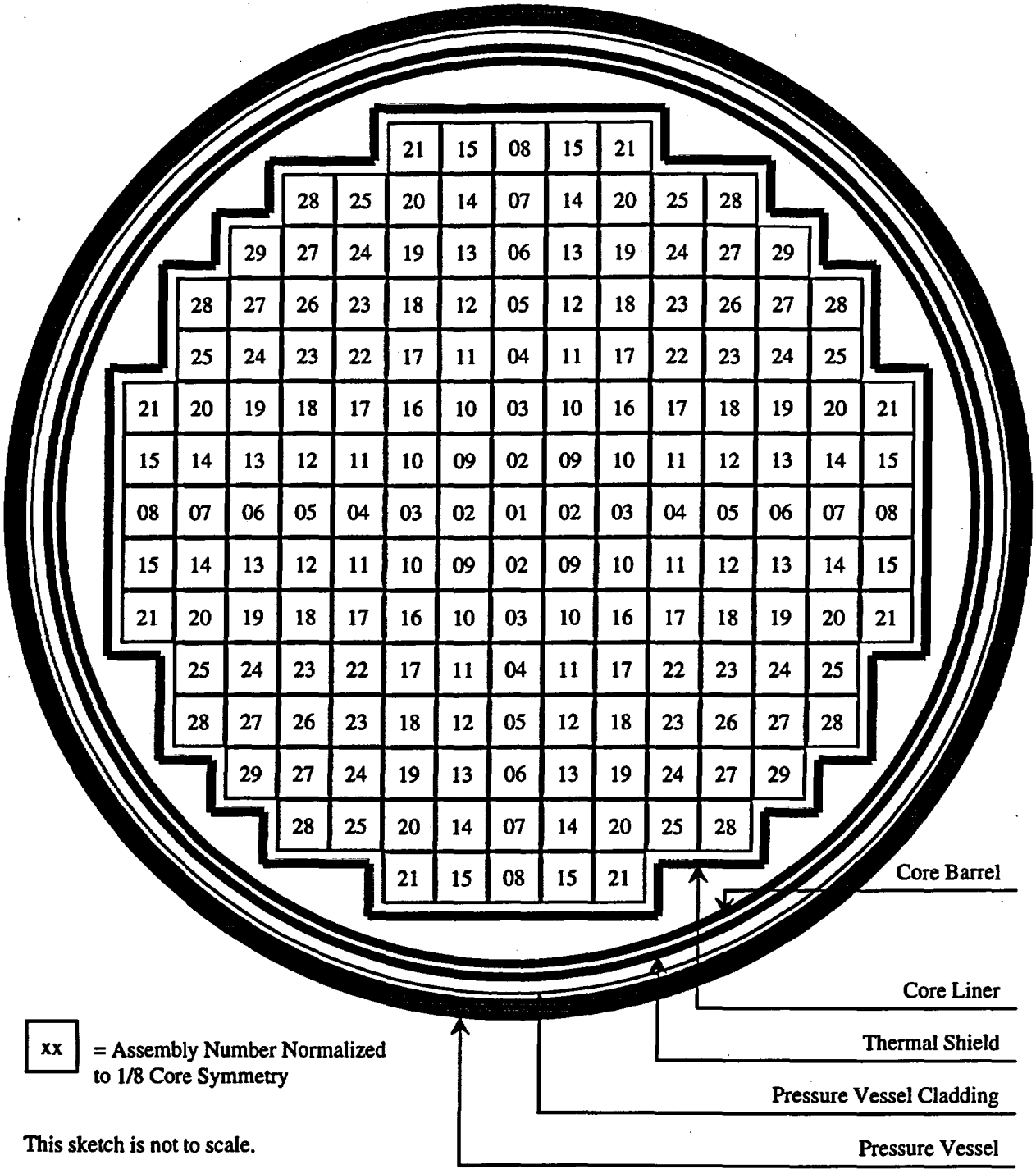
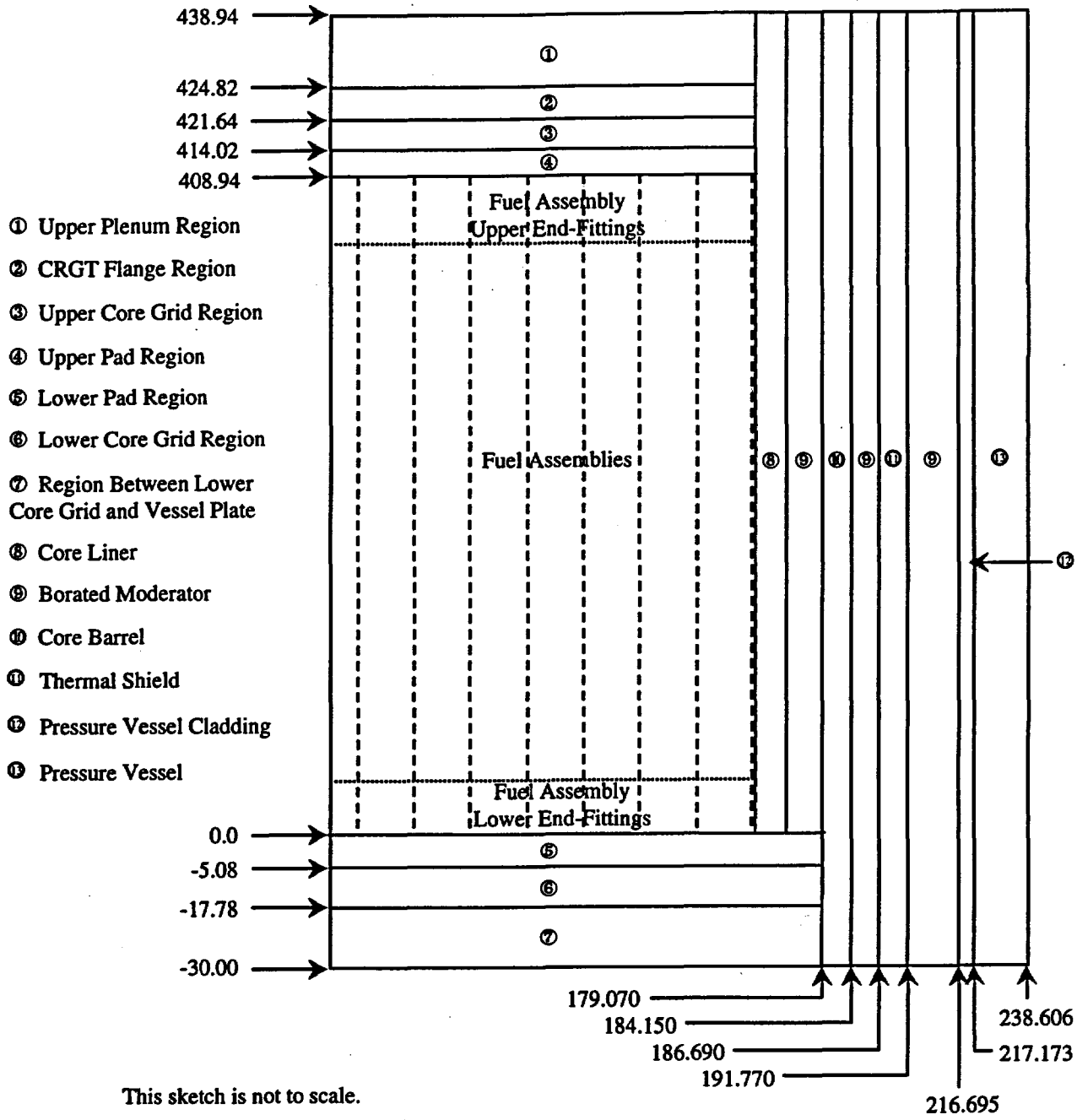


Figure 5.2.1-1. Radial View of the Three Mile Island Unit 1 Reactor Internals as Modeled in MCNP (p. 4, Ref. 7.11)



This sketch is not to scale.

All dimensions are presented in centimeters.

Figure 5.2.1-2. Axial View of the Three Mile Island Unit 1 Reactor Internals as Modeled in MCNP (Radial Dimensions: p. 3, Ref. 7.11) (Axial Dimensions: p. 7, Ref. 7.11)

5.2.2. Three Mile Island Unit 1 Fuel Assembly Geometric Descriptions

The Three Mile Island Unit 1 CRC configurations contained fuel assemblies from seven different fuel batches. Fuel assemblies from the various fuel batches were inserted into the reactor core in different combinations for each cycle. Three different fuel assembly designs are represented in the various fuel batches: Framatome Cogema Fuels Mark-B2, Framatome Cogema Fuels Mark-B3, and Framatome Cogema Fuels Mark-B4. All three of the fuel assembly designs utilize 15x15 pin cell lattices. The pin cell lattice pitch is 1.44272 cm (p. 5, Ref. 7.11) in each assembly design. The specifications for each design are summarized in Table 5.2.2-1.

Table 5.2.2-1. Fuel Assembly Specification Summary (p. 22, Ref. 7.11)

Fresh Batch Cycle	Fuel Batch	FA[1] Type	wt% U-235	kg U per FA	FP[2] Pellet OD[3] (cm)	FP Clad OD (cm)	FP Clad ID[4] (cm)	FA Grid Material
1	1	Mark-B2	2.06	463.63	0.93980	1.09220	0.95758	Inconel
1	2	Mark-B3	2.75	463.63	0.93980	1.09220	0.95758	Inconel
1	3	Mark-B3	3.05	463.63	0.93980	1.09220	0.95758	Inconel
2	4	Mark-B4	2.64	463.63	0.93980	1.09220	0.95758	Inconel
3	5	Mark-B4	2.85	463.63	0.93853	1.09220	0.95758	Inconel
4	6	Mark-B4	2.85	463.63	0.93853	1.09220	0.95758	Inconel
5	7	Mark-B4	2.85	463.63	0.93853	1.09220	0.95758	Inconel

[1] FA = Fuel Assembly, [2] FP = Fuel Pin, [3] OD = Outer Diameter, [4] ID = Inner Diameter

All fuel assembly designs contain one instrument tube and sixteen guide tubes (p. 5, Ref. 7.11). The instrument tube and guide tube dimensions are the same for each of the three fuel assembly types. Table 5.2.2-2 summarizes the instrument tube and guide tube specifications. The fuel pin, guide tube, and instrument tube positions for all assembly designs are shown in Figure 5.2.2-1.

Table 5.2.2-2. Instrument and Guide Tube Specification Summary (p. 22, Ref. 7.11)

Description	Material	OD (cm)	ID (cm)
Instrument Tube	zircaloy	1.38193	1.12014
Guide Tube	zircaloy	1.34620	1.26492

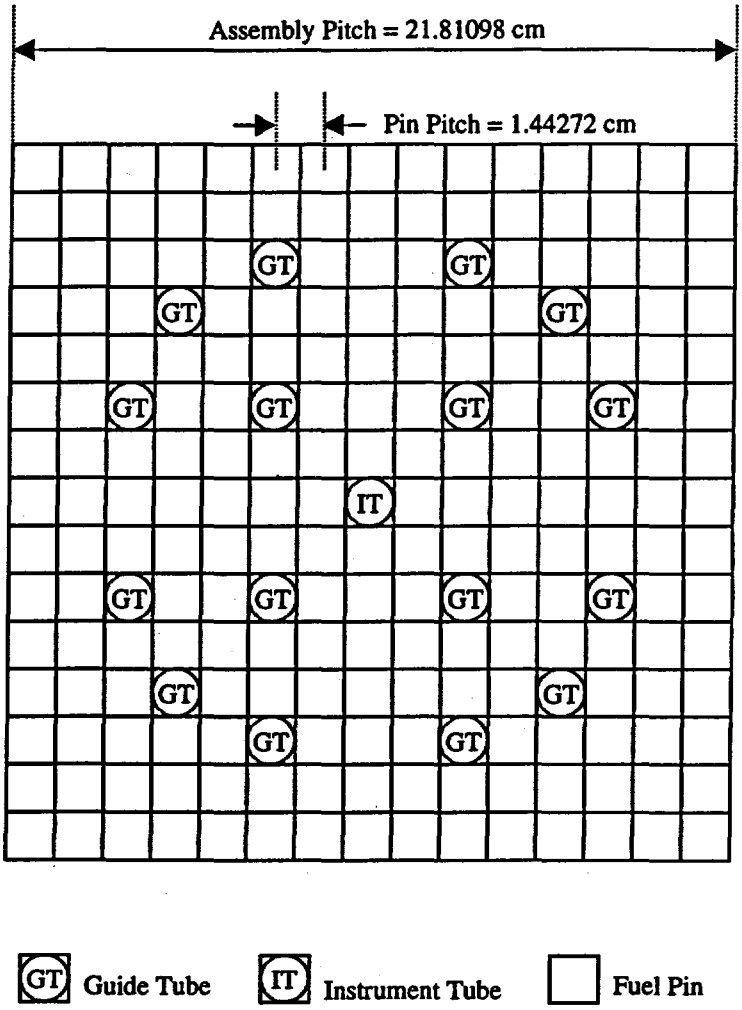
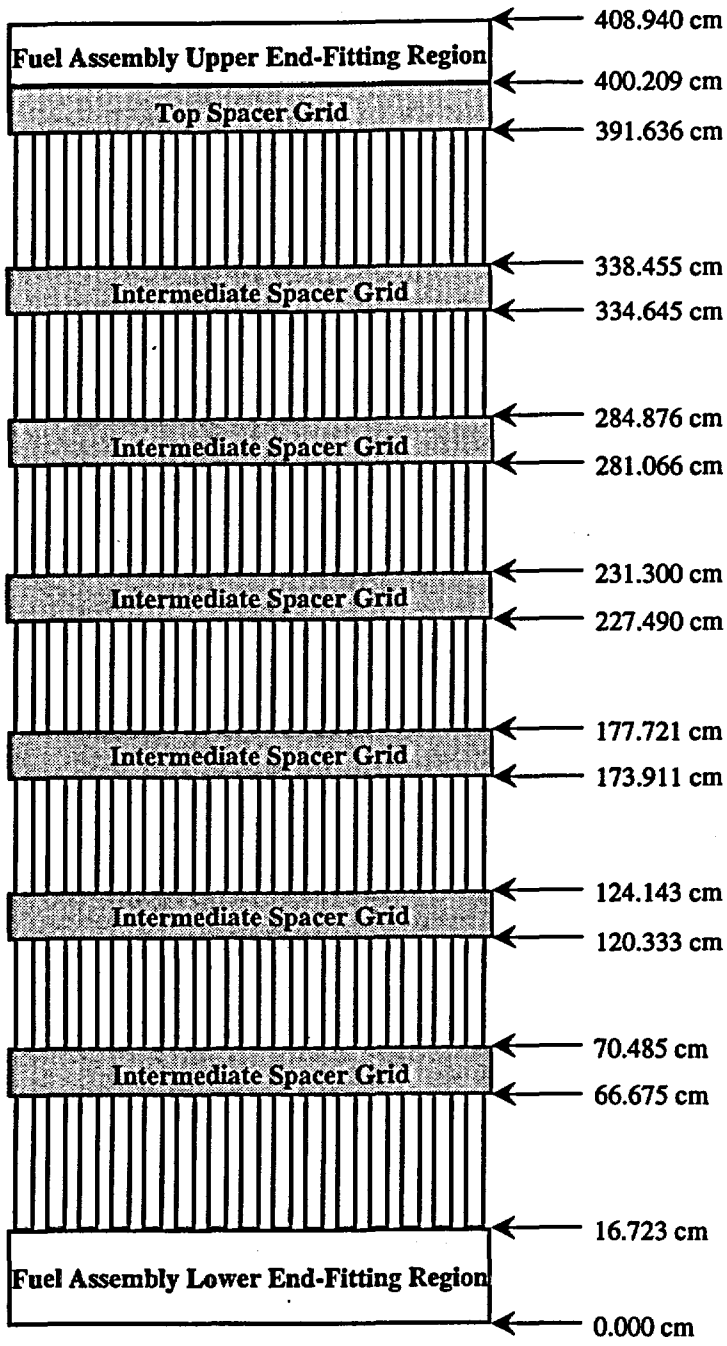


Figure 5.2.2-1. Fuel Pin, Guide Tube, and Instrument Tube Locations in Fuel Assembly (p. 6, Ref. 7.11)

All of the fuel assembly designs have six intermediate spacer grids and one upper end spacer grid (p. 7, Ref. 7.11). The intermediate and upper end spacer grids are made of Inconel (pp. 5, 7, Ref. 7.11). According to the reference, the upper end spacer grid homogenized region also contains a zircaloy volume fraction of 0.0069 (p. 8, Ref. 7.11). Since MACE does not allow a spacer grid homogenized combination of Inconel, zircaloy, and water, the zircaloy volume fraction was neglected in the modeling of the upper end spacer grids. The approximation of excluding the small zircaloy constituent in the upper spacer grid has no effect on the system reactivity. The intermediate spacer grid height and volume for the assembly designs are summarized in Table 5.2.2-3. The referenced upper end spacer grid height is 8.573 cm for each assembly design (p. 7, Ref. 7.11). Each spacer grid material volume was homogenized with the corresponding borated moderator volume and placed uniformly between the assembly rods and within the assembly pitch boundaries in each spacer grid location. The axial locations of the spacer grids are shown in Figure 5.2.2-2. The lower end-fitting of each fuel assembly design is modeled as a homogenized region, 16.723 cm in height (p. 7, Ref. 7.11), distributed uniformly between and below the fuel rods, guide tubes, and instrument tubes. The upper end-fitting of each fuel assembly design is modeled as a homogenized region, 8.731 cm in height (p. 7, Ref. 7.11), distributed uniformly between and above the fuel rods, guide tubes, instrument tubes, BPRAs, RCCAs, and APSRAs.

Table 5.2.2-3. Intermediate Spacer Grid Height and Volume (pp. 7, 8, Ref. 7.11)

Material	Inconel
Height (cm)	3.81
Volume (cm^3)	88.676



This sketch is not to scale.

Figure 5.2.2-2. Axial View of Mark-B2, Mark-B3, and Mark-B4 Assemblies (p. 7, Ref. 7.11)

5.2.3. Fuel Pin Geometric Description

The cross-sectional view along the length of a fuel pin is shown in Figure 5.2.3-1, to present the modeled axial dimensions. The radial dimensions of the fuel pins for each fuel batch are presented in Table 5.2.2-1. The fuel pins in each assembly design are modeled with eighteen axial fuel nodes, each representing a unique fuel composition corresponding to the fuel node depletion. The height of the top and bottom fuel nodes is 20.0660 cm. The height of the other sixteen fuel nodes is 20.0025 cm (p. 39, Ref. 7.11). The fuel pin upper end cap and upper plenum materials are homogenized and distributed uniformly throughout the plenum and end cap region. The fuel pin lower end cap and lower plenum materials are also homogenized and distributed uniformly throughout the plenum and end cap region.

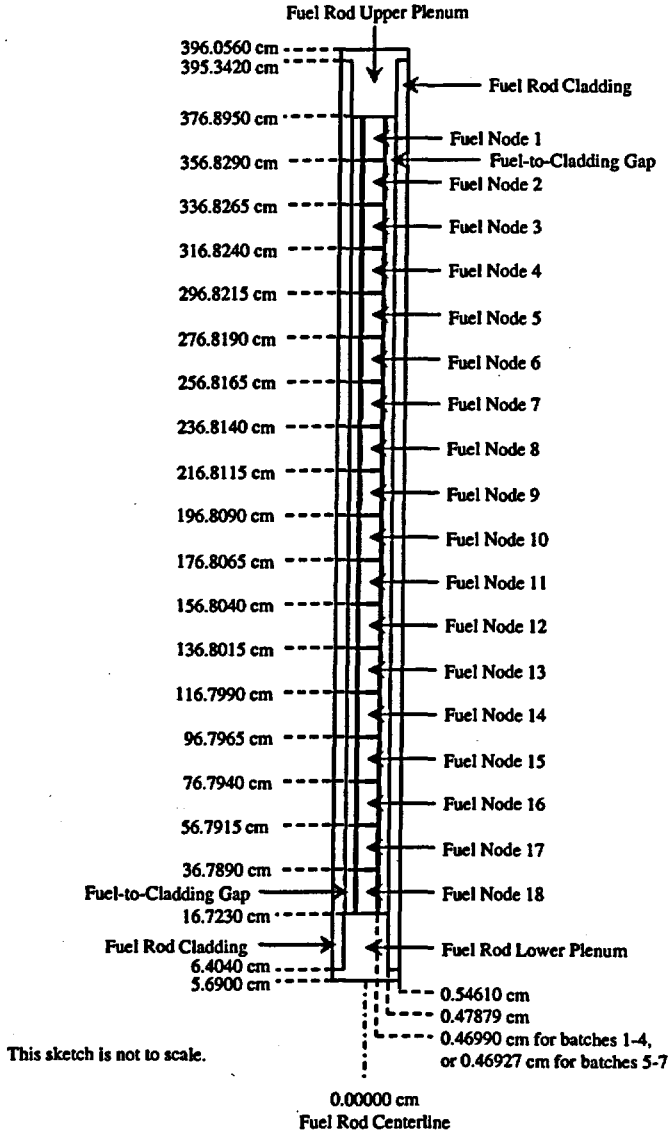


Figure 5.2.3-1. Fuel Pin Geometry Model in MCNP
(Axial Dimensions: p. 11, Ref. 7.11) (Radial Dimensions: p. 22, Ref. 7.11)

5.2.4. Guide Tube Geometric Description

The cross-sectional view along the length of a guide tube is presented in Figure 5.2.4-1. The MCNP model dimensions and reference dimensions are shown in Figure 5.2.4-1. The guide tubes are modeled explicitly into the upper and lower end-fittings of the fuel assembly. The 0.0 cm reference point in Figure 5.2.4-1 is located at the bottom of the lower end-fitting.

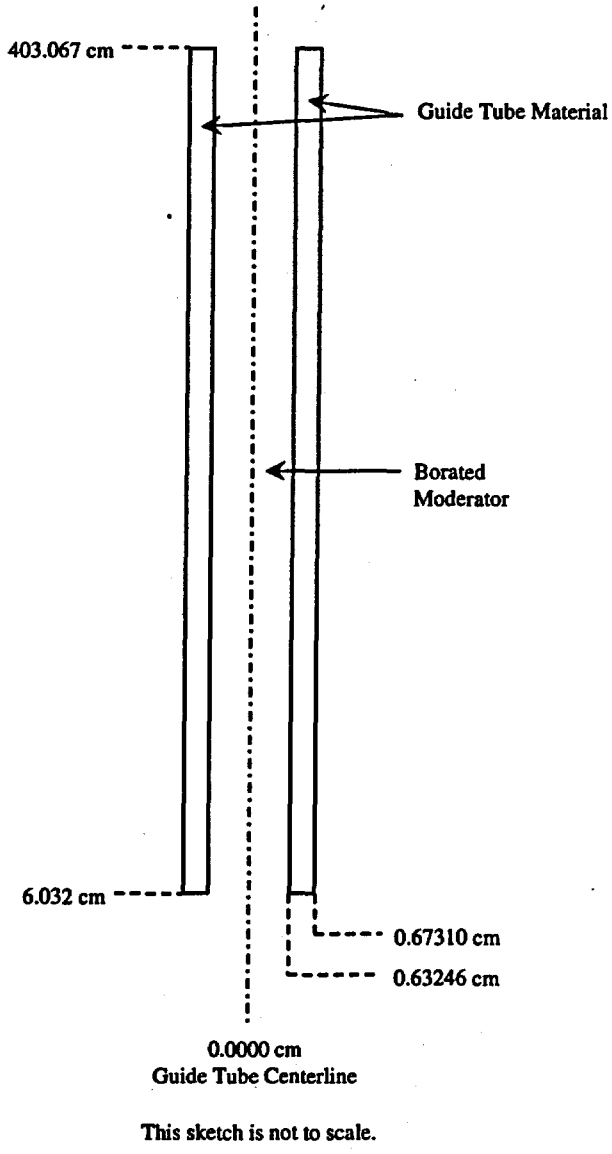


Figure 5.2.4-1. Guide Tube Geometry Model in MCNP (Radial Dimensions: p. 22, Ref. 7.11) (Axial Dimensions: p. 9, Ref. 7.11)

5.2.5. Instrument Tube Geometric Description

The cross-sectional view along the length of an instrument tube is presented in Figure 5.2.5-1. The MCNP model dimensions and reference dimensions are shown in Figure 5.2.5-1. The instrument tubes are modeled explicitly up to the bottom of the upper end-fitting and into the lower end-fitting of the fuel assembly. Truncating the instrument tube at the bottom of the upper end-fitting of the assembly has a negligible effect on the reactor core k_{eff}. The 0.0 cm reference point in Figure 5.2.5-1 is located at the bottom of the lower end-fitting.

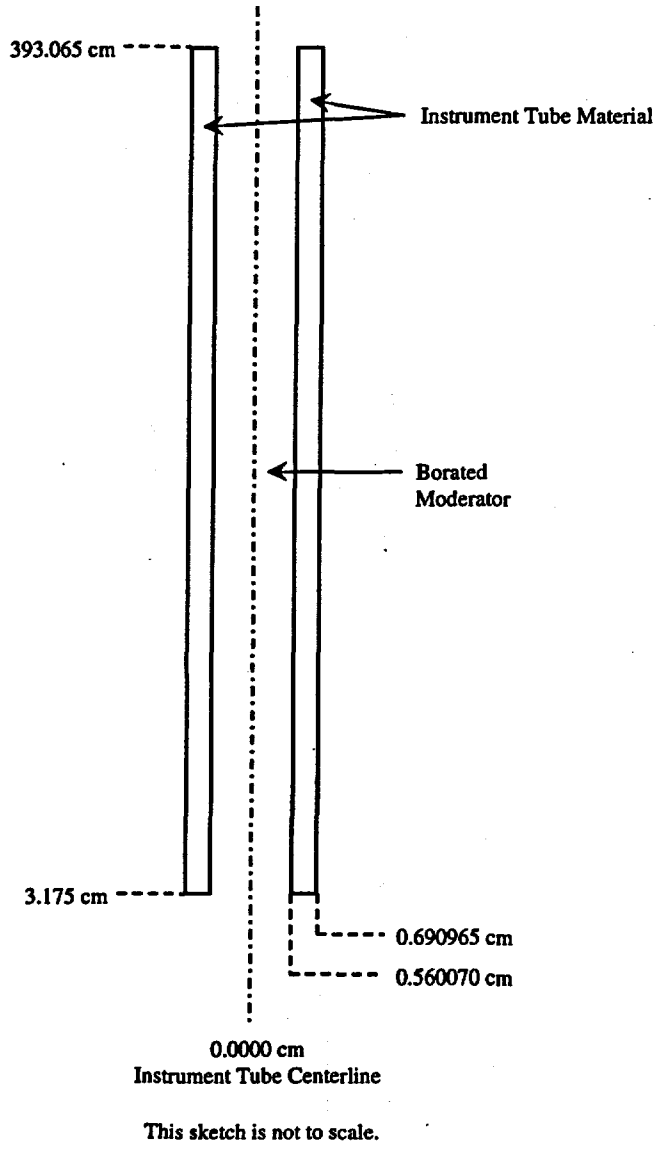


Figure 5.2.5-1. Instrument Tube Geometry Model in MCNP (Radial Dimensions: p. 22, Ref. 7.11) (Axial Dimensions: p. 10, Ref. 7.11)

5.2.6. BPRA Geometric Description

Through Cycle 5 of Three Mile Island Unit 1 operation, Cycle 1 was the only cycle in which BPRAs were present in the core. The BPRAs of Cycle 1 used B_4C-Al_2O_3 as the absorber material (p. 22, Ref. 7.11). The specifications for the BPRs are summarized in Table 5.2.6-1. Each of the BPRAs contained sixteen burnable poison rods (BPRs), each being inserted into a guide tube. Since there are no assemblies from Cycle 1 present in the Cycle 5 CRC statepoint evaluations, depleted BP compositions are not required in any of the MCNP models. The BPRAs present in the Cycle 1, 0.0 EFPD statepoint evaluation contain non-depleted burnable poison (BP). The cross-sectional view along the length of a modeled BPR is shown in Figure 5.2.6-2. The 0.0 cm reference point in Figure 5.2.6-2 is located at the bottom of the lower end-fitting.

Table 5.2.6-1. BPR Specification Summary (p. 22, Ref. 7.11)

BP Material	B_4C-Al_2O_3
BP Density (g/cm^3)	3.7
BP Diameter (cm)	0.8636
BPR Clad Material	zircaloy
BPR OD (cm)	1.0922
BPR ID (cm)	0.9144

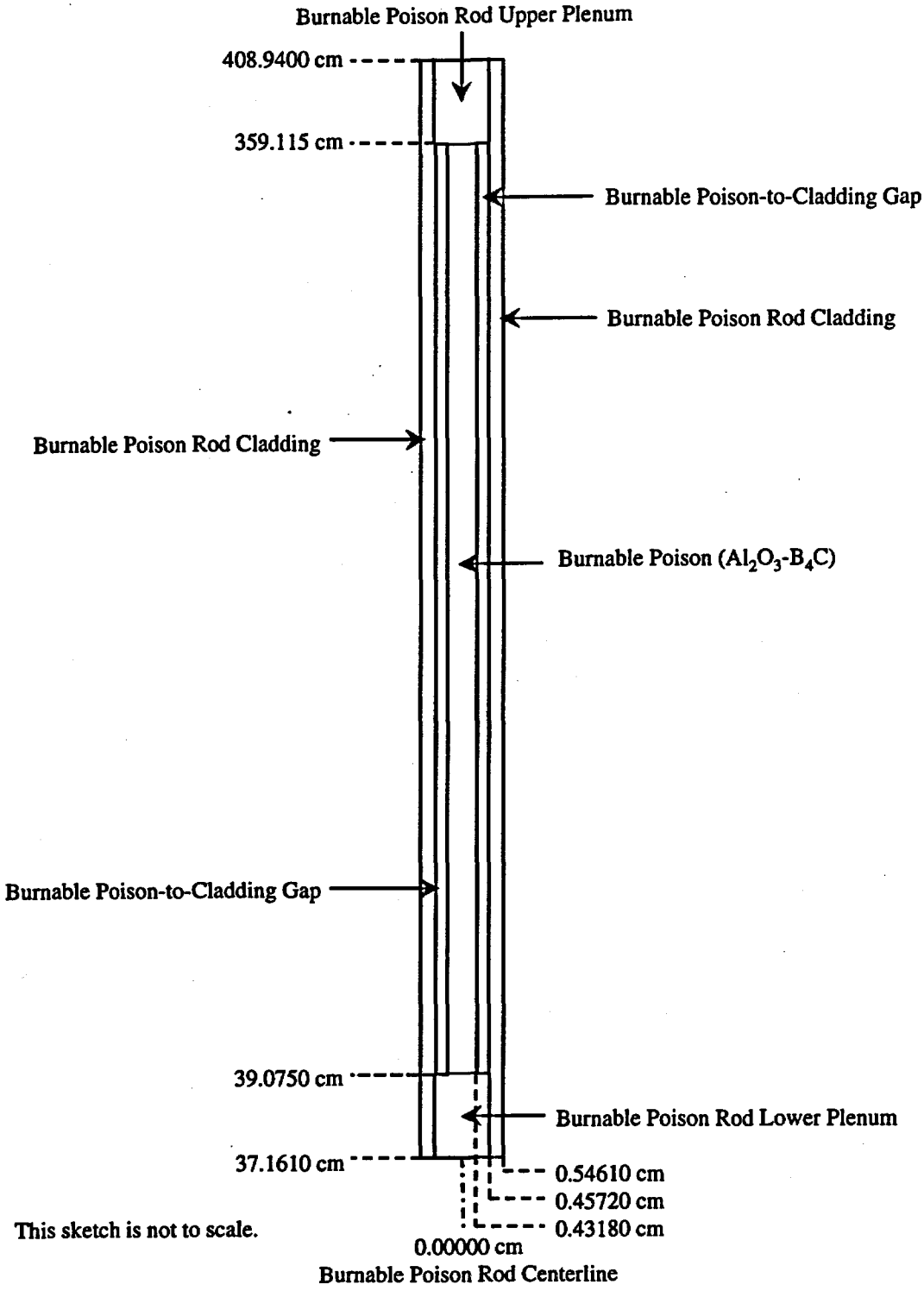


Figure 5.2.6-2. Cross-Sectional View Along Length of a BPR (Axial Dimensions: p. 19, Ref. 7.11) (Radial Dimensions: p. 22, Ref. 7.11)

5.2.7. RCCA Geometric Description

A RCCA is composed of sixteen control rods (CRs) distributed such that each guide tube has an inserted CR and all CRs are at the same height in the assembly. The CR specifications are summarized in Table 5.2.7-1. The Three Mile Island Unit 1 reactor contains RCCA banks that may be inserted into the core during startup and operation. Each RCCA in a given bank is moved up or down simultaneously. Each of the three RCCA banks modeled in MCNP are at a specified axial location in each CRC statepoint reactivity calculation. Table 5.2.7-2 shows the RCCA bank positions in the core for each of the CRC statepoint reactivity calculations. The absorber material of the CRs was modeled with a maximum height of 340.361 cm depending on the depth of the RCCA bank insertion (p. 13, Ref. 7.11). The CRs were always explicitly modeled to the top of the fuel assembly upper end-fitting. The truncation of the RCCA at the top of the assembly upper end-fittings is acceptable due to the decreasing reactivity worth of regions extending beyond the length of the active fuel. If the RCCA bank was partially inserted, the absorber material in the CRs was modeled explicitly from the top of the upper end-fitting to the depth of insertion. The CR lower end-plug was modeled inside the CR cladding directly below the absorber material. A cross-sectional view along the length of the CR is shown in Figure 5.2.7-1. The 0.0 cm reference point in Figure 5.2.7-1 is located at the bottom of the lower end-fitting.

Table 5.2.7-1. RCCA Control Rod Geometric Specification Summary (p. 22, Ref. 7.11)

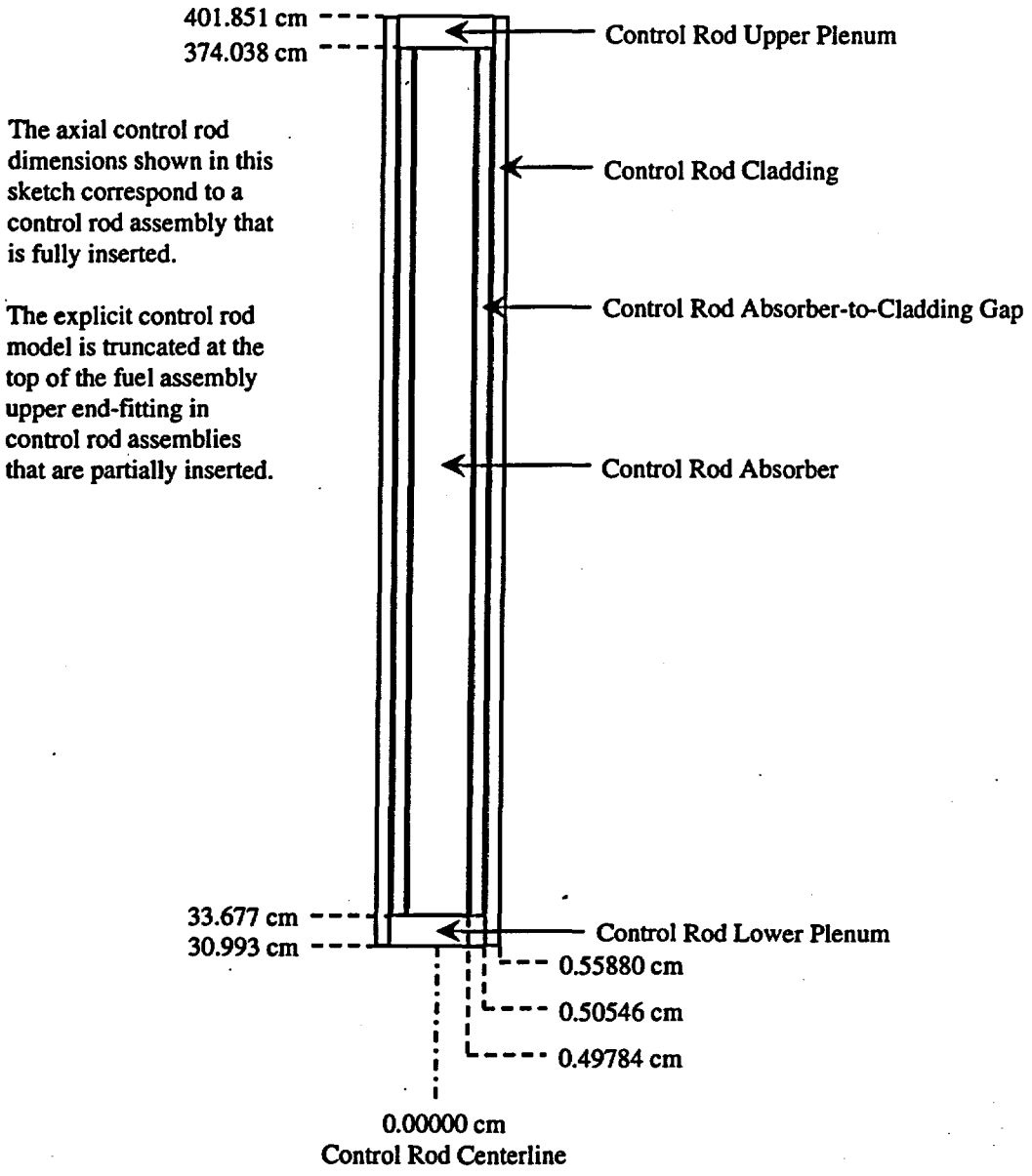
Pellet Material	Ag-In-Cd
Fraction of Pellet Materials	Ag (80 wt%), In (15 wt%), Cd (5 wt%)
Pellet Density	10.17 g/cm^3
Pellet Outer Diameter	0.99568 cm
Clad Material	Stainless Steel (Type 304)
Clad Outer Diameter	1.11760 cm
Clad Inner Diameter	1.01092 cm

Table 5.2.7-2. RCCA Bank Insertion Heights for the Three Mile Island Unit 1 CRC Statepoints[1] (p. 66, Ref. 7.11)

Cycle	Statepoint EFPD	Bank 5	Bank 6	Bank 7
1	0.0	WD[2]	WD	279
5	0.0	WD	WD	338
5	114.4	WD	324	62

[1] The RCCA bank insertion heights are presented as the distance in centimeters between the bottom of the CR absorber material and the bottom of the active fuel.

[2] WD means that the RCCA bank is 100% withdrawn. This corresponds to a height of 366.204 cm in the table.



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Note: Due to the axial position of the RCCA banks in the CRC configurations, modeling of the CR upper plenum was not required in any of the MCNP calculations for Three Mile Island Unit 1.

Figure 5.2.7-1. Cross-Sectional View Along the Length of a Control Rod (Axial Dimensions: p. 13, Ref. 7.11) (Radial Dimensions: p. 22, Ref. 7.11)

5.2.8. APSRA Geometric Description

Black APSRAs were used in Cycles 1 though 5 of Three Mile Island Unit 1 operation. The black axial power shaping rod (APSR) modeling description is shown in Figure 5.2.8-1. The 0.0 cm reference point in Figure 5.2.8-1 is located at the bottom of the lower end-fitting. The APSRA consists of 16 APSRs of uniform composition that are inserted uniformly down through the guide tubes of the fuel assembly to a specified height. The Three Mile Island Unit 1 reactor contains one APSRA bank (Bank 8). The insertion heights of the APSR bank in each CRC statepoint reactivity calculation are shown in Table 5.2.8-1. The black APSR cladding was modeled with outer and inner diameters of 1.11760 cm and 1.01092 cm, respectively (p. 22, Ref. 7.11). The black APSRA absorber material is Ag-In-Cd (p. 22, Ref. 7.11). The absorber material diameter of the black APSR is 0.99568 cm (p. 22, Ref. 7.11). The absorber height of the black APSR is 91.44 cm (p. 17, Ref. 7.11). The black APSR contains a lower, annular, zircaloy spacer with a volume of 0.3819 cm^3 (p. 18, Ref. 7.11). In the MCNP model, this spacer is smeared throughout the spacer region inside of the cladding. The black APSR contains a stainless steel lower end-plug with a height of 1.924 cm positioned directly below the lower spacer (p. 17, Ref. 7.11). The black APSR contains a gap (void) region 4.953 cm in height, positioned above the absorber material (p. 17, Ref. 7.11). Above this gap region is an intermediate plug. The intermediate plug is stainless steel with a height of 1.27 cm (p. 17, Ref. 7.11) and a volume of 1.0094 cm^3 (p. 18, Ref. 7.11). The region above the intermediate plug in the black APSRs contains moderator.

Table 5.2.8-1. RCCA Bank Insertion Heights for the Three Mile Island Unit 1 CRC Statepoints[1] (p. 66, Ref. 7.11)

Cycle	Statepoint EFPD	Bank 8 (Black APSRA)
1	0.0	WD[2]
5	0.0	140
5	114.4	103

[1] The APSRA bank insertion heights are presented as the distance in centimeters between the bottom of the CR absorber material and the bottom of the active fuel.

[2] WD means that the APSRA bank is 100% withdrawn. This corresponds to a height of 366.204 cm in the table.

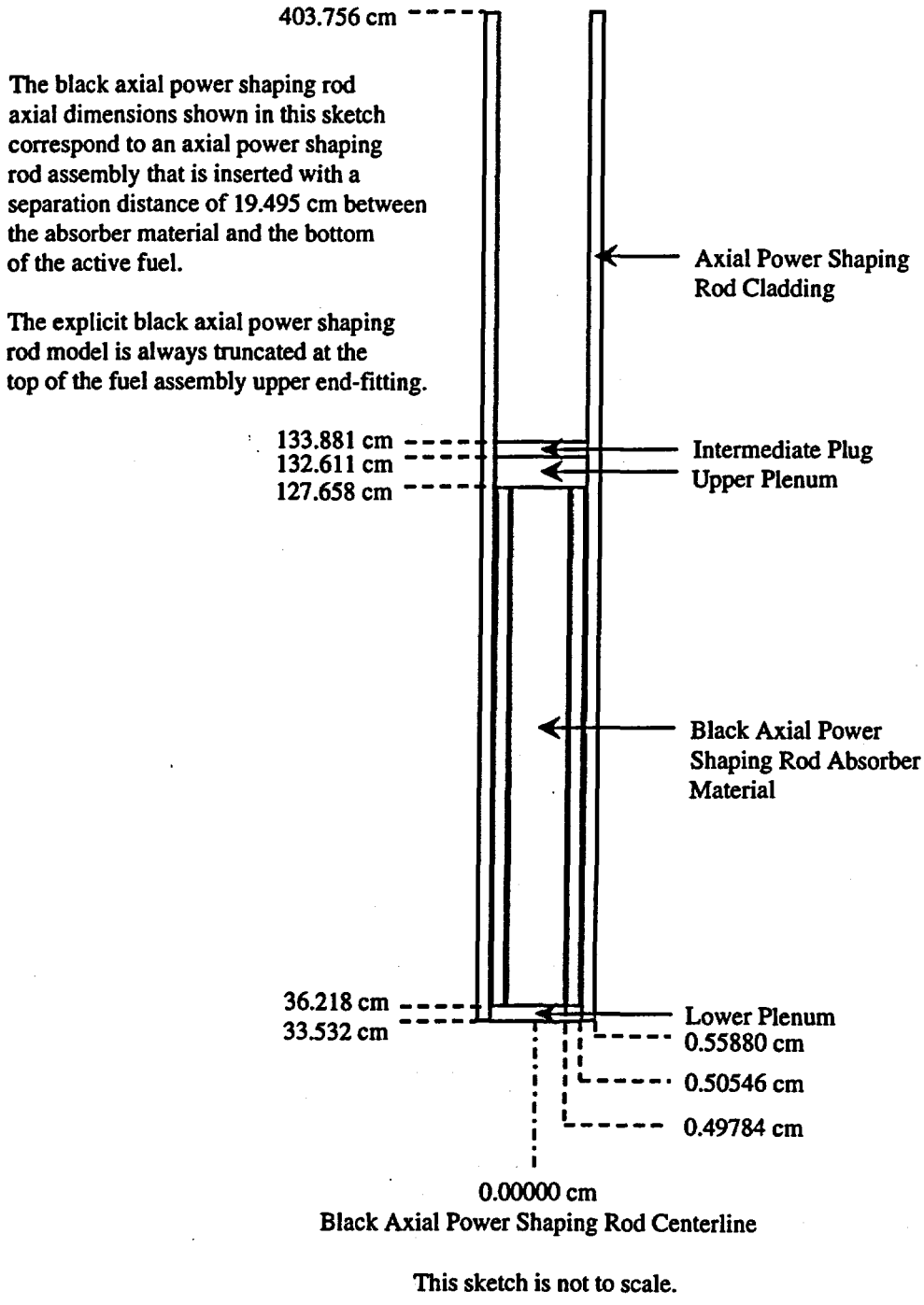

Figure 5.2.8-1. Cross-Sectional View Along the Length of a Black APSR (Axial Dimensions: p. 17, Ref. 7.11) (Radial Dimensions: p. 22, Ref. 7.11)

5.3. Three Mile Island Unit 1 MCNP Material Descriptions

The material descriptions used in the MCNP CRC reactivity calculations correspond to the actual reactor component materials. Components with detailed geometric features were homogenized where appropriate. The homogenization of these materials preserves the average neutron interaction rate such that the reactivity worth of these materials in the system is approximated. All homogenizations are based on the explicit volumes of the various component materials in the regions of interest. The depleted fuel and depleted burnable poison materials utilized in the MCNP reactivity calculations are obtained from depletion calculations performed using the SAS2H code in the SCALE 4.3 Modular Code System (Ref. 7.2). Detailed descriptions of the fuel and burnable poison depletion calculations are documented throughout Reference 7.3.

5.3.1. MCNP Cross Section Libraries

The MCNP cross section libraries utilized in the reactivity calculations are one of the primary components of the calculation that determines whether or not the neutronic behavior of the system is simulated correctly. Table 5.3.1-1 lists all of the MCNP cross section library identifiers (ZAID's) utilized in the CRC reactivity calculations documented in this calculation file. The MCNP ZAID's are used to identify the cross section libraries. The ZAID consists of a 5 integer element and isotope identifier followed by a cross section library designation suffix. The first one or two integers in the ZAID refer to the atomic number of the corresponding element. The three integers preceding the decimal always refer to the isotopic mass number. The ZAID suffixes presented in Table 5.3.1-1, correspond to libraries compiled from either ENDF/B-V, ENDF/B-VI, LANL/T-2, or LLNL evaluated cross section data sets. The atom percent in nature of the various isotopes presented in Table 5.3.1-1 are obtained from Reference 7.5. The atomic weight ratios, temperatures, library names, and data sources are obtained from Attachment I of Reference 7.12.

The cross section libraries used for the various isotopes and elements do not correspond to the temperature at which these isotopes and elements exist in the critical configurations. The U-235 and U-238 cross section libraries were processed at 587.0 K. The effects of temperature on the U-238 cross sections dominate with respect to the effects of temperature on the other isotopic and elemental cross sections. The majority of the other cross section libraries utilized in the MCNP calculations were processed at 294.0 K. Some less significant isotopic and elemental cross section libraries were processed at 0 K.

The isotopes used in the fuel of the MCNP calculations represent the majority of the isotopes present in the actual material. However, cross section libraries for some of the less significant isotopes were not available in the standard cross section package that accompanies the MCNP software distribution. The isotopes not modeled in the fuel of the MCNP calculations have a relatively low reactivity worth due to a combination of their microscopic cross sections and low abundance.

Table 5.3.1-1. MCNP Cross Section Libraries Used in the CRC Reactivity Calculations

Element / Isotope	MCNP ZAID	Atom % in Nature	Atomic Wt. Ratio [1]	Temp. (K)	Library Name	Data Source
H-1	1001.50c	99.985	0.999167	294.0	rmccs	ENDF/B-V.0

Table 5.3.1-1. MCNP Cross Section Libraries Used in the CRC Reactivity Calculations

Element / Isotope	MCNP ZAID	Atom % in Nature	Atomic Wt. Ratio [1]	Temp. (K)	Library Name	Data Source
H-3	1003.50c	0.0	2.990140	294.0	rmccs	ENDF/B-V.0
He-4	2004.50c	99.999	3.968219	294.0	rmccs	ENDF/B-V.0
Li-6	3006.50c	7.5	5.963450	294.0	rmccs	ENDF/B-V.0
Li-7	3007.55c	92.5	6.955733	294.0	rmccs	ENDF/B-V.2
Be-9	4009.50c	100.0	8.934763	294.0	rmccs	ENDF/B-V.0
B-10	5010.50c	19.400 [2]	9.926922	294.0	rmccs	ENDF/B-V.0
B-11	5011.56c	80.600 [2]	10.914730	294.0	newxs	LANL/T-2
C-nat	6000.50c	100.0	11.907856	294.0	rmccs	ENDF/B-V.0
N-14	7014.50c	99.630	13.882780	294.0	rmccs	ENDF/B-V.0
O-16	8016.50c	99.760	15.857510	294.0	rmccs	ENDF/B-V.0
Al-27	13027.50c	100.0	26.749756	294.0	rmccs	ENDF/B-V.0
Si-nat	14000.50c	100.0	27.844241	294.0	endf5p	ENDF/B-V.0
P-31	15031.50c	100.0	30.707682	294.0	endf5u	ENDF/B-V.0
S-32	16032.50c	95.02	31.788939 [3]	294.0	endf5u	ENDF/B-V.0
Ti-nat	22000.50c	100.0	47.467124	294.0	endf5u	ENDF/B-V.0
Cr-50	24050.60c	4.345	49.516983	294.0	endf60	ENDF/B-VI.1
Cr-52	24052.60c	83.790	51.494313	294.0	endf60	ENDF/B-VI.1
Cr-53	24053.60c	9.500	52.485863	294.0	endf60	ENDF/B-VI.1
Cr-54	24054.60c	2.365	53.475519	294.0	endf60	ENDF/B-VI.1
Mn-55	25055.50c	100.0	54.466099	294.0	endf5u	ENDF/B-V.0
Fe-54	26054.60c	5.900	53.476242	294.0	endf60	ENDF/B-VI.1
Fe-56	26056.60c	91.720	55.454429	294.0	endf60	ENDF/B-VI.1
Fe-57	26057.60c	2.100	56.446290	294.0	endf60	ENDF/B-VI.1
Fe-58	26058.60c	0.280	57.435600	294.0	endf60	ENDF/B-VI.1
Co-59	27059.50c	100.0	58.426930	294.0	endf5u	ENDF/B-V.0
Ni-58	28058.60c	68.270	57.437652	294.0	endf60	ENDF/B-VI.1
Ni-60	28060.60c	26.100	59.415952	294.0	endf60	ENDF/B-VI.1
Ni-61	28061.60c	1.130	60.407628	294.0	endf60	ENDF/B-VI.1
Ni-62	28062.60c	3.590	61.396349	294.0	endf60	ENDF/B-VI.1
Ni-64	28064.60c	0.910	63.378793	294.0	endf60	ENDF/B-VI.1
Cu-63	29063.60c	69.170	62.389001	294.0	endf60	ENDF/B-VI.2

Table 5.3.1-1. MCNP Cross Section Libraries Used in the CRC Reactivity Calculations

Element / Isotope	MCNP ZAID	Atom % in Nature	Atomic Wt. Ratio [1]	Temp. (K)	Library Name	Data Source
Cu-65	29065.60c	30.830	64.370028	294.0	endf60	ENDF/B-VI.2
As-75	33075.35c	100.0	74.277979	0.0	rmccsa	ENDF/B-V.0
Kr-80	36080.50c	2.25	79.229851	294.0	rmccsa	ENDF/B-V.0
Kr-82	36082.50c	11.6	81.209803	294.0	rmccsa	ENDF/B-V.0
Kr-83	36083.50c	11.5	82.201858	294.0	rmccsa	ENDF/B-V.0
Kr-84	36084.50c	57.0	83.190662	294.0	rmccsa	ENDF/B-V.0
Kr-86	36086.50c	17.3	85.172596	294.0	rmccsa	ENDF/B-V.0
Y-89	39089.50c	100.0	88.142108	294.0	endf5u	ENDF/B-V.0
Zr-nat	40000.60c	100.0	90.439990	294.0	endf60	ENDF/B-VI.1
Zr-93	40093.50c	0.0	92.108361	294.0	kidman	ENDF/B-V.0
Nb-93	41093.50c	100.0	92.108263	294.0	endf5p	ENDF/B-V.0
Mo-nat	42000.50c	100.0	95.107188	294.0	endf5u	ENDF/B-V.0
Mo-95	42095.50c	15.92	94.090546	294.0	kidman	ENDF/B-V.0
Tc-99	43099.50c	0.0	98.056595	294.0	kidman	ENDF/B-V.0
Ru-101	44101.50c	17.1	100.038748	294.0	kidman	ENDF/B-V.0
Ru-103	44103.50c	0.0	102.022	294.0	kidman	ENDF/B-V.0
Rh-103	45103.50c	100.0	102.021490	294.0	rmccsa	ENDF/B-V.0
Rh-105	45105.50c	0.0	104.005	294.0	kidman	ENDF/B-V.0
Pd-105	46105.50c	22.33	104.003885	294.0	kidman	ENDF/B-V.0
Pd-108	46108.50c	26.46	106.976942	294.0	kidman	ENDF/B-V.0
Ag-107	47107.60c	51.839	105.986724	294.0	endf60	ENDF/B-VI.0
Ag-109	47109.60c	48.161	107.969204	294.0	endf60	ENDF/B-VI.0
Cd-nat	48000.50c	100.0	111.445880	294.0	endf5u	ENDF/B-V.0
In-nat	49000.60c	100.0	113.831536	294.0	endf60	ENDF/B-VI.0
Sn-nat	50000.35c	100.0	117.690428	0.0	endl85	LLNL
Xe-131	54131.50c	21.2	129.780532	294.0	kidman	ENDF/B-V.0
Xe-134	54134.35c	10.4	132.755077	0.0	endl85	LLNL
Xe-135	54135.53c	0.0	133.748208	587.0	eprixs	ENDF/B-V
Cs-133	55133.50c	100.0	131.763705	294.0	kidman	ENDF/B-V.0
Cs-135	55135.50c	0.0	133.746975	294.0	kidman	ENDF/B-V.0
Ba-138	56138.50c	71.70	136.720557	294.0	rmccs	ENDF/B-V.0

Table 5.3.1-1. MCNP Cross Section Libraries Used in the CRC Reactivity Calculations

Element / Isotope	MCNP ZAID	Atom % in Nature	Atomic Wt. Ratio [1]	Temp. (K)	Library Name	Data Source
Pr-141	59141.50c	100.0	139.697185	294.0	kidman	ENDF/B-V.0
Nd-143	60143.50c	12.18	141.682152	294.0	kidman	ENDF/B-V.0
Nd-145	60145.50c	8.30	143.667706	294.0	kidman	ENDF/B-V.0
Nd-147	60147.50c	0.0	145.654	294.0	kidman	ENDF/B-V.0
Nd-148	60148.50c	5.76	146.646216	294.0	kidman	ENDF/B-V.0
Pm-147	61147.50c	0.0	145.653	294.0	kidman	ENDF/B-V.0
Pm-148	61148.50c	0.0	146.647	294.0	kidman	ENDF/B-V.0
Pm-149	61149.50c	0.0	147.639	294.0	kidman	ENDF/B-V.0
Sm-147	62147.50c	15.0	145.652830	294.0	kidman	ENDF/B-V.0
Sm-149	62149.50c	13.8	147.637915	294.0	endf5u	ENDF/B-V.0
Sm-150	62150.50c	7.4	148.629416	294.0	kidman	ENDF/B-V.0
Sm-151	62151.50c	0.0	149.623	294.0	kidman	ENDF/B-V.0
Sm-152	62152.50c	26.7	150.614670	294.0	kidman	ENDF/B-V.0
Eu-151	63151.55c	47.8	149.623378	294.0	newxs	LANL/T-2
Eu-152	63152.50c	0.0	150.616668	294.0	endf5u	ENDF/B-V.0
Eu-153	63153.55c	52.2	151.607568	294.0	newxs	LANL/T-2
Eu-154	63154.50c	0.0	152.600719	294.0	endf5u	ENDF/B-V.0
Eu-155	63155.50c	0.0	153.592	294.0	kidman	ENDF/B-V.0
Gd-152	64152.50c	0.20	150.614731	294.0	endf5u	ENDF/B-V.0
Gd-154	64154.50c	2.18	152.598614	294.0	endf5u	ENDF/B-V.0
Gd-155	64155.50c	14.80	153.591761	294.0	endf5u	ENDF/B-V.0
Gd-156	64156.50c	20.47	154.582676	294.0	endf5u	ENDF/B-V.0
Gd-157	64157.50c	15.65	155.575907	294.0	endf5u	ENDF/B-V.0
Gd-158	64158.50c	24.84	156.567459	294.0	endf5u	ENDF/B-V.0
Gd-160	64160.50c	21.86	158.553203	294.0	endf5u	ENDF/B-V.0
Ho-165	67165.55c	100.0	163.513493	294.0	newxs	LANL/T-2
Ta-181	73181.50c	99.988	179.393575	294.0	endf5u	ENDF/B-V.0
Th-232	90232.50c	100.0	230.044724	294.0	endf5u	ENDF/B-V.0
Pa-233	91233.50c	0.0	231.038304	294.0	endf5u	ENDF/B-V.0
U-233	92233.50c	0.0	231.037695	294.0	rmccs	ENDF/B-V.0
U-234	92234.50c	0.0055	232.030412	294.0	endf5p	ENDF/B-V.0

Table 5.3.1-1. MCNP Cross Section Libraries Used in the CRC Reactivity Calculations

Element / Isotope	MCNP ZAID	Atom % in Nature	Atomic Wt. Ratio [1]	Temp. (K)	Library Name	Data Source
U-235	92235.53c	0.7200	233.024773	587.0	eprixs	ENDF/B-V.0
U-236	92236.50c	0.0	234.017806	294.0	endf5p	ENDF/B-V.0
U-237	92237.50c	0.0	235.012352	294.0	endf5p	ENDF/B-V.0
U-238	92238.53c	99.2745	236.005803	587.0	eprixs	ENDF/B-V.0
Np-235	93235.35c	0.0	233.024904	0.0	endl85	LLNL
Np-236	93236.35c	0.0	234.018854	0.0	endl85	LLNL
Np-237	93237.50c	0.0	235.011799	294.0	endf5p	ENDF/B-V.0
Np-238	93238.35c	0.0	236.005958	0.0	endl85	LLNL
Pu-237	94237.35c	0.0	235.012031	0.0	endl85	LLNL
Pu-238	94238.50c	0.0	236.004583	294.0	endf5p	ENDF/B-V.0
Pu-239	94239.55c	0.0	236.998573	294.0	rmccs	ENDF/B-V.2
Pu-240	94240.50c	0.0	237.991619	294.0	rmccs	ENDF/B-V.0
Pu-241	94241.50c	0.0	238.986041	294.0	endf5p	ENDF/B-V.0
Pu-242	94242.50c	0.0	239.979326	294.0	endf5p	ENDF/B-V.0
Am-241	95241.50c	0.0	238.986019	294.0	endf5u	ENDF/B-V.0
Am-242m	95242.50c	0.0	239.980121	294.0	endf5u	ENDF/B-V.0
Am-243	95243.50c	0.0	240.973348	294.0	endf5u	ENDF/B-V.0
Cm-242	96242.50c	0.0	239.979418	294.0	endf5u	ENDF/B-V.0
Cm-243	96243.35c	0.0	240.973356	0.0	endl85	LLNL
Cm-244	96244.50c	0.0	241.966119	294.0	endf5u	ENDF/B-V.0
Cm-245	96245.35c	0.0	242.960245	0.0	endl85	LLNL
Cm-246	96246.35c	0.0	243.953373	0.0	endl85	LLNL
Cm-247	96247.35c	0.0	244.947884	0.0	endl85	LLNL
Cm-248	96248.35c	0.0	245.941272	0.0	endl85	LLNL

[1] The atomic weight ratio presented for each isotope/element is the ratio of the isotope/element mass to the mass of a neutron. The mass of a neutron is 1.008664904 amu (p. 57, Ref. 7.5). The atomic weight ratio values are obtained from the "xsdir" file for MCNP as identified on page III-2 of Reference 7.4.

[2] The atom percent in nature of B-10 and B-11 varies significantly between different geographical regions of the world. The atom percents in nature that are listed in Table 5.3.1-1 for B-10 and B-11 were obtained from page 232 of Reference 7.6.

[3] The atomic weight ratio for natural sulfur is utilized in conjunction with the S-32 cross section library in the determination of the sulfur content in the various materials modeled in the MCNP calculations documented herein.

5.3.2. Reactor Materials

The tables presenting calculated material compositions in this section show excessive significant figures. The number of significant figures in the composition values are a result of the composition calculation and should not be interpreted as reflecting an excessively high level of accuracy.

The reactor components modeled in the MCNP CRC reactivity calculations include the following: core liner, core barrel, thermal shield, pressure vessel cladding, pressure vessel, borated moderator, upper plenum region, CRGT flange region, upper core grid region, upper pad region, lower pad region, lower core grid region, and region between the lower core grid and the vessel plate. The material compositions are described in terms of elemental or isotopic weight percents with an overall material density.

The core liner, core barrel, thermal shield, and pressure vessel cladding are composed of Stainless Steel 304 (SS304) (p. 3, Ref. 7.11). The SS304 composition is shown in Table 5.3.2-1. The pressure vessel is composed of carbon steel (p. 3, Ref. 7.11). The carbon steel composition is shown in Table 5.3.2-2.

The borated moderator is composed of a homogeneous mixture of boron and water. The boron concentration in water is provided in terms of parts-per-million (ppm) by mass. Since the moderator in each CRC statepoint configuration has a different boron concentration and temperature, the overall borated moderator composition and density is different in each configuration.

The composition of the borated moderator and the borated moderator constituents in the homogenized spacer grid compositions as defined in the MCNP input decks are calculated by MACE. MACE uses linear interpolation in a steam table to obtain the borated moderator density value as described in Attachment I of Reference 7.14. Other materials in the MCNP input deck that contain borated moderator as a constituent are not calculated by MACE. These other material compositions are calculated in an EXCEL spreadsheet and are provided to MACE as input to be placed in the MCNP input decks. The density of the borated moderator that is used in the spreadsheet calculation of the material compositions is the same as that calculated by MACE. Table 5.3.2-3 presents the borated moderator composition, temperature, and density for each CRC statepoint reactivity calculation. The borated moderator is used throughout the core configuration and between the various reactor components.

The following set of equations are used to calculate the borated moderator compositions shown in Table 5.3.2-3. The atomic weight ratio values for hydrogen, oxygen, boron-10, and boron-11 are obtained from Table 5.3.1-1. The atomic weight ratio for natural boron is 10.718156 (Ref. 7.12).

Equation 5.3.2-1. Boron Weight Percent in Borated Moderator

$$Boron\ wt\ \% = \frac{(Boron\ ppm)(1.0E-4)}{1+(Boron\ ppm)(1.0E-6)}$$

Equation 5.3.2-2. Boron-10 (B-10) Weight Percent in Borated Moderator

$$B\text{-}10\ wt\% = \frac{(B\text{-}10\ atom\%\ in\ B)(B\text{-}10\ Atomic\ Wt.\ Ratio)}{(B\ Atomic\ Wt.\ Ratio)(100.0)}(B\ wt\%)$$

where B is natural boron.

Equation 5.3.2-3. Boron-11 (B-11) Weight Percent in Borated Moderator

$$B\text{-}11\ wt\% = \frac{(B\text{-}11\ atom\%\ in\ B)(B\text{-}11\ Atomic\ Wt.\ Ratio)}{(B\ Atomic\ Wt.\ Ratio)(100.0)}(B\ wt\%)$$

Equation 5.3.2-4. Hydrogen Weight Percent in Borated Moderator

$$Hydrogen\ wt\% = \frac{(H\ Atomic\ Wt.\ Ratio)(2)(100.0-B\ wt\%)}{[(H\ Atomic\ Wt.\ Ratio)(2)+(O\ Atomic\ Wt.\ Ratio)]}$$

where H is hydrogen, B is natural boron, and O is oxygen.

Equation 5.3.2-5. Oxygen Weight Percent in Borated Moderator

$$Oxygen\ wt\% = \frac{(O\ Atomic\ Wt.\ Ratio)(100.0-B\ wt\%)}{[(H\ Atomic\ Wt.\ Ratio)(2)+(O\ Atomic\ Wt.\ Ratio)]}$$

where H is hydrogen, B is natural boron, and O is oxygen.

A large number of homogenized material compositions are provided to MACE as input. These homogenized material compositions are made up of various base components such as SS304, Inconel, zircaloy, and borated moderator that are present in certain volume fractions. The homogenization of the base components into a single homogenized material compositions is performed using Equations 5.3.2-6 through 5.3.2-8. Once the calculations in Equations 5.3.2-6 through 5.3.2-8 are performed, the homogenized material composition is provided as input to MACE in terms of the homogenized material composition density and various isotopic and/or elemental weight percents.

Equation 5.3.2-6. Homogenized Material Density Calculation

$$Homogenized\ Material\ Density = \sum_{m}^{M}\left[(\rho)_m (Volume\ Fraction\ in\ Homogenized\ Material)_m\right]$$

where, m=a single base component material of the homogenized material, M=the total number of base component materials in the homogenized material, ρ=the mass density of the base component material.

Equation 5.3.2-7. Calculation of Mass Fraction of Base Component Material in Homogenized Material

$$\left(\begin{array}{l}\textit{Mass Fraction of Base Component}\\ \textit{Material in Homogenized Material}\end{array}\right)=\left[\frac{(\rho)_m(\textit{Volume Fraction in Homogenized Material})_m}{\textit{Homogenized Material Density}}\right]$$

Equation 5.3.2-8. Calculation of Weight Percent of Base Component Material Constituent in Homogenized Material

$$\left(\begin{array}{l}\textit{Weight Percent of Base}\\ \textit{Component Material}\\ \textit{Constituent in}\\ \textit{Homogenized Material}\end{array}\right)=\left(\begin{array}{l}\textit{Mass Fraction of Base}\\ \textit{Component Material in}\\ \textit{Homogenized Material}\end{array}\right)\left(\begin{array}{l}\textit{Weight Percent of Base}\\ \textit{Component Material Constituent}\\ \textit{in Base Component Material}\end{array}\right)$$

The upper plenum region of the reactor contains borated moderator and hardware composed of SS304 (pp. 8, 14, 18, 20, Ref. 7.11). This region is modeled with a homogenized material composition in the MCNP CRC reactivity calculations. The upper plenum region is modeled as a number of rectangular sub-regions each placed directly above a fuel assembly. The material volume fractions in each of the rectangular upper plenum sub-regions depend on whether or not the fuel assembly below the sub-region is empty or has either a BPRA, RCCA, or APSRA inserted at the critical statepoint. Table 5.3.2-4 contains the material volume fractions for the upper plenum sub-region positioned above a fuel assembly containing no insertion assembly, a BPRA, a RCCA, and an APSRA. The SS304 material composition is presented in Table 5.3.2-1. The borated moderator compositions are presented in Table 5.3.2-3. The component material compositions are used in conjunction with their volume fractions in each of the upper plenum sub-regions to obtain a homogenized material composition and density that can be specified in the MCNP input decks. The calculated homogenized material compositions for the upper plenum sub-regions positioned above a fuel assembly containing no insertion assembly, a BPRA, a RCCA, and an APSRA are presented in Tables 5.3.2-5 through 5.3.2-8, respectively. Due to the difference in moderator specifications between the statepoints, the homogenized material compositions for each of the upper plenum sub-regions are different between CRC statepoints, as shown in Tables 5.3.2-5 through 5.3.2-8.

The CRGT flange region of the reactor contains borated moderator and hardware composed of SS304 (pp. 8, 14, 18, 20, Ref. 7.11). This region is modeled with a homogenized material composition in the MCNP CRC reactivity calculations. The CRGT flange region is modeled as a number of rectangular sub-regions each placed directly above a fuel assembly. The material volume fractions in each of the rectangular CRGT flange sub-regions depend on whether or not the fuel assembly below the sub-region is empty or has either a BPRA, RCCA, or APSRA inserted at the critical statepoint. Table 5.3.2-9 contains the material volume fractions for the CRGT flange sub-region positioned above a fuel assembly containing no insertion assembly, a BPRA, a RCCA, and an APSRA. The SS304 material composition is presented in Table 5.3.2-1. The borated moderator compositions are presented in Table 5.3.2-3. The component material compositions are used in conjunction with their volume fractions in each of the CRGT flange sub-regions to obtain a homogenized material composition and density that can be

specified in the MCNP input decks. The calculated homogenized material compositions for the CRGT flange sub-regions positioned above a fuel assembly containing no insertion assembly, a BPRA, a RCCA, and an APSRA are presented in Tables 5.3.2-10 through 5.3.2-13, respectively. Due to the difference in moderator specifications between the statepoints, the homogenized material compositions for each of the CRGT flange sub-regions are different between CRC statepoints, as shown in Tables 5.3.2-10 through 5.3.2-13.

The upper core grid region of the reactor contains borated moderator and hardware composed of SS304 and zircaloy (pp. 8, 14, 18, 20, Ref. 7.11). This region is modeled with a homogenized material composition in the MCNP CRC reactivity calculations. The upper core grid region is modeled as a number of rectangular sub-regions each placed directly above a fuel assembly. The material volume fractions in each of the rectangular upper core grid sub-regions depend on whether or not the fuel assembly below the sub-region is empty or has either a BPRA, RCCA, or APSRA inserted at the critical statepoint. Table 5.3.2-14 contains the material volume fractions for the upper core grid sub-region positioned above a fuel assembly containing no insertion assembly, a BPRA, a RCCA, and an APSRA. The SS304 material composition is presented in Table 5.3.2-1. The zircaloy material composition is presented in Table 5.3.2-15. The borated moderator compositions are presented in Table 5.3.2-3. The component material compositions are used in conjunction with their volume fractions in each of the upper core grid sub-regions to obtain a homogenized material composition and density that can be specified in the MCNP input decks. The calculated homogenized material compositions for the upper core grid sub-regions positioned above a fuel assembly containing no insertion assembly, a BPRA, a RCCA, and an APSRA are presented in Tables 5.3.2-16 through 5.3.2-19, respectively. Due to the difference in moderator specifications between the statepoints, the homogenized material compositions for each of the upper core grid sub-regions are different between CRC statepoints, as shown in Tables 5.3.2-16 through 5.3.2-19.

The upper pad region of the reactor contains borated moderator and hardware composed of SS304 and zircaloy (pp. 8, 14, 18, 20, Ref. 7.11). This region is modeled with a homogenized material composition in the MCNP CRC reactivity calculations. The upper pad region is modeled as a number of rectangular sub-regions each placed directly above a fuel assembly. The material volume fractions in each of the rectangular upper pad sub-regions depend on whether or not the fuel assembly below the sub-region is empty or has either a BPRA, RCCA, or APSRA inserted at the critical statepoint. Table 5.3.2-20 contains the material volume fractions for the upper pad sub-region positioned above a fuel assembly containing no insertion assembly, a BPRA, a RCCA, and an APSRA. The SS304 material composition is presented in Table 5.3.2-1. The zircaloy material composition is presented in Table 5.3.2-15. The borated moderator compositions are presented in Table 5.3.2-3. The component material compositions are used in conjunction with their volume fractions in each of the upper pad sub-regions to obtain a homogenized material composition and density that can be specified in the MCNP input decks. The calculated homogenized material compositions for the upper pad sub-regions positioned above a fuel assembly containing no insertion assembly, a BPRA, a RCCA, and an APSRA are presented in Tables 5.3.2-21 through 5.3.2-24, respectively. Due to the difference in moderator specifications between the statepoints, the homogenized material compositions for each of the upper pad sub-regions are different between CRC statepoints, as shown in Tables 5.3.2-21 through 5.3.2-24.

The lower core pad region contains SS304 hardware and borated moderator. The volume fractions of SS304 and borated moderator in the lower core pad region is presented in Table 5.3.2-25. The SS304 and borated moderator compositions are presented in Tables 5.3.2-1 and 5.3.2-3, respectively. The

calculated homogenized material compositions for the lower core pad region are presented in Table 5.3.2-26. The homogenized material composition for the lower core pad region is different between CRC statepoints, as shown in Table 5.3.2-26, due to the difference in moderator specifications between the statepoints.

The lower core grid region contains SS304 hardware and borated moderator. The volume fractions of SS304 and borated moderator in the lower core grid region is presented in Table 5.3.2-27. The SS304 and borated moderator compositions are presented in Tables 5.3.2-1 and 5.3.2-3, respectively. The calculated homogenized material compositions for the lower core grid region are presented in Table 5.3.2-28. The homogenized material composition for the lower core grid region is different between CRC statepoints, as shown in Table 5.3.2-28, due to the difference in moderator specifications between the statepoints.

The region between the lower core grid and vessel plate contains SS304 hardware and borated moderator. The volume fractions of SS304 and borated moderator in this region is presented in Table 5.3.2-29. The SS304 and borated moderator compositions are presented in Tables 5.3.2-1 and 5.3.2-3, respectively. The calculated homogenized material compositions for the region between the lower core grid and vessel plate are presented in Table 5.3.2-30. The homogenized material composition for this region is different between CRC statepoints, as shown in Table 5.3.2-30, due to the difference in moderator specifications between the statepoints.

The homogenizations of the upper and lower reactor internals regions are expected to have a minimal effect on the core reactivity due to their limited reactivity worth and proximity to the active fuel. The primary objective in modeling the upper and lower reactor internals regions is to obtain a reasonable approximation of the axial leakage from the reactor core.

Table 5.3.2-1. Type 304 Stainless Steel Composition (p. 12, Ref. 7.7)

Element / Isotope	MCNP ZAID	Wt. %	Element / Isotope	MCNP ZAID	Wt. %
C-nat	6000.50c	0.080	Fe-54	26054.60c	3.918
N-14	7014.50c	0.100	Fe-56	26056.60c	63.156
Si-nat	14000.50c	0.750	Fe-57	26057.60c	1.472
P-31	15031.50c	0.045	Fe-58	26058.60c	0.200
S-nat	16032.50c	0.030	Ni-58	28058.60c	6.234
Cr-50	24050.60c	0.793	Ni-60	28060.60c	2.465
Cr-52	24052.60c	15.903	Ni-61	28061.60c	0.109
Cr-53	24053.60c	1.838	Ni-62	28062.60c	0.350
Cr-54	24054.60c	0.466	Ni-64	28064.60c	0.092
Mn-55	25055.50c	2.000	Density = 7.9 g/cm^3		

Table 5.3.2-2. Grade 55 A 516 Carbon Steel Composition (p. 5, Ref. 7.7)[1]

Element / Isotope	MCNP ZAID	Wt. %	Element / Isotope	MCNP ZAID	Wt. %
C-nat	6000.50c	0.220	Fe-54	26054.60c	5.615
Si-nat	14000.50c	0.275	Fe-56	26056.60c	90.524
P-31	15031.50c	0.035	Fe-57	26057.60c	2.110
S-nat	16032.50c	0.035	Fe-58	26058.60c	0.286
Mn-55	25055.50c	0.900	Density = 7.832 g/cm^3		

[1] The pressure vessel was actually made of CS508 carbon steel (p. 3, Ref. 7.11). Grade 55 A 516 was substituted for CS508. The pressure vessel has no neutronic importance with respect to the k_{eff} of the reactor core. Therefore, this substitution is acceptable.

Table 5.3.2-3. Borated Moderator Composition for Each CRC Statepoint Calculation

Cycle / EFPD	Temp. (F)	Boron (ppm)	Density (g/cm^3)	H wt%	O wt%	B-10 wt%	B-11 wt%
1 / 0.0	532.0	1609	0.76815	11.17351	88.66586	0.02885	0.13179
5 / 0.0	532.0	1178	0.76815	11.17832	88.70403	0.02113	0.09653
5 / 114.4	532.0	777	0.76815	11.18280	88.73957	0.01394	0.06370

Table 5.3.2-4. Upper Plenum Sub-Region Material Volume Fractions

Insertion Assembly	Material Volume Fractions	
	SS304	Borated Water
None (p. 8, Ref. 7.11)	0.0578	0.9422
BPRA (p. 20, Ref. 7.11)	0.0699	0.9301
RCCA (p. 14, Ref. 7.11)	0.0934	0.9066
APSRA (p. 18, Ref. 7.11)	0.1096	0.8904

Table 5.3.2-5. Homogenized Composition for Upper Plenum Sub-Region Above a Fuel Assembly Containing No Insertion Assembly

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.030948	0.030948	0.030948
7014.50c	0.038684	0.038684	0.038684
14000.50c	0.290133	0.290133	0.290133
15031.50c	0.017408	0.017408	0.017408
16032.50c	0.011605	0.011605	0.011605
24050.60c	0.306769	0.306769	0.306769

Table 5.3.2-5. Homogenized Composition for Upper Plenum Sub-Region Above a Fuel Assembly Containing No Insertion Assembly

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
24052.60c	6.152030	6.152030	6.152030
24053.60c	0.710940	0.710940	0.710940
24054.60c	0.180324	0.180324	0.180324
25055.50c	0.773688	0.773688	0.773688
26054.60c	1.515476	1.515476	1.515476
26056.60c	24.431495	24.431495	24.431495
26057.60c	0.569365	0.569365	0.569365
26058.60c	0.077246	0.077246	0.077246
28058.60c	2.411585	2.411585	2.411585
28060.60c	0.953717	0.953717	0.953717
28061.60c	0.041980	0.041980	0.041980
28062.60c	0.135554	0.135554	0.135554
28064.60c	0.035470	0.035470	0.035470
1001.50c	6.851086	6.854044	6.856795
5010.50c	0.017727	0.012978	0.008560
5011.56c	0.080976	0.059285	0.039104
8016.50c	54.365869	54.389339	54.411174
Density (g/cm^3)	1.180373	1.180373	1.180373

Table 5.3.2-6. Homogenized Composition for Upper Plenum Sub-Region Above a Fuel Assembly Containing a BPRA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.034876	0.034876	0.034876
7014.50c	0.043595	0.043595	0.043595
14000.50c	0.326966	0.326966	0.326966
15031.50c	0.019618	0.019618	0.019618
16032.50c	0.013079	0.013079	0.013079
24050.60c	0.345714	0.345714	0.345714
24052.60c	6.933046	6.933046	6.933046
24053.60c	0.801196	0.801196	0.801196
24054.60c	0.203216	0.203216	0.203216
25055.50c	0.871909	0.871909	0.871909

Table 5.3.2-6. Homogenized Composition for Upper Plenum Sub-Region Above a Fuel Assembly Containing a BPRA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
26054.60c	1.707870	1.707870	1.707870
26056.60c	27.533139	27.533139	27.533139
26057.60c	0.641648	0.641648	0.641648
26058.60c	0.087052	0.087052	0.087052
28058.60c	2.717742	2.717742	2.717742
28060.60c	1.074794	1.074794	1.074794
28061.60c	0.047310	0.047310	0.047310
28062.60c	0.152763	0.152763	0.152763
28064.60c	0.039973	0.039973	0.039973
1001.50c	6.302347	6.305068	6.307599
5010.50c	0.016307	0.011939	0.007875
5011.56c	0.074490	0.054536	0.035972
8016.50c	50.011424	50.033014	50.053100
Density (g/cm^3)	1.266668	1.266668	1.266668

Table 5.3.2-7. Homogenized Composition for Upper Plenum Sub-Region Above a Fuel Assembly Containing a RCCA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.041156	0.041156	0.041156
7014.50c	0.051445	0.051445	0.051445
14000.50c	0.385838	0.385838	0.385838
15031.50c	0.023150	0.023150	0.023150
16032.50c	0.015434	0.015434	0.015434
24050.60c	0.407962	0.407962	0.407962
24052.60c	8.181384	8.181384	8.181384
24053.60c	0.945456	0.945456	0.945456
24054.60c	0.239807	0.239807	0.239807
25055.50c	1.028902	1.028902	1.028902
26054.60c	2.015383	2.015383	2.015383
26056.60c	32.490650	32.490650	32.490650
26057.60c	0.757180	0.757180	0.757180
26058.60c	0.102727	0.102727	0.102727

Table 5.3.2-7. Homogenized Composition for Upper Plenum Sub-Region Above a Fuel Assembly Containing a RCCA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
28058.60c	3.207088	3.207088	3.207088
28060.60c	1.268317	1.268317	1.268317
28061.60c	0.055828	0.055828	0.055828
28062.60c	0.180269	0.180269	0.180269
28064.60c	0.047170	0.047170	0.047170
1001.50c	5.425270	5.427612	5.429791
5010.50c	0.014037	0.010277	0.006779
5011.56c	0.064123	0.046947	0.030966
8016.50c	43.051498	43.070083	43.087374
Density (g/cm^3)	1.434267	1.434267	1.434267

Table 5.3.2-8. Homogenized Composition for Upper Plenum Sub-Region Above a Fuel Assembly Containing an APSRA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.044694	0.044694	0.044694
7014.50c	0.055868	0.055868	0.055868
14000.50c	0.419008	0.419008	0.419008
15031.50c	0.025140	0.025140	0.025140
16032.50c	0.016760	0.016760	0.016760
24050.60c	0.443033	0.443033	0.443033
24052.60c	8.884724	8.884724	8.884724
24053.60c	1.026735	1.026735	1.026735
24054.60c	0.260423	0.260423	0.260423
25055.50c	1.117355	1.117355	1.117355
26054.60c	2.188642	2.188642	2.188642
26056.60c	35.283819	35.283819	35.283819
26057.60c	0.822274	0.822274	0.822274
26058.60c	0.111558	0.111558	0.111558
28058.60c	3.482796	3.482796	3.482796
28060.60c	1.377352	1.377352	1.377352
28061.60c	0.060628	0.060628	0.060628
28062.60c	0.195767	0.195767	0.195767

Table 5.3.2-8. Homogenized Composition for Upper Plenum Sub-Region Above a Fuel Assembly Containing an APSRA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
28064.60c	0.051226	0.051226	0.051226
1001.50c	4.931106	4.933234	4.935215
5010.50c	0.012759	0.009341	0.006161
5011.56c	0.058283	0.042671	0.028145
8016.50c	39.130123	39.147016	39.162732
Density (g/cm^3)	1.549803	1.549803	1.549803

Table 5.3.2-9. CRGT Flange Sub-Region Material Volume Fractions

Insertion Assembly	Material Volume Fractions	
	SS304	Borated Water
None (p. 8, Ref. 7.11)	0.1381	0.8619
BPRA (p. 20, Ref. 7.11)	0.1827	0.8173
RCCA (p. 14, Ref. 7.11)	0.1945	0.8055
APSRA (p. 18, Ref. 7.11)	0.2212	0.7788

Table 5.3.2-10. Homogenized Composition for CRGT Flange Sub-Region Above a Fuel Assembly Containing No Insertion Assembly

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.049787	0.049787	0.049787
7014.50c	0.062233	0.062233	0.062233
14000.50c	0.466751	0.466751	0.466751
15031.50c	0.028005	0.028005	0.028005
16032.50c	0.018670	0.018670	0.018670
24050.60c	0.493514	0.493514	0.493514
24052.60c	9.897070	9.897070	9.897070
24053.60c	1.143724	1.143724	1.143724
24054.60c	0.290096	0.290096	0.290096
25055.50c	1.244669	1.244669	1.244669
26054.60c	2.438021	2.438021	2.438021
26056.60c	39.304136	39.304136	39.304136
26057.60c	0.915966	0.915966	0.915966
26058.60c	0.124269	0.124269	0.124269

Table 5.3.2-10. Homogenized Composition for CRGT Flange Sub-Region Above a Fuel Assembly Containing No Insertion Assembly

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
28058.60c	3.879633	3.879633	3.879633
28060.60c	1.534291	1.534291	1.534291
28061.60c	0.067536	0.067536	0.067536
28062.60c	0.218073	0.218073	0.218073
28064.60c	0.057062	0.057062	0.057062
1001.50c	4.219836	4.221658	4.223352
5010.50c	0.010918	0.007994	0.005273
5011.56c	0.049876	0.036516	0.024086
8016.50c	33.485939	33.500395	33.513844
Density (g/cm^3)	1.753060	1.753060	1.753060

Table 5.3.2-11. Homogenized Composition for CRGT Flange Sub-Region Above a Fuel Assembly Containing a BPRA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.055750	0.055750	0.055750
7014.50c	0.069688	0.069688	0.069688
14000.50c	0.522658	0.522658	0.522658
15031.50c	0.031359	0.031359	0.031359
16032.50c	0.020906	0.020906	0.020906
24050.60c	0.552626	0.552626	0.552626
24052.60c	11.082525	11.082525	11.082525
24053.60c	1.280717	1.280717	1.280717
24054.60c	0.324843	0.324843	0.324843
25055.50c	1.393754	1.393754	1.393754
26054.60c	2.730043	2.730043	2.730043
26056.60c	44.011925	44.011925	44.011925
26057.60c	1.025679	1.025679	1.025679
26058.60c	0.139154	0.139154	0.139154
28058.60c	4.344330	4.344330	4.344330
28060.60c	1.718066	1.718066	1.718066
28061.60c	0.075625	0.075625	0.075625
28062.60c	0.244193	0.244193	0.244193

Table 5.3.2-11. Homogenized Composition for CRGT Flange Sub-Region Above a Fuel Assembly Containing a BPRA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
28064.60c	0.063897	0.063897	0.063897
1001.50c	3.386939	3.388402	3.389762
5010.50c	0.008763	0.006416	0.004232
5011.56c	0.040032	0.029308	0.019332
8016.50c	26.876601	26.888204	26.898998
Density (g/cm^3)	2.071141	2.071141	2.071141

Table 5.3.2-12. Homogenized Composition for CRGT Flange Sub-Region Above a Fuel Assembly Containing a RCCA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.057033	0.057033	0.057033
7014.50c	0.071292	0.071292	0.071292
14000.50c	0.534689	0.534689	0.534689
15031.50c	0.032081	0.032081	0.032081
16032.50c	0.021388	0.021388	0.021388
24050.60c	0.565347	0.565347	0.565347
24052.60c	11.337632	11.337632	11.337632
24053.60c	1.310198	1.310198	1.310198
24054.60c	0.332320	0.332320	0.332320
25055.50c	1.425836	1.425836	1.425836
26054.60c	2.792885	2.792885	2.792885
26056.60c	45.025029	45.025029	45.025029
26057.60c	1.049288	1.049288	1.049288
26058.60c	0.142357	0.142357	0.142357
28058.60c	4.444331	4.444331	4.444331
28060.60c	1.757614	1.757614	1.757614
28061.60c	0.077366	0.077366	0.077366
28062.60c	0.249814	0.249814	0.249814
28064.60c	0.065368	0.065368	0.065368
1001.50c	3.207702	3.209087	3.210375
5010.50c	0.008300	0.006076	0.004008
5011.56c	0.037913	0.027757	0.018309

Table 5.3.2-12. Homogenized Composition for CRGT Flange Sub-Region Above a Fuel Assembly Containing a RCCA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
8016.50c	25.454289	25.465277	25.475501
Density (g/cm^3)	2.155296	2.155296	2.155296

Table 5.3.2-13. Homogenized Composition for CRGT Flange Sub-Region Above a Fuel Assembly Containing an APSRA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.059597	0.059597	0.059597
7014.50c	0.074497	0.074497	0.074497
14000.50c	0.558725	0.558725	0.558725
15031.50c	0.033523	0.033523	0.033523
16032.50c	0.022349	0.022349	0.022349
24050.60c	0.590761	0.590761	0.590761
24052.60c	11.847298	11.847298	11.847298
24053.60c	1.369096	1.369096	1.369096
24054.60c	0.347259	0.347259	0.347259
25055.50c	1.489933	1.489933	1.489933
26054.60c	2.918435	2.918435	2.918435
26056.60c	47.049060	47.049060	47.049060
26057.60c	1.096458	1.096458	1.096458
26058.60c	0.148757	0.148757	0.148757
28058.60c	4.644120	4.644120	4.644120
28060.60c	1.836625	1.836625	1.836625
28061.60c	0.080844	0.080844	0.080844
28062.60c	0.261044	0.261044	0.261044
28064.60c	0.068307	0.068307	0.068307
1001.50c	2.849613	2.850843	2.851988
5010.50c	0.007373	0.005398	0.003561
5011.56c	0.033681	0.024659	0.016265
8016.50c	22.612720	22.622482	22.631564
Density (g/cm^3)	2.345717	2.345717	2.345717

Table 5.3.2-14. Upper Core Grid Sub-Region Material Volume Fractions

Insertion Assembly	Material Volume Fractions		
	SS304	zircaloy	Borated Water
None (p. 8, Ref. 7.11)	0.2491	0.0000	0.7509
BPRA (p. 20, Ref. 7.11)	0.2937	0.0069	0.6994
RCCA (p. 14, Ref. 7.11)	0.3481	0.0000	0.6519
APSRA (p. 18, Ref. 7.11)	0.2828	0.0000	0.7172

Table 5.3.2-15. Zircaloy-4 Composition (p. 21, Ref. 7.7)

Element / Isotope	MCNP ZAID	Wt. %	Element / Isotope	MCNP ZAID	Wt. %
Cr-50	24050.60c	0.004	Fe-57	26057.60c	0.004
Cr-52	24052.60c	0.084	Fe-58	26058.60c	0.001
Cr-53	24053.60c	0.010	O-16	8016.50c	0.120
Cr-54	24054.60c	0.002	Zr-nat	40000.60c	98.180
Fe-54	26054.60c	0.011	Sn-nat	50000.35c	1.400
Fe-56	26056.60c	0.184	Density = 6.56 g/cm^3		

Table 5.3.2-16. Homogenized Composition for Upper Core Grid Sub-Region Above a Fuel Assembly Containing No Insertion Assembly

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.061866	0.061866	0.061866
7014.50c	0.077333	0.077333	0.077333
14000.50c	0.579998	0.579998	0.579998
15031.50c	0.034800	0.034800	0.034800
16032.50c	0.023200	0.023200	0.023200
24050.60c	0.613254	0.613254	0.613254
24052.60c	12.298374	12.298374	12.298374
24053.60c	1.421223	1.421223	1.421223
24054.60c	0.360481	0.360481	0.360481
25055.50c	1.546661	1.546661	1.546661
26054.60c	3.029552	3.029552	3.029552
26056.60c	48.840414	48.840414	48.840414
26057.60c	1.138204	1.138204	1.138204
26058.60c	0.154420	0.154420	0.154420
28058.60c	4.820941	4.820941	4.820941

Table 5.3.2-16. Homogenized Composition for Upper Core Grid Sub-Region Above a Fuel Assembly Containing No Insertion Assembly

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
28060.60c	1.906552	1.906552	1.906552
28061.60c	0.083922	0.083922	0.083922
28062.60c	0.270983	0.270983	0.270983
28064.60c	0.070907	0.070907	0.070907
1001.50c	2.532689	2.533782	2.534799
5010.50c	0.006553	0.004798	0.003165
5011.56c	0.029935	0.021916	0.014456
8016.50c	20.097810	20.106486	20.114559
Density (g/cm^3)	2.544695	2.544695	2.544695

Table 5.3.2-17. Homogenized Composition for Upper Core Grid Sub-Region Above a Fuel Assembly Containing a BPRA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.063946	0.063946	0.063946
7014.50c	0.079932	0.079932	0.079932
14000.50c	0.599493	0.599493	0.599493
15031.50c	0.035970	0.035970	0.035970
16032.50c	0.023980	0.023980	0.023980
24050.60c	0.633932	0.633932	0.633932
24052.60c	12.713064	12.713064	12.713064
24053.60c	1.469145	1.469145	1.469145
24054.60c	0.372636	0.372636	0.372636
25055.50c	1.598648	1.598648	1.598648
26054.60c	3.131562	3.131562	3.131562
26056.60c	50.484951	50.484951	50.484951
26057.60c	1.176530	1.176530	1.176530
26058.60c	0.159620	0.159620	0.159620
28058.60c	4.982987	4.982987	4.982987
28060.60c	1.970637	1.970637	1.970637
28061.60c	0.086743	0.086743	0.086743
28062.60c	0.280092	0.280092	0.280092
28064.60c	0.073291	0.073291	0.073291

Table 5.3.2-17. Homogenized Composition for Upper Core Grid Sub-Region Above a Fuel Assembly Containing a BPRA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
1001.50c	2.068012	2.068905	2.069735
5010.50c	0.005351	0.003917	0.002584
5011.56c	0.024443	0.017895	0.011804
8016.50c	16.412303	16.419387	16.425978
40000.60c	1.530974	1.530974	1.530974
50000.35c	0.021831	0.021831	0.021831
Density (g/cm^3)	2.902740	2.902740	2.902740

Table 5.3.2-18. Homogenized Composition for Upper Core Grid Sub-Region Above a Fuel Assembly Containing a RCCA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.067676	0.067676	0.067676
7014.50c	0.084596	0.084596	0.084596
14000.50c	0.634467	0.634467	0.634467
15031.50c	0.038068	0.038068	0.038068
16032.50c	0.025379	0.025379	0.025379
24050.60c	0.670846	0.670846	0.670846
24052.60c	13.453350	13.453350	13.453350
24053.60c	1.554694	1.554694	1.554694
24054.60c	0.394335	0.394335	0.394335
25055.50c	1.691912	1.691912	1.691912
26054.60c	3.314066	3.314066	3.314066
26056.60c	53.427160	53.427160	53.427160
26057.60c	1.245096	1.245096	1.245096
26058.60c	0.168922	0.168922	0.168922
28058.60c	5.273689	5.273689	5.273689
28060.60c	2.085602	2.085602	2.085602
28061.60c	0.091803	0.091803	0.091803
28062.60c	0.296432	0.296432	0.296432
28064.60c	0.077566	0.077566	0.077566
1001.50c	1.721207	1.721950	1.722642
5010.50c	0.004453	0.003261	0.002151

Table 5.3.2-18. Homogenized Composition for Upper Core Grid Sub-Region Above a Fuel Assembly Containing a RCCA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
5011.56c	0.020344	0.014894	0.009824
8016.50c	13.658408	13.664304	13.669790
Density (g/cm^3)	3.250748	3.250748	3.250748

Table 5.3.2-19. Homogenized Composition for Upper Core Grid Sub-Region Above a Fuel Assembly Containing an APSRA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.064175	0.064175	0.064175
7014.50c	0.080219	0.080219	0.080219
14000.50c	0.601640	0.601640	0.601640
15031.50c	0.036098	0.036098	0.036098
16032.50c	0.024066	0.024066	0.024066
24050.60c	0.636137	0.636137	0.636137
24052.60c	12.757276	12.757276	12.757276
24053.60c	1.474254	1.474254	1.474254
24054.60c	0.373932	0.373932	0.373932
25055.50c	1.604373	1.604373	1.604373
26054.60c	3.142597	3.142597	3.142597
26056.60c	50.662847	50.662847	50.662847
26057.60c	1.180675	1.180675	1.180675
26058.60c	0.160182	0.160182	0.160182
28058.60c	5.000829	5.000829	5.000829
28060.60c	1.977694	1.977694	1.977694
28061.60c	0.087053	0.087053	0.087053
28062.60c	0.281095	0.281095	0.281095
28064.60c	0.073553	0.073553	0.073553
1001.50c	2.210266	2.211220	2.212108
5010.50c	0.005719	0.004187	0.002762
5011.56c	0.026124	0.019126	0.012616
8016.50c	17.539269	17.546841	17.553885
Density (g/cm^3)	2.785039	2.785039	2.785039

Table 5.3.2-20. Upper Pad Sub-Region Material Volume Fractions

Insertion Assembly	Material Volume Fractions		
	SS304	zircaloy	Borated Water
None (p. 8, Ref. 7.11)	0.3418	0.0000	0.6582
BPRA (p. 20, Ref. 7.11)	0.3890	0.0120	0.5990
RCCA (p. 14, Ref. 7.11)	0.3748	0.0000	0.6252
APSRA (p. 18, Ref. 7.11)	0.3748	0.0000	0.6252

Table 5.3.2-21. Homogenized Composition for Upper Pad Sub-Region Above a Fuel Assembly Containing No Insertion Assembly

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.067383	0.067383	0.067383
7014.50c	0.084229	0.084229	0.084229
14000.50c	0.631716	0.631716	0.631716
15031.50c	0.037903	0.037903	0.037903
16032.50c	0.025269	0.025269	0.025269
24050.60c	0.667937	0.667937	0.667937
24052.60c	13.395009	13.395009	13.395009
24053.60c	1.547952	1.547952	1.547952
24054.60c	0.392625	0.392625	0.392625
25055.50c	1.684575	1.684575	1.684575
26054.60c	3.299695	3.299695	3.299695
26056.60c	53.195470	53.195470	53.195470
26057.60c	1.239697	1.239697	1.239697
26058.60c	0.168190	0.168190	0.168190
28058.60c	5.250819	5.250819	5.250819
28060.60c	2.076558	2.076558	2.076558
28061.60c	0.091405	0.091405	0.091405
28062.60c	0.295146	0.295146	0.295146
28064.60c	0.077230	0.077230	0.077230
1001.50c	1.762197	1.762958	1.763666
5010.50c	0.004560	0.003338	0.002202
5011.56c	0.020828	0.015249	0.010058
8016.50c	13.983681	13.989717	13.995334
Density (g/cm^3)	3.205818	3.205818	3.205818

Table 5.3.2-22. Homogenized Composition for Upper Pad Sub-Region Above a Fuel Assembly Containing a BPRA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.068065	0.068065	0.068065
7014.50c	0.085082	0.085082	0.085082
14000.50c	0.638112	0.638112	0.638112
15031.50c	0.038287	0.038287	0.038287
16032.50c	0.025524	0.025524	0.025524
24050.60c	0.674791	0.674791	0.674791
24052.60c	13.532469	13.532469	13.532469
24053.60c	1.563837	1.563837	1.563837
24054.60c	0.396654	0.396654	0.396654
25055.50c	1.701633	1.701633	1.701633
26054.60c	3.333355	3.333355	3.333355
26056.60c	53.738121	53.738121	53.738121
26057.60c	1.252343	1.252343	1.252343
26058.60c	0.169906	0.169906	0.169906
28058.60c	5.303988	5.303988	5.303988
28060.60c	2.097585	2.097585	2.097585
28061.60c	0.092331	0.092331	0.092331
28062.60c	0.298135	0.298135	0.298135
28064.60c	0.078012	0.078012	0.078012
1001.50c	1.423382	1.423996	1.424568
5010.50c	0.003683	0.002696	0.001778
5011.56c	0.016824	0.012317	0.008124
8016.50c	11.297671	11.302547	11.307083
40000.60c	2.139771	2.139771	2.139771
50000.35c	0.030512	0.030512	0.030512
Density (g/cm^3)	3.611943	3.611943	3.611943

Table 5.3.2-23. Homogenized Composition for Upper Pad Sub-Region Above a Fuel Assembly Containing a RCCA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.068835	0.068835	0.068835
7014.50c	0.086044	0.086044	0.086044

Table 5.3.2-23. Homogenized Composition for Upper Pad Sub-Region Above a Fuel Assembly Containing a RCCA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
14000.50c	0.645330	0.645330	0.645330
15031.50c	0.038720	0.038720	0.038720
16032.50c	0.025813	0.025813	0.025813
24050.60c	0.682332	0.682332	0.682332
24052.60c	13.683696	13.683696	13.683696
24053.60c	1.581313	1.581313	1.581313
24054.60c	0.401087	0.401087	0.401087
25055.50c	1.720881	1.720881	1.720881
26054.60c	3.370809	3.370809	3.370809
26056.60c	54.341927	54.341927	54.341927
26057.60c	1.266415	1.266415	1.266415
26058.60c	0.171815	0.171815	0.171815
28058.60c	5.363984	5.363984	5.363984
28060.60c	2.121312	2.121312	2.121312
28061.60c	0.093375	0.093375	0.093375
28062.60c	0.301507	0.301507	0.301507
28064.60c	0.078894	0.078894	0.078894
1001.50c	1.559368	1.560041	1.560667
5010.50c	0.004035	0.002954	0.001948
5011.56c	0.018431	0.013494	0.008900
8016.50c	12.374152	12.379494	12.384464
Density (g/cm^3)	3.441169	3.441169	3.441169

Table 5.3.2-24. Homogenized Composition for Upper Pad Sub-Region Above a Fuel Assembly Containing an APSRA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.068835	0.068835	0.068835
7014.50c	0.086044	0.086044	0.086044
14000.50c	0.645330	0.645330	0.645330
15031.50c	0.038720	0.038720	0.038720
16032.50c	0.025813	0.025813	0.025813
24050.60c	0.682332	0.682332	0.682332

Table 5.3.2-24. Homogenized Composition for Upper Pad Sub-Region Above a Fuel Assembly Containing an APSRA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
24052.60c	13.683696	13.683696	13.683696
24053.60c	1.581313	1.581313	1.581313
24054.60c	0.401087	0.401087	0.401087
25055.50c	1.720881	1.720881	1.720881
26054.60c	3.370809	3.370809	3.370809
26056.60c	54.341927	54.341927	54.341927
26057.60c	1.266415	1.266415	1.266415
26058.60c	0.171815	0.171815	0.171815
28058.60c	5.363984	5.363984	5.363984
28060.60c	2.121312	2.121312	2.121312
28061.60c	0.093375	0.093375	0.093375
28062.60c	0.301507	0.301507	0.301507
28064.60c	0.078894	0.078894	0.078894
1001.50c	1.559368	1.560041	1.560667
5010.50c	0.004035	0.002954	0.001948
5011.56c	0.018431	0.013494	0.008900
8016.50c	12.374152	12.379494	12.384464
Density (g/cm^3)	3.441169	3.441169	3.441169

Table 5.3.2-25. Lower Core Pad Region Material Volume Fractions (p. 8, Ref. 7.11)

SS304	Borated Water
0.2848	0.7152

Table 5.3.2-26. Homogenized Composition for Lower Core Pad Region

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.064299	0.064299	0.064299
7014.50c	0.080374	0.080374	0.080374
14000.50c	0.602807	0.602807	0.602807
15031.50c	0.036168	0.036168	0.036168
16032.50c	0.024112	0.024112	0.024112
24050.60c	0.637371	0.637371	0.637371

Table 5.3.2-26. Homogenized Composition for Lower Core Pad Region

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
24052.60c	12.782034	12.782034	12.782034
24053.60c	1.477115	1.477115	1.477115
24054.60c	0.374658	0.374658	0.374658
25055.50c	1.607486	1.607486	1.607486
26054.60c	3.148696	3.148696	3.148696
26056.60c	50.761166	50.761166	50.761166
26057.60c	1.182967	1.182967	1.182967
26058.60c	0.160493	0.160493	0.160493
28058.60c	5.010534	5.010534	5.010534
28060.60c	1.981532	1.981532	1.981532
28061.60c	0.087222	0.087222	0.087222
28062.60c	0.281640	0.281640	0.281640
28064.60c	0.073696	0.073696	0.073696
1001.50c	2.192872	2.193818	2.194699
5010.50c	0.005674	0.004154	0.002740
5011.56c	0.025918	0.018976	0.012516
8016.50c	17.401238	17.408750	17.415739
Density (g/cm^3)	2.799302	2.799302	2.799302

Table 5.3.2-27. Lower Core Grid Region Material Volume Fractions (p. 8, Ref. 7.11)

SS304	Borated Water
0.2400	0.7600

Table 5.3.2-28. Homogenized Composition for Lower Core Grid Region

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.061166	0.061166	0.061166
7014.50c	0.076458	0.076458	0.076458
14000.50c	0.573434	0.573434	0.573434
15031.50c	0.034406	0.034406	0.034406
16032.50c	0.022937	0.022937	0.022937
24050.60c	0.606314	0.606314	0.606314
24052.60c	12.159204	12.159204	12.159204

Table 5.3.2-28. Homogenized Composition for Lower Core Grid Region

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
24053.60c	1.405140	1.405140	1.405140
24054.60c	0.356402	0.356402	0.356402
25055.50c	1.529158	1.529158	1.529158
26054.60c	2.995269	2.995269	2.995269
26056.60c	48.287728	48.287728	48.287728
26057.60c	1.125324	1.125324	1.125324
26058.60c	0.152673	0.152673	0.152673
28058.60c	4.766386	4.766386	4.766386
28060.60c	1.884978	1.884978	1.884978
28061.60c	0.082972	0.082972	0.082972
28062.60c	0.267917	0.267917	0.267917
28064.60c	0.070105	0.070105	0.070105
1001.50c	2.630469	2.631605	2.632661
5010.50c	0.006806	0.004983	0.003287
5011.56c	0.031091	0.022762	0.015014
8016.50c	20.873734	20.882746	20.891129
Density (g/cm^3)	2.479796	2.479796	2.479796

Table 5.3.2-29. Region Between Lower Core Grid and Vessel Plate Material Volume Fractions (p. 8, Ref. 7.11)

SS304	Borated Water
0.0300	0.9700

Table 5.3.2-30. Homogenized Composition for Region Between Lower Core Grid and Vessel Plate

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.019305	0.019305	0.019305
7014.50c	0.024132	0.024132	0.024132
14000.50c	0.180988	0.180988	0.180988
15031.50c	0.010859	0.010859	0.010859
16032.50c	0.007240	0.007240	0.007240
24050.60c	0.191366	0.191366	0.191366
24052.60c	3.837709	3.837709	3.837709

Table 5.3.2-30. Homogenized Composition for Region Between Lower Core Grid and Vessel Plate

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
24053.60c	0.443493	0.443493	0.443493
24054.60c	0.112488	0.112488	0.112488
25055.50c	0.482636	0.482636	0.482636
26054.60c	0.945372	0.945372	0.945372
26056.60c	15.240656	15.240656	15.240656
26057.60c	0.355177	0.355177	0.355177
26058.60c	0.048187	0.048187	0.048187
28058.60c	1.504375	1.504375	1.504375
28060.60c	0.594940	0.594940	0.594940
28061.60c	0.026188	0.026188	0.026188
28062.60c	0.084560	0.084560	0.084560
28064.60c	0.022127	0.022127	0.022127
1001.50c	8.477118	8.480778	8.484183
5010.50c	0.021934	0.016058	0.010592
5011.56c	0.100195	0.073356	0.048385
8016.50c	67.269030	67.298070	67.325088
Density (g/cm^3)	0.982107	0.982107	0.982107

5.3.3. Fuel Assembly Materials

The fuel assembly materials listed in this section refer to the upper and lower end-fitting materials and the spacer grid materials. The upper end-fitting material compositions vary within a given fuel assembly design depending upon whether the assembly contains no insertion assembly, a BPRA, a RCCA, or an APSRA at the critical statepoint. Both the upper and lower end-fitting homogenized material compositions vary between critical statepoint configurations due to the different moderator conditions. The primary material components in the upper and lower end-fitting regions are SS304, Inconel, zircaloy, and borated moderator. Both the upper and lower end-fitting regions are modeled with material compositions that represent the homogenization of all of the components in the regions. Table 5.3.2-1 presents the material composition of SS304. Table 5.3.2-3 presents the material compositions for the borated moderator in CRC statepoint configuration. Table 5.3.3.1 presents the material composition of Inconel. Table 5.3.2-15 presents the material composition of zircaloy. Table 5.3.3-2 presents the component material volume fractions for the upper end-fitting region for each assembly design. Table 5.3.3-3 presents the component material volume fractions for the lower end-fitting region for each assembly design. Tables 5.3.3-4 through 5.3.3-7 present the upper end-fitting homogenized material compositions for each CRC statepoint configuration for the assemblies containing no insertion assembly, a BPRA, a RCCA, and an APSRA, respectively. Table 5.3.3-8 presents the lower end-fitting

homogenized material compositions for each CRC statepoint configuration for the assemblies regardless of their insertion assembly condition. The homogenized material compositions presented in this section were calculated using the method described in Section 5.3.2.

The upper end spacer grid region is composed of Inconel, zircaloy, and borated moderator (p. 8, Ref. 7.11). The upper end spacer grid region is located directly below the upper end-fitting, and covers a height of 8.573 cm along the length of the fuel assembly (p. 7, Ref. 7.11). The materials of the upper end spacer grid are homogenized and modeled in the region between the fuel rods, guide tubes, and instrument tube. The volume fractions of Inconel, zircaloy, and borated moderator in the upper end spacer grid composition are 0.0457, 0.0069, and 0.9474, respectively (p. 8, Ref. 7.11). MACE Version 3 does not allow the specification of an Inconel/zircaloy spacer grid material combination. Therefore, the zircaloy volume fraction was neglected in the homogenized composition. The borated moderator volume fraction was increased by 0.0069. This modeling approximation has a vanishingly small effect on the system reactivity. The homogenized material composition for each upper spacer grid for a given fuel assembly design will be different between the CRC statepoint configurations due to the different moderator conditions. Table 5.3.3.9 presents the homogenized material compositions for the upper end spacer grid of the assemblies in each CRC statepoint configuration.

The six spacer grids below the upper end spacer grid are called the intermediate spacer grids. These intermediate spacer grids are composed of Inconel (p. 5, Ref. 7.11). The intermediate spacer grid height is 3.81 cm (p. 5, Ref. 7.11). The individual intermediate spacer grid volume is 88.676 cm^3 (p. 5, Ref. 7.11). The volume between the fuel rods, guide tubes, and instrument tube that is occupied by an explicit intermediate spacer grid and borated moderator is 977.531 cm^3 (p. 5, Ref. 7.11). Therefore, the volume fraction of Inconel in the intermediate spacer grid homogenized region is 0.0907. The intermediate spacer grid materials and borated moderator are homogenized and modeled in the region between the fuel rods, guide tubes, and instrument tube over the explicit height of each spacer grid. The homogenized material composition for the intermediate spacer grid of each fuel assembly design will be different between the CRC statepoint configurations due to the different moderator conditions. Table 5.3.3.10 presents the homogenized material compositions for the intermediate spacer grid of the assemblies in each CRC statepoint configuration.

Table 5.3.3-1. Inconel 718 Composition (Ref. 7.8)

Element / Isotope	MCNP ZAID	Wt. %	Element / Isotope	MCNP ZAID	Wt. %
C-nat	6000.50c	0.080	Ni-60	28060.60c	13.993
Si-nat	14000.50c	0.350	Ni-61	28061.60c	0.616
P-31	15031.50c	0.015	Ni-62	28062.60c	1.989
S-nat	16032.50c	0.015	Ni-64	28064.60c	0.520
Cr-50	24050.60c	0.793	B-10	5010.50c	1.078E-03
Cr-52	24052.60c	15.903	B-11	5011.56c	4.925E-03
Cr-53	24053.60c	1.838	Ti-nat	22000.50c	0.900
Cr-54	24054.60c	0.466	Al-27	13027.50c	0.500
Mn-55	25055.50c	0.350	Co-59	27059.50c	1.000

Table 5.3.3-1. Inconel 718 Composition (Ref. 7.8)

Element / Isotope	MCNP ZAID	Wt. %	Element / Isotope	MCNP ZAID	Wt. %
Fe-54	26054.60c	0.958	Cu-63	29063.60c	0.205
Fe-56	26056.60c	15.442	Cu-65	29065.60c	0.095
Fe-57	26057.60c	0.360	Nb-93	41093.50c	2.563
Fe-58	26058.60c	0.049	Mo-nat	42000.50c	3.050
Ni-58	28058.60c	35.382	Ta-181	73181.50c	2.563
Density = 8.19 g/cm^3					

Table 5.3.3-2. Upper End-Fitting Component Material Volume Fractions for Each Assembly Design

Insertion Assembly Specification	Volume Fractions in Upper End-Fitting Region			
	SS304	Inconel	zircaloy	Borated Moderator
No Insertion Assembly (p. 8, Ref. 7.11)	0.2756	0.0441	0.0081	0.6722
BPRA Inserted (p. 20, Ref. 7.11)	0.2874	0.0450	0.0083	0.6593
RCCA Inserted (p. 14, Ref. 7.11)	0.2981	0.0441	0.0081	0.6497
APSRA Inserted (p. 18, Ref. 7.11)	0.2960	0.0441	0.0081	0.6518

Table 5.3.3-3. Lower End-Fitting Component Material Volume Fractions for Each Assembly Design

SS304	Inconel	zircaloy	Borated Moderator
0.1656	0.0306	0.0125	0.7913

Table 5.3.3-4. Homogenized Composition for the Upper End-Fitting of the Fuel Assemblies Containing No Insertion Assembly

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.065341	0.065341	0.065341
7014.50c	0.070055	0.070055	0.070055
14000.50c	0.566086	0.566086	0.566086
15031.50c	0.033268	0.033268	0.033268
16032.50c	0.022760	0.022760	0.022760
24050.60c	0.647766	0.647766	0.647766

Table 5.3.3-4. Homogenized Composition for the Upper End-Fitting of the Fuel Assemblies Containing No Insertion Assembly

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
24052.60c	12.990500	12.990500	12.990500
24053.60c	1.501206	1.501206	1.501206
24054.60c	0.380768	0.380768	0.380768
25055.50c	1.441772	1.441772	1.441772
26054.60c	2.855941	2.855941	2.855941
26056.60c	46.041571	46.041571	46.041571
26057.60c	1.072979	1.072979	1.072979
26058.60c	0.145571	0.145571	0.145571
28058.60c	8.479085	8.479085	8.479085
28060.60c	3.353250	3.353250	3.353250
28061.60c	0.147602	0.147602	0.147602
28062.60c	0.476606	0.476606	0.476606
28064.60c	0.124712	0.124712	0.124712
1001.50c	1.856376	1.857178	1.857923
5010.50c	0.004928	0.003642	0.002445
5011.56c	0.022514	0.016636	0.011168
8016.50c	14.733076	14.739436	14.745352
13027.50c	0.058106	0.058106	0.058106
22000.50c	0.104592	0.104592	0.104592
27059.50c	0.116213	0.116213	0.116213
29063.60c	0.023882	0.023882	0.023882
29065.60c	0.010982	0.010982	0.010982
41093.50c	0.297796	0.297796	0.297796
42000.50c	0.354449	0.354449	0.354449
73181.50c	0.297796	0.297796	0.297796
40000.60c	1.678587	1.678587	1.678587
50000.35c	0.023936	0.023936	0.023936
Density (g/cm^3)	3.107907	3.107907	3.107907

Table 5.3.3-5. Homogenized Composition for the Upper End-Fitting of the Fuel Assemblies Containing a BPRA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD

Table 5.3.3-5. Homogenized Composition for the Upper End-Fitting of the Fuel Assemblies Containing a BPRA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.065977	0.065977	0.065977
7014.50c	0.070954	0.070954	0.070954
14000.50c	0.572467	0.572467	0.572467
15031.50c	0.033657	0.033657	0.033657
16032.50c	0.023014	0.023014	0.023014
24050.60c	0.654074	0.654074	0.654074
24052.60c	13.116996	13.116996	13.116996
24053.60c	1.515824	1.515824	1.515824
24054.60c	0.384476	0.384476	0.384476
25055.50c	1.459393	1.459393	1.459393
26054.60c	2.890173	2.890173	2.890173
26056.60c	46.593440	46.593440	46.593440
26057.60c	1.085840	1.085840	1.085840
26058.60c	0.147316	0.147316	0.147316
28058.60c	8.498433	8.498433	8.498433
28060.60c	3.360902	3.360902	3.360902
28061.60c	0.147939	0.147939	0.147939
28062.60c	0.477693	0.477693	0.477693
28064.60c	0.124996	0.124996	0.124996
1001.50c	1.768407	1.769170	1.769880
5010.50c	0.004700	0.003474	0.002334
5011.56c	0.021469	0.015870	0.010661
8016.50c	14.034993	14.041051	14.046687
13027.50c	0.057588	0.057588	0.057588
22000.50c	0.103658	0.103658	0.103658
27059.50c	0.115175	0.115175	0.115175
29063.60c	0.023668	0.023668	0.023668
29065.60c	0.010884	0.010884	0.010884
41093.50c	0.295137	0.295137	0.295137
42000.50c	0.351285	0.351285	0.351285
73181.50c	0.295137	0.295137	0.295137
40000.60c	1.670585	1.670585	1.670585
50000.35c	0.023822	0.023822	0.023822

Table 5.3.3-5. Homogenized Composition for the Upper End-Fitting of the Fuel Assemblies Containing a BPRA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
Density (g/cm^3)	3.199901	3.199901	3.199901

Table 5.3.3-6. Homogenized Composition for the Upper End-Fitting of the Fuel Assemblies Containing a RCCA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.066484	0.066484	0.066484
7014.50c	0.072054	0.072054	0.072054
14000.50c	0.579082	0.579082	0.579082
15031.50c	0.034082	0.034082	0.034082
16032.50c	0.023274	0.023274	0.023274
24050.60c	0.659090	0.659090	0.659090
24052.60c	13.217598	13.217598	13.217598
24053.60c	1.527450	1.527450	1.527450
24054.60c	0.387425	0.387425	0.387425
25055.50c	1.479755	1.479755	1.479755
26054.60c	2.928778	2.928778	2.928778
26056.60c	47.215806	47.215806	47.215806
26057.60c	1.100344	1.100344	1.100344
26058.60c	0.149284	0.149284	0.149284
28058.60c	8.401824	8.401824	8.401824
28060.60c	3.322696	3.322696	3.322696
28061.60c	0.146257	0.146257	0.146257
28062.60c	0.472263	0.472263	0.472263
28064.60c	0.123575	0.123575	0.123575
1001.50c	1.706148	1.706885	1.707570
5010.50c	0.004534	0.003351	0.002251
5011.56c	0.020710	0.015308	0.010282
8016.50c	13.540859	13.546704	13.552142
13027.50c	0.055254	0.055254	0.055254
22000.50c	0.099457	0.099457	0.099457
27059.50c	0.110507	0.110507	0.110507
29063.60c	0.022709	0.022709	0.022709

Table 5.3.3-6. Homogenized Composition for the Upper End-Fitting of the Fuel Assemblies Containing a RCCA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
29065.60c	0.010443	0.010443	0.010443
41093.50c	0.283175	0.283175	0.283175
42000.50c	0.337047	0.337047	0.337047
73181.50c	0.283175	0.283175	0.283175
40000.60c	1.596174	1.596174	1.596174
50000.35c	0.022761	0.022761	0.022761
Density (g/cm^3)	3.268373	3.268373	3.268373

Table 5.3.3-7. Homogenized Composition for the Upper End-Fitting of the Fuel Assemblies Containing an APSRA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.066382	0.066382	0.066382
7014.50c	0.071876	0.071876	0.071876
14000.50c	0.577923	0.577923	0.577923
15031.50c	0.034009	0.034009	0.034009
16032.50c	0.023228	0.023228	0.023228
24050.60c	0.658081	0.658081	0.658081
24052.60c	13.197350	13.197350	13.197350
24053.60c	1.525110	1.525110	1.525110
24054.60c	0.386831	0.386831	0.386831
25055.50c	1.476369	1.476369	1.476369
26054.60c	2.922284	2.922284	2.922284
26056.60c	47.111112	47.111112	47.111112
26057.60c	1.097904	1.097904	1.097904
26058.60c	0.148953	0.148953	0.148953
28058.60c	8.408713	8.408713	8.408713
28060.60c	3.325420	3.325420	3.325420
28061.60c	0.146377	0.146377	0.146377
28062.60c	0.472650	0.472650	0.472650
28064.60c	0.123677	0.123677	0.123677
1001.50c	1.719542	1.720285	1.720975
5010.50c	0.004569	0.003377	0.002268

Table 5.3.3-7. Homogenized Composition for the Upper End-Fitting of the Fuel Assemblies Containing an APSRA

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
5011.56c	0.020871	0.015427	0.010361
8016.50c	13.647157	13.653047	13.658528
13027.50c	0.055508	0.055508	0.055508
22000.50c	0.099914	0.099914	0.099914
27059.50c	0.111016	0.111016	0.111016
29063.60c	0.022814	0.022814	0.022814
29065.60c	0.010491	0.010491	0.010491
41093.50c	0.284478	0.284478	0.284478
42000.50c	0.338599	0.338599	0.338599
73181.50c	0.284478	0.284478	0.284478
40000.60c	1.603522	1.603522	1.603522
50000.35c	0.022865	0.022865	0.022865
Density (g/cm^3)	3.253396	3.253396	3.253396

Table 5.3.3-8. Homogenized Composition for the Lower End-Fitting of the Fuel Assemblies

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
6000.50c	0.055458	0.055458	0.055458
7014.50c	0.058178	0.058178	0.058178
14000.50c	0.475341	0.475341	0.475341
15031.50c	0.027852	0.027852	0.027852
16032.50c	0.019125	0.019125	0.019125
24050.60c	0.549884	0.549884	0.549884
24052.60c	11.027530	11.027530	11.027530
24053.60c	1.274362	1.274362	1.274362
24054.60c	0.323231	0.323231	0.323231
25055.50c	1.202563	1.202563	1.202563
26054.60c	2.386309	2.386309	2.386309
26056.60c	38.470485	38.470485	38.470485
26057.60c	0.896538	0.896538	0.896538
26058.60c	0.121633	0.121633	0.121633
28058.60c	7.570101	7.570101	7.570101
28060.60c	2.993772	2.993772	2.993772

Table 5.3.3-8. Homogenized Composition for the Lower End-Fitting of the Fuel Assemblies

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
28061.60c	0.131779	0.131779	0.131779
28062.60c	0.425512	0.425512	0.425512
28064.60c	0.111342	0.111342	0.111342
1001.50c	3.020276	3.021579	3.022793
5010.50c	0.007935	0.005842	0.003894
5011.56c	0.036247	0.026684	0.017788
8016.50c	23.971366	23.981712	23.991339
13027.50c	0.055724	0.055724	0.055724
22000.50c	0.100304	0.100304	0.100304
27059.50c	0.111449	0.111449	0.111449
29063.60c	0.022903	0.022903	0.022903
29065.60c	0.010532	0.010532	0.010532
41093.50c	0.285587	0.285587	0.285587
42000.50c	0.339919	0.339919	0.339919
73181.50c	0.285587	0.285587	0.285587
40000.60c	3.580196	3.580196	3.580196
50000.35c	0.051052	0.051052	0.051052
Density (g/cm^3)	2.248693	2.248693	2.248693

Table 5.3.3-9. Homogenized Composition for the Upper End Spacer Grid of the Fuel Assemblies

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
1001.50c	7.396822	7.400007	7.402972
8016.50c	58.696480	58.721748	58.745277
5010.50c	0.019463	0.014353	0.009595
5011.56c	0.088909	0.065566	0.043830
6000.50c	0.027040	0.027040	0.027040
14000.50c	0.118301	0.118301	0.118301
15031.50c	0.005070	0.005070	0.005070
16032.50c	0.005070	0.005070	0.005070
24050.60c	0.268037	0.268037	0.268037
24052.60c	5.375271	5.375271	5.375271
24053.60c	0.621251	0.621251	0.621251

Table 5.3.3-9. Homogenized Composition for the Upper End Spacer Grid of the Fuel Assemblies

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
24054.60c	0.157510	0.157510	0.157510
25055.50c	0.118301	0.118301	0.118301
26054.60c	0.323807	0.323807	0.323807
26056.60c	5.219512	5.219512	5.219512
26057.60c	0.121655	0.121655	0.121655
26058.60c	0.016529	0.016529	0.016529
28058.60c	11.959299	11.959299	11.959299
28060.60c	4.728853	4.728853	4.728853
28061.60c	0.209105	0.209105	0.209105
28062.60c	0.671440	0.671440	0.671440
28064.60c	0.176493	0.176493	0.176493
13027.50c	0.169002	0.169002	0.169002
22000.50c	0.304203	0.304203	0.304203
27059.50c	0.338004	0.338004	0.338004
29063.60c	0.069257	0.069257	0.069257
29065.60c	0.032144	0.032144	0.032144
41093.50c	0.866134	0.866134	0.866134
42000.50c	1.030911	1.030911	1.030911
73181.50c	0.866134	0.866134	0.866134
Density (g/cm^3)	1.107329	1.107329	1.107329

Table 5.3.3-10. Homogenized Composition for the Intermediate Spacer Grid of the Fuel Assemblies

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
1001.50c	5.414355	5.416686	5.418856
8016.50c	42.964878	42.983372	43.000595
5010.50c	0.014536	0.010795	0.007312
5011.56c	0.066399	0.049313	0.033402
6000.50c	0.041234	0.041234	0.041234
14000.50c	0.180400	0.180400	0.180400
15031.50c	0.007731	0.007731	0.007731
16032.50c	0.007731	0.007731	0.007731

Table 5.3.3-10. Homogenized Composition for the Intermediate Spacer Grid of the Fuel Assemblies

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	Cycle 1 0.0 EFPD	Cycle 5 0.0 EFPD	Cycle 5 114.4 EFPD
24050.60c	0.408735	0.408735	0.408735
24052.60c	8.196872	8.196872	8.196872
24053.60c	0.947359	0.947359	0.947359
24054.60c	0.240190	0.240190	0.240190
25055.50c	0.180400	0.180400	0.180400
26054.60c	0.493781	0.493781	0.493781
26056.60c	7.959350	7.959350	7.959350
26057.60c	0.185514	0.185514	0.185514
26058.60c	0.025206	0.025206	0.025206
28058.60c	18.237001	18.237001	18.237001
28060.60c	7.211134	7.211134	7.211134
28061.60c	0.318870	0.318870	0.318870
28062.60c	1.023893	1.023893	1.023893
28064.60c	0.269138	0.269138	0.269138
13027.50c	0.257715	0.257715	0.257715
22000.50c	0.463886	0.463886	0.463886
27059.50c	0.515429	0.515429	0.515429
29063.60c	0.105611	0.105611	0.105611
29065.60c	0.049017	0.049017	0.049017
41093.50c	1.320787	1.320787	1.320787
42000.50c	1.572059	1.572059	1.572059
73181.50c	1.320787	1.320787	1.320787
Density (g/cm^3)	1.441420	1.441420	1.441420

5.3.4. Fuel Rod Materials

The fuel rod components include the fuel rod cladding, the upper and lower fuel rod plenums (including end-caps), and the fuel. The fuel rod cladding is modeled as zircaloy as presented in Table 5.3.2-15. The upper and lower fuel rod plenum regions contain SS304 springs. The zircaloy end-caps are also homogenized in the upper and lower fuel rod plenum. Fission gases present in the upper and lower fuel rod plenum region are modeled as void in the homogenization. Table 5.3.4-1 contains the component material volume fractions for the fuel rod plenum regions (with end-caps included). These component material volume fractions were calculated as follows:

1. The fuel rod upper plenum region includes a homogenization of regions 6 and 7 as presented on page 12 of Reference 7.11. The cladding is not included in the homogenization volume.

2. The volume fraction data as presented on page 12 of Reference 7.11 is as follows:

Region	SS304	zircaloy	Cladding	Gas
6	0.0	0.3344	0.1940	0.4716
7	0.0810	0.0439	0.2313	0.6438
9	0.1230	0.1926	0.2163	0.4681

This data was renormalized to exclude the cladding volume fractions as follows:

Region	SS304	zircaloy	Cladding	Gas
6	0.0	0.4149	0.0	0.5851 (balance)
7	0.1054	0.0571	0.0	0.8375 (balance)
9	0.1569	0.2458	0.0	0.5973 (balance)

3. According to the data provided on pages 11 and 22 of Reference 7.11, the volume fraction of region 6 to the combination of regions 6 and 7 is equal to 4.42/19.161 which equals 0.2307.

4. The volume fraction of 0.2307 for region 6 was used to calculate the following volume fractions for the combination of regions 6 and 7: SS304=0.0811, zircaloy=0.1396, Cladding=0.0, Gas=0.7793 (balance).

5. The reference lower fuel rod plenum volume fractions were renormalized to exclude the cladding as shown in step 2.

Table 5.3.4-2 contains the homogenized material compositions for the upper and lower fuel rod plenum regions. The helium-filled gap between the fuel rod cladding and the fuel is modeled as void. The fresh fuel composition is uniform along the axial length of the fuel rod. The weight percent (wt%) enrichment of U-235 in the uranium of the fabricated UO_2 is presented in Table 5.3.4-3 for each fuel batch. The mass loading of uranium in the entire fuel assembly is also presented in Table 5.3.4-3. The compositions of the fresh fuel are presented in Table 5.3.4-4. The isotopic weight percentages in the fresh fuel composition are calculated using the following equations.

Equation 5.3.4-1. Uranium Isotope Weight Percents in Fabricated UO_2 (p. 20, Ref. 7.10)

$$U^{234}\ wt\% = (0.007731) * (U^{235}\ wt\%)^{1.0837}$$

$$U^{236}\ wt\% = (0.0046) * (U^{235}\ wt\%)$$

$$U^{238}\ wt\% = 100 - U^{234}\ wt\% - U^{235}\ wt\% - U^{236}\ wt\%$$

Equation 5.3.4-2. Uranium Mass per mol of UO_2

$$\frac{U\ Mass}{mol\ UO_2} = (1.008664904)\begin{bmatrix}(232.030)(U^{234}\ wt\%)+(233.025)(U^{235}\ wt\%)+\\(234.018)(U^{236}\ wt\%)+(236.006)(U^{238}\ wt\%)\end{bmatrix}(0.01)$$

where the weight percentages of the uranium isotopes (U^{234}, U^{235}, U^{236}, and U^{238}) in uranium are calculated using Equation 5.3.4-1.

Equation 5.3.4-3. Oxygen Mass per mol of UO_2

$$\frac{O\ Mass}{mol\ UO_2} = (2)(1.008664904)(15.858)$$

Equation 5.3.4-4. Oxygen Mass in UO_2

$$O\ Mass\ in\ UO_2 = \left(\frac{O\ Mass/mol\ UO_2}{U\ Mass/mol\ UO_2}\right)(U\ Mass\ in\ UO_2)$$

The wt% of each uranium isotope in the fresh UO_2 composition is determined by multiplying the wt% of each uranium isotope in the enriched uranium by the weight fraction of uranium in the UO_2. The wt% of oxygen in the UO_2 is the weight fraction of oxygen in UO_2 multiplied by 100.

The burned fuel is delineated into eighteen axial regions each having a unique material composition. The height of top and bottom axial nodes is 20.0660 cm. The height of the other axial nodes is 20.0025 cm. These nodal heights correspond directly to the nodal heights utilized in the fuel depletion calculations. Each nodal depleted fuel composition is obtained from SAS2H depletion calculations documented throughout Reference 7.3. The depleted fuel compositions for the best-estimate reactivity calculations may contain up to 85 isotopes from the list presented in Table 5.3.4-5. The depleted fuel compositions for the principal isotope reactivity calculations may contain up to 30 isotopes from the list presented in Table 5.3.4-6. The depleted fuel compositions for the principal actinide reactivity calculations may contain up to 15 isotopes from the list presented in Table 5.3.4-7. The depleted fuel compositions for the principal actinide reactivity calculations may contain up to 11 isotopes from the list presented in Table 5.3.4-8. Each depleted fuel composition is modeled in terms of isotopic weight percents and an overall nodal fuel density. The weight percent of each isotope in the nodal depleted fuel composition is calculated based on the total mass of all isotopes in the nodal composition. The mass of oxygen in each nodal depleted fuel composition is calculated based on the fresh fuel characteristics as described in Equations 5.3.4-1 through 5.3.4-4. This mass of oxygen is combined with the total isotopic fuel mass obtained from the depletion calculations to determine an overall total depleted fuel mass upon which the various isotopic weight percents are based. The MCNP output files for each CRC reactivity calculation are contained in Attachment III (this attachment has been moved to Reference 7.15). These output files contain an echo of the MCNP input decks for each CRC statepoint reactivity calculation. The nodal fuel isotopic compositions are listed in the input decks in terms of ZAID's, weight percents, and density (g/cm^3). Each nodal fuel composition is identified by assembly and node in the material

specification section of the input decks. The nodal fuel densities are shown on the geometric cell specifications for each fuel node. The nodal fuel densities are based on the fuel mass and fuel volume in each nodal region. The fuel volume is calculated using the number of fuel rods, nodal height, and pellet diameter. Therefore, dishing and chamfering of the fresh fuel pellets are accounted for on a mass basis by a slightly adjusted fuel density. However, the geometrical features of the fresh fuel pellet dishing and chamfering are not captured in the MCNP models. The purpose of the pellet dishing and chamfering is to enhance fuel performance. These geometrical features have no significant impact on system reactivity. The most important concern in determining system reactivity is to assure that fuel mass preservation is maintained. The fuel densities used in the MCNP models ensure preservation of mass.

Table 5.3.4-1. Fuel Rod Plenum Material Volume Fractions

Plenum Location	Type 304 Stainless Steel	Gas (modeled as void)	zircaloy
Upper	0.0811	0.7793	0.1396
Lower	0.1569	0.5973	0.2458

Table 5.3.4-2. Fuel Rod Plenum Homogenized Material Compositions

MCNP ZAID	Wt. % of Element/Isotope in Material Composition	
	Upper Fuel Rod Plenum	Lower Fuel Rod Plenum
6000.50c	0.032930	0.034769
7014.50c	0.041163	0.043462
14000.50c	0.308723	0.325963
15031.50c	0.018523	0.019558
16032.50c	0.012349	0.013039
24050.60c	0.328881	0.347013
24052.60c	6.595473	6.959098
24053.60c	0.762185	0.804206
24054.60c	0.193322	0.203980
25055.50c	0.823262	0.869234
26054.60c	1.619288	1.709074
26056.60c	26.105070	27.552548
26057.60c	0.608367	0.642100
26058.60c	0.082537	0.087114
28058.60c	2.566109	2.709403
28060.60c	1.014827	1.071496
28061.60c	0.044670	0.047165
28062.60c	0.144240	0.152294
28064.60c	0.037743	0.039850
8016.50c	0.070604	0.067846
40000.60c	57.766047	55.509283

Table 5.3.4-2. Fuel Rod Plenum Homogenized Material Compositions

MCNP ZAID	Wt. % of Element/Isotope in Material Composition	
	Upper Fuel Rod Plenum	Lower Fuel Rod Plenum
50000.35c	0.823716	0.791536
Density (g/cm^3)	1.556466	2.851958

Table 5.3.4-3. Fuel Batch Enrichment and Uranium Mass Loading (p. 22, Ref. 7.11)

Fuel Batch Identifier	U-235 wt. % in Uranium	Mass of Uranium per Fuel Assembly (kg)
1	2.06	463.63
2	2.75	463.63
3	3.05	463.63
4	2.64	463.63
5	2.85	463.63
6	2.85	463.63
7	2.85	463.63

Table 5.3.4-4. Fresh Fuel Material Composition for Each Fuel Batch

Fuel Batch Identifier	Wt. % of Element/Isotope in Material Composition					
	U-234	U-235	U-236	U-238	Oxygen	Density (g/cm^3)[1]
1	0.01491	1.81590	0.00835	86.31146	11.84938	10.1207
2	0.02040	2.42412	0.01115	85.69404	11.85030	10.1208
3	0.02282	2.68855	0.01237	85.42555	11.85070	10.1209
4	Not Used [2]	Not Used	Not Used	Not Used	Not Used	Not Used
5	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used
6	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used
7	0.02120	2.51226	0.01156	85.60455	11.85043	10.1480

[1] This density is the fresh fuel density based on preservation of mass using the mass loading of uranium in the assembly, the initial enrichment, and the pellet stack height dimensions.

[2] The fresh fuel compositions for fuel batches 4, 5, and 6 did not have to be specified in any of the MCNP input decks for the Three Mile Island Unit 1 CRC evaluations. However, depleted fuel compositions were specified for these fuel batches.

Table 5.3.4-5. Isotope Set from which Best-Estimate MCNP Depleted Fuel Compositions are Developed

Isotope	MCNP ZAID	Isotope	MCNP ZAID	Isotope	MCNP ZAID
H-3	1003.50c	Cs-135	55135.50c	Pa-233	91233.50c
He-4	2004.50c	Ba-138	56138.50c	U-233	92233.50c
Li-6	3006.50c	Pr-141	59141.50c	U-234	92234.50c
Li-7	3007.55c	Nd-143	60143.50c	U-235	92235.53c
Be-9	4009.50c	Nd-145	60145.50c	U-236	92236.50c
O-16	8016.50c	Nd-147	60147.50c	U-237	92237.50c
As-75	33075.35c	Nd-148	60148.50c	U-238	92238.53c
Kr-80	36080.50c	Pm-147	61147.50c	Np-235	93235.35c
Kr-82	36082.50c	Pm-148	61148.50c	Np-236	93236.35c
Kr-83	36083.50c	Pm-149	61149.50c	Np-237	93237.50c
Kr-84	36084.50c	Sm-147	62147.50c	Np-238	93238.35c
Kr-86	36086.50c	Sm-149	62149.50c	Pu-237	94237.35c
Y-89	39089.50c	Sm-150	62150.50c	Pu-238	94238.50c
Zr-93	40093.50c	Sm-151	62151.50c	Pu-239	94239.55c
Nb-93	41093.50c	Sm-152	62152.50c	Pu-240	94240.50c
Mo-95	42095.50c	Eu-151	63151.55c	Pu-241	94241.50c
Tc-99	43099.50c	Eu-152	63152.50c	Pu-242	94242.50c
Ru-101	44101.50c	Eu-153	63153.55c	Am-241	95241.50c
Ru-103	44103.50c	Eu-154	63154.50c	Am-242	95242.50c
Rh-103	45103.50c	Eu-155	63155.50c	Am-243	95243.50c
Rh-105	45105.50c	Gd-152	64152.50c	Cm-242	96242.50c
Pd-105	46105.50c	Gd-154	64154.50c	Cm-243	96243.35c
Pd-108	46108.50c	Gd-155	64155.50c	Cm-244	96244.50c
Ag-107	47107.50c	Gd-156	64156.50c	Cm-245	96245.35c
Ag-109	47109.50c	Gd-157	64157.50c	Cm-246	96246.35c
Xe-131	54131.50c	Gd-158	64158.50c	Cm-247	96247.35c
Xe-134	54134.35c	Gd-160	64160.50c	Cm-248	96248.35c
Xe-135	54135.53c	Ho-165	67165.55c		
Cs-133	55133.50c	Th-232	90232.50c		

Table 5.3.4-6. Isotope Set from which Principal Isotope MCNP Depleted Fuel Compositions are Developed

Isotope	MCNP ZAID	Isotope	MCNP ZAID	Isotope	MCNP ZAID
O-16	8016.50c	Sm-150	62150.50c	U-238	92238.53c
Mo-95	42095.50c	Sm-151	62151.50c	Np-237	93237.50c
Tc-99	43099.50c	Sm-152	62152.50c	Pu-238	94238.50c
Ru-101	44101.50c	Eu-151	63151.55c	Pu-239	94239.55c
Rh-103	45103.50c	Eu-153	63153.55c	Pu-240	94240.50c
Ag-109	47109.50c	Gd-155	64155.50c	Pu-241	94241.50c
Nd-143	60143.50c	U-233	92233.50c	Pu-242	94242.50c
Nd-145	60145.50c	U-234	92234.50c	Am-241	95241.50c
Sm-147	62147.50c	U-235	92235.53c	Am-242	95242.50c
Sm-149	62149.50c	U-236	92236.50c	Am-243	95243.50c

Table 5.3.4-7. Isotope Set from which Principal Actinide MCNP Depleted Fuel Compositions are Developed

Isotope	MCNP ZAID	Isotope	MCNP ZAID	Isotope	MCNP ZAID
O-16	8016.50c	U-238	92238.53c	Pu-241	94241.50c
U-233	92233.50c	Np-237	93237.50c	Pu-242	94242.50c
U-234	92234.50c	Pu-238	94238.50c	Am-241	95241.50c
U-235	92235.53c	Pu-239	94239.55c	Am-242	95242.50c
U-236	92236.50c	Pu-240	94240.50c	Am-243	95243.50c

Table 5.3.4-8. Isotope Set from which Actinide-Only MCNP Depleted Fuel Compositions are Developed

Isotope	MCNP ZAID	Isotope	MCNP ZAID	Isotope	MCNP ZAID
O-16	8016.50c	U-238	92238.53c	Pu-241	94241.50c
U-234	92234.50c	Pu-238	94238.50c	Pu-242	94242.50c
U-235	92235.53c	Pu-239	94239.55c	Am-241	95241.50c
U-236	92236.50c	Pu-240	94240.50c		

5.3.5. Guide Tube and Instrument Tube Materials

The guide tubes and instrument tubes are composed of zircaloy (p. 22, Ref. 7.11). The zircaloy material composition is presented in Table 5.3.2-15. The guide tubes and instrument tubes contain borated moderator as presented in Table 5.3.2-3.

5.3.6. BPRA Materials

Each BPRA contains sixteen BPRs (one BPR per guide tube). The BPR components include cladding, upper plenum, and lower end-plug, and burnable poison (BP). The cladding of the BPRs is zircaloy as presented in Table 5.3.2-15 (p. 22, Ref. 7.11). The upper plenum region is modeled as SS304 with a volume fraction of 0.2090 inside of the cladding (p. 20, Ref. 7.11). The SS304 composition is presented in Table 5.3.2-1. The lower end-plug region is modeled as zircaloy inside of the cladding (p. 20, Ref. 7.11).

The fresh BP is uniform along the axial length of the BPR. The BP material is Al_2O_3-B_4C with an initial density of 3.7 g/cm^3 (p. 22, Ref. 7.11). The weight percent of B_4C in the Al_2O_3-B_4C is either 1.09, 1.26, or 1.43 (p. 25, Ref. 7.11). Table 5.3.6-1 presents the fresh BP compositions. The placement of the various BPRAs in the reactor core in the Cycle 1, 0.0 EFPD, statepoint configuration is presented in Section 5.4. Modeling of depleted BP compositions was not required in any of the Three Mile Island Unit 1 CRC reactivity calculations.

Table 5.3.6-1. Fresh Burnable Poison Material Composition

MCNP ZAID	Wt. % of Element/Isotope in Material Composition		
	1.09 wt% B_4C	1.26 wt% B_4C	1.43 wt% B_4C
5010.50c	0.15325	0.17715	0.20106
5011.56c	0.70007	0.80925	0.91843
6000.50c	0.23668	0.27360	0.31051
8016.50c	46.55544	46.47542	46.39541
13027.50c	52.35457	52.26458	52.17460

5.3.7. RCCA Materials

Each RCCA contains sixteen identical control rods (CRs). The CR components include cladding, upper plenum, lower end-plug, and absorber material. The CR cladding is modeled as SS304 as presented in Table 5.3.2-1 (p. 22, Ref. 7.11). The CR upper plenum is not modeled in any of the CRC statepoint configurations due to the partial insertion of the RCCAs. The CR lower end-plug is modeled as SS304 as presented in Table 5.3.2-1 (p. 14, Ref. 7.11). The CR absorber material is Ag-In-Cd with a density of 10.17 g/cm^3 (p. 22, Ref. 7.11). Table 5.3.7-1 presents the Ag-In-Cd material composition.

Table 5.3.7-1. Ag-In-Cd Material Composition [1]

Element / Isotope	MCNP ZAID	Wt. %
Ag-107	47107.60c	41.101
Ag-109	47109.60c	38.899
Cd	48000.50c	5.000
In	49000.60c	15.000

[1] Page 22 of Reference 7.11 shows Ag with a weight percentage of 79.8, and the Ag-In-Cd material with a total weight percentage of 99.8. The missing 0.2 weight percent was given to Ag in the modeled Ag-In-Cd material composition.

5.3.8. Black APSRA Materials

Each APSRA contains 16 identical APSR's. The Three Mile Island Unit 1 reactor cycles containing CRC statepoints (Cycles 1 and 5) used only black APSRAs. The black APSR contains Ag-In-Cd as the absorber material. The components of the black APSR include cladding, intermediate-plug, upper plenum, lower end-plug, absorber material, and lower spacer. Refer to Figure 5.2.8-1 for the black APSR geometrical modeling specifications. The APSR cladding is modeled as SS304 as presented in Table 5.3.2-1. From the information provided on page 18 of Reference 7.11, the intermediate plug volume is 16.15 cm^3/16 which equals 1.0094 cm^3. According to the dimensions on page 17 of Reference 7.11, the volume occupied by the intermediate plug is 1.0194 cm^3. This results in an intermediate plug volume fraction of 1.0094 cm^3/1.0194 cm^3 which equals 0.9902. The upper plenum region is modeled as a gap filled with helium at an arbitrary density of 0.00001 g/cm^3. The black APSR type contains a lower zircaloy spacer and a lower SS304 end-plug. The lower spacer and lower end-plug are homogenized together to define the material of the lower plenum region in the MCNP model of the APSR. According to page 18 of Reference 7.11, the lower spacer has a volume of 6.11 cm^3/16 which equals 0.3819 cm^3. According to the dimensions on page 17 and 22 of Reference 7.11, the volumes of the lower spacer region and lower end-plug region are 0.6116 cm^3 and 1.8874 cm^3, respectively. The total volume of the lower plenum in the MCNP model is then 0.6116 cm^3 + 1.8874 cm^3 which equals 2.4990 cm^3. The total volume of zircaloy in the modeled lower plenum is 0.3819 cm^3. The total volume of SS304 in the modeled lower plenum is 1.8874 cm^3. The volume fraction of zircaloy in the modeled lower plenum region is 0.3819 cm^3/2.4990 cm^3 which equals 0.1528. The volume fraction of SS304 in the modeled lower plenum region is 1.8874 cm^3/2.4990 cm^3 which equals 0.7553. The remaining volume fraction in the modeled lower plenum region of 0.0919 is modeled as void. The composition of the Ag-In-Cd absorber material in the black APSR is presented in Table 5.3.7-1.

5.4. Core Loading Descriptions

The core loading description for each CRC statepoint reactivity calculation includes the specification of the various fuel assembly locations, BPRA locations, RCCA locations, and APSRA locations. A core loading description is provided for a particular cycle. All CRC statepoint reactivity calculations in the same reactor cycle use the same core loading description. Figures 5.4-1 and 5.4-2 present the core loading descriptions for cycles 1 and 5 of Three Mile Island Unit 1, respectively. Each fuel assembly has a unique identifier corresponding to the identifiers used in the SAS2H depletion analyses. The fuel assembly placements in each core loading description are presented in Figures 5.4-3 and 5.4-4. The fuel assembly identifiers shown in Figures 5.4-3 and 5.4-4 refer to the assembly identifiers used in the depletion analyses documented throughout Reference 7.3.

	08	09	10	11	12	13	14	15
H	F(1) 2	F(1) 2	F(1) 1	F(1) 2	F(1) 1	F(1) 2	F(1) 3	F(1) 3
K		F(1) 1	F(1) 2	F(1) 1	F(1) 2	F(1) 1	F(1) 2	F(1) 3
L			F(1) 1	F(1) 2	F(1) 1	F(1) 2	F(1) 3	F(1) 3
M				F(1) 1	F(1) 2	F(1) 1	F(1) 3	
N					F(1) 1	F(1) 3	F(1) 3	
O						F(1) 3		

RC	= Previous Fuel Assembly Position, Row (R), Column (C), {normalized to 1/8 core}
F(c)	= Cycle (c) in which the Fuel Assembly was Fresh (F)
B	= Fuel Batch Identifier (B)

Wt. % U-235 Enrichments		
Fresh Cycle	Batch	Wt. %
1	1	2.06
	2	2.75
	3	3.05

Burnable Poison Rod Assembly (BPRA) Locations	
Wt. % B_4C in BPRA	1/8 Core Row & Column
1.09	L11, M12
1.26	H11, H13, K12, L13, N13
1.43	H09, K10, K14

Rod Cluster Control Assembly (RCCA) Locations			
RCCA Bank Identifier	1/8 Core Row & Column	RCCA Bank Identifier	1/8 Core Row & Column
Bank 5	K09, M13	Bank 7	H08, L14
Bank 6	H12, M11	Bank 8 (Black Axial Power Shaping Rod)	L12

Figure 5.4-1. Core Loading Description for Cycle 1 of Three Mile Island Unit 1 (p. 25, Ref. 7.11)

	08	09	10	11	12	13	14	15
H	N12 F (2) 4	H10 F (3) 5	H15 F (4) 6	H14 F (2) 4	L14 F (4) 6	H12 F (3) 5	L14 F (4) 6	F (5) 7
K		M14 F (4) 6	K11 F (3) 5	N14 F (4) 6	M12 F (3) 5	K15 F (4) 6	K12 F (2) 4	F (5) 7
L			M14 F (4) 6	L12 F (3) 5	L15 F (4) 6	L11 F (2) 4	F (5) 7	F (5) 7
M				K9 F (3) 5	K13 F (3) 5	N13 F (4) 6	F (5) 7	
N					O13 F (2) 4	F (5) 7	F (5) 7	
O						L10 F (3) 5		

RC	= Previous Fuel Assembly Position, Row (R), Column (C), {normalized to 1/8 core}
F(c)	= Cycle (c) in which the Fuel Assembly was Fresh (F)
B	= Fuel Batch Identifier (B)

Wt. % U-235 Enrichments		
Fresh Cycle	Batch	Wt. %
5	4	2.64
	5	2.85
	6	2.85
	7	2.85

NO BPRAs

Rod Cluster Control Assembly (RCCA) Locations			
RCCA Bank Identifier	1/8 Core Row & Column	RCCA Bank Identifier	1/8 Core Row & Column
Bank 5	H10, H12, M11	Bank 7	H14, L10, N12
Bank 6	K13	Bank 8 (Black Axial Power Shaping Rod)	L12

Figure 5.4-2. Core Loading Description for Cycle 5 of Three Mile Island Unit 1 (p. 29, Ref. 7.11)

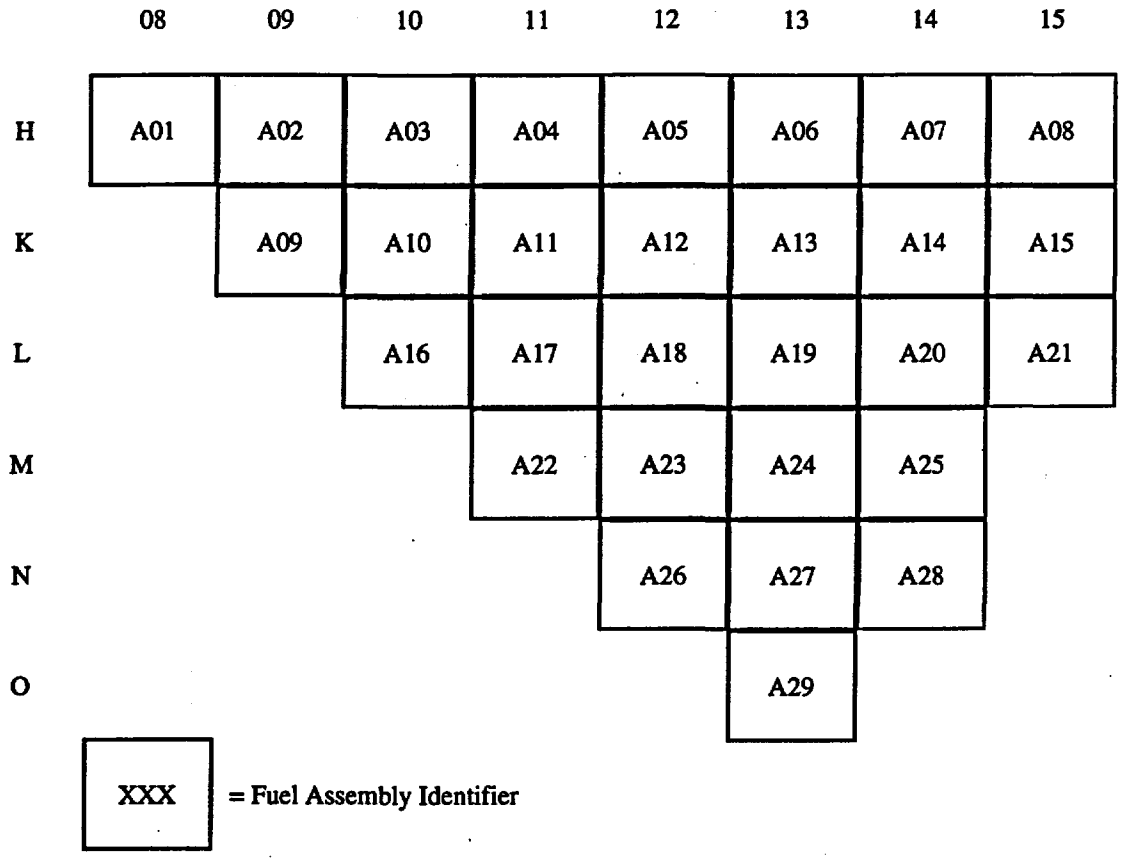

Figure 5.4-3. Fuel Assembly Placement in Cycle 1 of Three Mile Island Unit 1 (p. 30, Ref. 7.11)

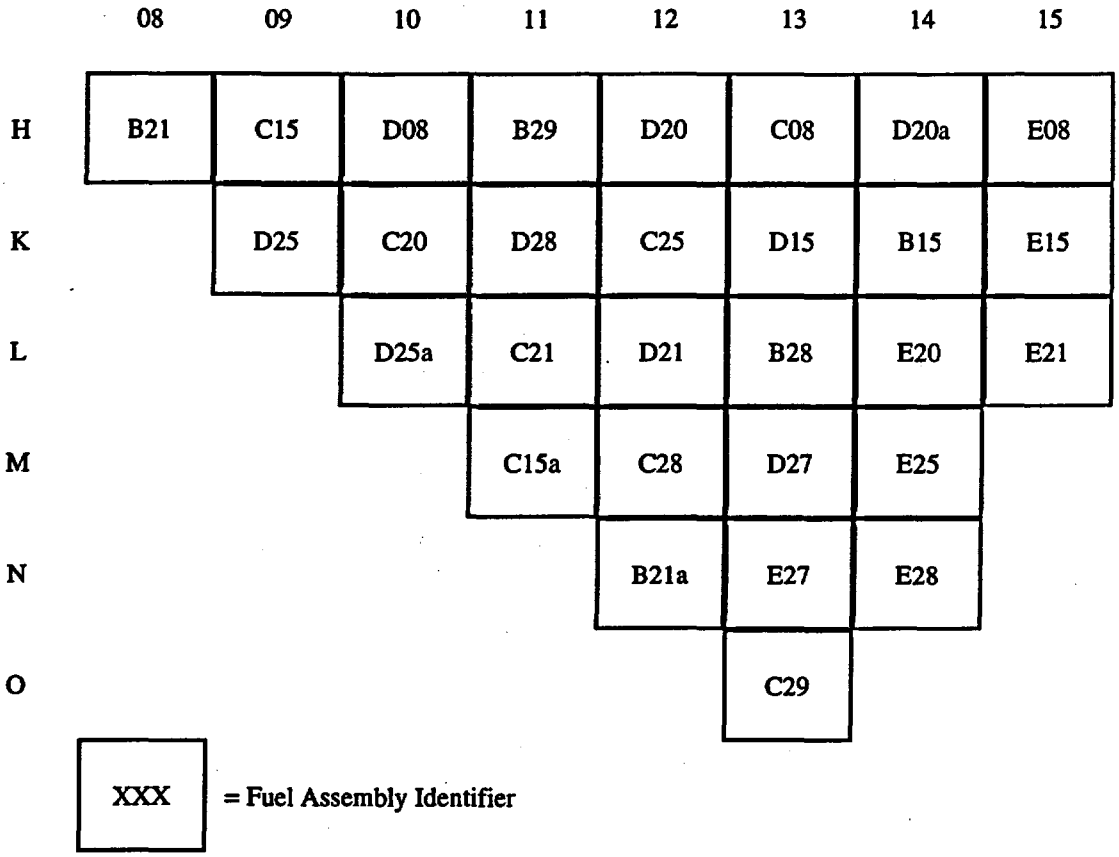

Figure 5.4-4. Fuel Assembly Placements in Cycle 5 of Three Mile Island Unit 1 (p. 34, Ref. 7.11)

6. Results

This calculation file documents the CRC reactivity evaluations that were performed for three statepoints from Three Mile Island Unit 1. Four reactivity calculations were performed for each of the statepoints other than the beginning-of-life of the reactor (Cycle 1, 0.0 EFPD). Each of these four calculations for each statepoint used a different depleted fuel composition. The four sets of depleted fuel isotopes shown in Tables 5.3.4-5 through 5.3.4-8 were used for the "Best-Estimate", "Principal Isotope", "Principal Actinide", and "Actinide-Only" calculations. Table 6-1 presents the k_{eff} results for each of the Three Mile Island Unit 1 CRC evaluations. The k_{eff} results represent the average combined collision, absorption, and track-length estimator from the MCNP calculations. The standard deviation represents the standard deviation of k_{eff} about the average combined collision, absorption, and track-length estimate due to the Monte Carlo calculation statistics.

Table 6-1. k_{eff} Results for the Three Mile Island Unit 1 CRC Evaluations

Fuel Isotope Set	Three Mile Island Unit 1 CRC Statepoint (k_{eff} / standard deviation)		
	Cycle 1, 0.0 EFPD	Cycle 5, 0.0 EFPD	Cycle 5, 114.4 EFPD
Best-Estimate	1.00141 / 0.00042	0.99088 / 0.00046	0.99162 / 0.00048
Principal Isotope	Not Applicable	1.00048 / 0.00046	1.00443 / 0.00047
Principal Actinide	Not Applicable	1.04072 / 0.00045	1.05157 / 0.00048
Actinide-Only	Not Applicable	1.04243 / 0.00046	1.05363 / 0.00044

The principal isotope set criticality calculations were originally performed using the Ru-103 cross section library (44103.50c) instead of the Rh-103 cross section library (45103.50c) for Rh-103. The cross section library identifier 44103.50c was manually changed to 45103.50c in the principal isotope set MCNP input decks. The principal isotope set results shown in Table 6-1 are from the corrected calculations.

The corresponding MCNP input and output filenames for the cases shown in Table 6-1, are presented in Table 6-2. The MACE input decks used to generate the MCNP input decks are presented in Attachment I (this attachment has been moved to Reference 7.15). The MACE generated MCNP input decks are presented in Attachment II (this attachment has been moved to Reference 7.15). The MCNP output files are presented in Attachment III (this attachment has been moved to Reference 7.15). The principal isotope cases contained in Attachments II and III used the incorrect cross section library for Rh-103. Attachment IV (this attachment has been moved to Reference 7.15) contains the corrected principal isotope set MCNP input and output files.

Table 6-2. MCNP Input and Output Filenames for the Three Mile Island Unit 1 CRC Evaluations

Fuel Isotope Set	Three Mile Island Unit 1 CRC Statepoint (input filename / output filename)		
	Cycle 1, 0.0 EFPD	Cycle 5, 0.0 EFPD	Cycle 5, 114.4 EFPD
Best-Estimate	tmii1a / tmii1a.O	tmii2a / tmii2a.O	tmii3a / tmii3a.O
Principal Isotope	Not Applicable	tmii2b / tmii2b.O	tmii3b / tmii3b.O
Principal Actinide	Not Applicable	tmii2c / tmii2c.O	tmii3c / tmii3c.O
Actinide-Only	Not Applicable	tmii2d / tmii2d.O	tmii3d / tmii3d.O

7. References

7.1 *MCNP 4B: Monte Carlo N-Particle Transport Code System.* User manual. Los Alamos National Laboratory, Los Alamos, NM. Document Number: LA-12625-M.

7.2 *SCALE 4.3: Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation.* User Manual Volumes 0 through 3, Oak Ridge National Laboratory, Document Number: CCC-545.

7.3 *CRC Depletion Calculations for Three Mile Island Unit 1.* Document Identifier Number (DI#): B00000000-01717-0210-00007 REV 00, Civilian Radioactive Waste Management System (CRWMS) Management and Operating Contractor (M&O).

7.4 *Software Qualification Report for MCNP Version 4B2, A General Monte Carlo N-Particle Transport Code.* DI#: 30033-2003 REV 01, CRWMS M&O.

7.5 *Nuclide and Isotopes, Chart of the Nuclides, Fourteenth Edition.* General Electric Company, 1989.

7.6 *Radiological Health Handbook, January 1970 Revision.* Bureau of Radiological Health; U. S. Department of Health, Education, and Welfare; Public Health Service; Food and Drug Administration.

7.7 *Material Compositions and Number Densities for Neutronics Calculations.* DI#: BBA000000-01717-0200-00002 REV 00, CRWMS M&O.

7.8 *Huntington Alloys: Inconel Alloy 718*, Third Edition, 1978.

7.9 This reference is intentionally left blank.

7.10 *Scale-4 Analysis of Pressurized Water Reactor Critical Configurations: Volume 2-Sequoyah Unit 2 Cycle 3.* Document Number: ORNL/TM-12294/V2. Oak Ridge National Laboratory, March 1995.

7.11 *Summary Report of Commercial Reactor Criticality Data for Three Mile Island Unit 1.* DI#: B00000000-01717-5705-00069 REV 00, CRWMS M&O.

7.12 *Addendum to Software Qualification Report for MCNP4A Covering Addition of ENDF/B-VI Cross Sections.* DI#: 30006-2005 REV 00, CRWMS M&O.

7.13 This reference is intentionally left blank.

7.14 *CRC Reactivity Calculations for Sequoyah Unit 2.* DI#: B00000000-01717-0210-00006 REV 00, CRWMS M&O.

7.15 CRC Reactivity Calculations for Three Mile Island Unit 1 (DI#: B00000000-01717-0210-00008 REV 00) - Attachments I through IV - 1 Data Cartridge. Batch Number: MOY-980604-07.

8. Attachments

Table 8-1 presents the attachment specifications for this calculation file. Attachments I through IV have been moved to Reference 7.15. Attachments I through IV were written in ASCII format to an attachment tape. This attachment tape was provided with REV 00A of this calculational file. After checking of the attachment tape in REV 00A, the tape was made a reference (Ref. 7.15). Detailed listings of the content of Attachments I through IV on the tape are provided in their corresponding hard-copy attachment locations in this calculation file. The tape containing Attachments I through IV (Ref. 7.15) was written using the HP Colorado Model T1000e External Parallel Port Backup System for personal computers.

Table 8-1. Attachment Listing

Attachment #	# of Pages	Creation Date	Description
I	1 (Hard-Copy Listing of Tape Content)	04/01/98	MACE Input Decks for the Three Mile Island Unit 1 Reactivity Calculations (moved to Reference 7.15)
II	1 (Hard-Copy Listing of Tape Content)	04/01/98	MACE Generated MCNP Input Decks for the Three Mile Island Unit 1 Reactivity Calculations (moved to Reference 7.15)
III	1 (Hard-Copy Listing of Tape Content)	04/01/98	MCNP Output Files for the Three Mile Island Unit 1 Reactivity Calculations (moved to Reference 7.15)
IV	1 (Hard-Copy Listing of Tape Content)	06/03/98	MCNP Input and Output Files for the Corrected Principal Isotope Set Reactivity Calculations (moved to Reference 7.15)

This attachment contains the MACE input decks used to generate the MCNP input decks. These files are contained on an attachment tape of this calculational file (the attachment tape has been moved to Reference 7.15). The filenames indicate the CRC reactivity calculation to which they apply by correspondence with Table 6-2. The file sizes listed in the following table are the file sizes as contained on the attachment tape (Ref. 7.15). The tape containing Attachment I was written using the HP Colorado Model T1000e External Parallel Port Backup System for personal computers.

Filename	File Type	File Size (Bytes)	Date File Copied to Tape
tmii1a.txt	ASCII	74,689	04/01/98
tmii2a.txt	ASCII	59,713	04/01/98
tmii2b.txt	ASCII	59,693	04/01/98
tmii2c.txt	ASCII	59,693	04/01/98
tmii2d.txt	ASCII	59,693	04/01/98
tmii3a.txt	ASCII	59,709	04/01/98
tmii3b.txt	ASCII	59,689	04/01/98
tmii3c.txt	ASCII	59,689	04/01/98
tmii3d.txt	ASCII	59,689	04/01/98

This attachment contains the MCNP input decks for the Three Mile Island Unit 1 reactivity calculations. These files are contained on an attachment tape of this calculational file (the attachment tape has been moved to Reference 7.15). The filenames indicate the CRC reactivity calculation to which they apply by correspondence with Table 6-2. The file sizes listed in the following table are the file sizes as contained on the attachment tape (Ref. 7.15). The tape containing Attachment II was written using the HP Colorado Model T1000e External Parallel Port Backup System for personal computers.

Filename	File Type	File Size (Bytes)	Date File Copied to Tape
tmii1a	ASCII	602,701	04/01/98
tmii2a	ASCII	1,335,681	04/01/98
tmii2b	ASCII	835,923	04/01/98
tmii2c	ASCII	635,149	04/01/98
tmii2d	ASCII	582,085	04/01/98
tmii3a	ASCII	1,666,344	04/01/98
tmii3b	ASCII	942,079	04/01/98
tmii3c	ASCII	677,481	04/01/98
tmii3d	ASCII	607,839	04/01/98

This attachment contains the MCNP output files for the Three Mile Island Unit 1 reactivity calculations. These files are contained on an attachment tape of this calculational file (the attachment tape has been moved to Reference 7.15). The filenames indicate the CRC reactivity calculation to which they apply by correspondence with Table 6-2. The file sizes listed in the following table are the file sizes as contained on the attachment tape (Ref. 7.15). The tape containing Attachment III was written using the HP Colorado Model T1000e External Parallel Port Backup System for personal computers.

Filename	File Type	File Size (Bytes)	Date File Copied to Tape
tmii1a.O	ASCII	7,309,459	04/01/98
tmii2a.O	ASCII	11,447,330	04/01/98
tmii2b.O	ASCII	8,263,450	04/01/98
tmii2c.O	ASCII	6,974,089	04/01/98
tmii2d.O	ASCII	6,634,822	04/01/98
tmii3a.O	ASCII	13,529,508	04/01/98
tmii3b.O	ASCII	8,914,820	04/01/98
tmii3c.O	ASCII	7,213,121	04/01/98
tmii3d.O	ASCII	6,769,723	04/01/98

This attachment contains the MCNP input and output files for the corrected principal isotope set reactivity calculations. These files are contained on an attachment tape of this calculational file (the attachment tape has been moved to Reference 7.15). The filenames indicate the CRC reactivity calculation to which they apply by correspondence with Table 6-2. The file sizes listed in the following table are the file sizes as contained on the attachment tape (Ref. 7.15). The tape containing Attachment IV was written using the HP Colorado Model T1000e External Parallel Port Backup System for personal computers.

Filename	File Type	File Size (Bytes)	Date File Copied to Tape
tmii2b	ASCII	835,923	06/03/98
tmii2b.O	ASCII	8,262,973	06/03/98
tmii3b	ASCII	942,079	06/03/98
tmii3b.O	ASCII	8,909,789	06/03/98