December 2019
Revision 19A

NAC-UMS

Universal MPC System

SAFETY ANALYSIS REPORT

Damaged BWR
Amendment 8, Initial Application

Non-Proprietary Version

Docket No. 72-1015

NAC INTERNATIONAL

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Enclosure 1

Proposed Changes for the NAC-UMS Technical Specifications Amendment 8 (Docket No 72-1015)

NAC International

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APPENDIX A

TECHNICAL SPECIFICATIONS
FOR THE NAC-UMS® SYSTEM

AMENDMENT 8

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A 1.0 USE AND APPLICATION

A 1.1 Definitions

---NOTE---
The defined terms of this section appear in capitalized type and are applicable throughout this section.

Term	Definition
ACTIONS	ACTIONS shall be that part of a Specification that prescribes Required Actions to be taken under designated Conditions within specified Completion Times.
ASSEMBLY DEFECT	Any change in the physical as-built condition of the assembly, with the exception of normal in-reactor changes such as elongation from irradiation growth or assembly bow. Examples of ASSEMBLY DEFECTS include: (a) missing rods, (b) broken or missing grids or grid straps (spacer), and (c) missing or broken grid springs, etc. An assembly with a defect is damaged only if it cannot meet its fuel-specific and system-related functions.
BREACHED SPENT FUEL ROD	Spent fuel with cladding defects that permit the release of gas from the interior of the fuel rod. A fuel rod breach may be a minor defect (i.e., hairline crack or pinhole), allowing the rod to be classified as undamaged, or be a gross breach requiring a damaged fuel classification.
BWR DAMAGED FUEL CAN (BWR DFC)	A specially designed stainless steel screened can sized to hold BWR UNDAMAGED FUEL, DAMAGED FUEL or FUEL DEBRIS. The screens preclude the release of gross particulate from the can into the canister cavity. The BWR DFC may only be loaded in a Class 5DF canister and replaces a fuel tube.
CANISTER	See TRANSPORTABLE STORAGE CANISTER

(continued)

CANISTER HANDLING FACILITY	The CANISTER HANDLING FACILITY includes the following components and equipment: (1) a canister transfer station that allows the staging of the TRANSFER CASK with the CONCRETE CASK or transport cask to facilitate CANISTER lifts involving spent fuel handling not covered by 10 CFR 50; and (2) either a stationary lift device or mobile lifting device used to lift the TRANSFER CASK and CANISTER.
CONCRETE CASK	See VERTICAL CONCRETE CASK
CONSOLIDATED FUEL	A nonstandard fuel configuration in which the undamaged individual fuel rods from one or more fuel assemblies are placed in a single container or a lattice structure that is similar to a fuel assembly. CONSOLIDATED FUEL is stored in a MAINE YANKEE FUEL CAN.
DAMAGED FUEL	Spent nuclear fuel (SNF) that cannot fulfill its fuel-specific or system-related function. DAMAGED FUEL must be placed in a MAINE YANKEE FUEL CAN in the case of Site Specific fuel and in a BWR Damaged Fuel Can (DFC) for BWR fuel unless otherwise noted. Spent fuel is classified as damaged under the following conditions. 1. There is visible deformation of the rods in the SNF assembly. Note: This is not referring to the uniform bowing that occurs in the reactor; this refers to bowing that significantly opens up the lattice spacing. 2. Individual fuel rods are missing from the assembly and the missing rods are not replaced by solid dummy/filler rods that displace a volume equal to, or greater than, the original fuel rods. Note: Maine Yankee fuel assemblies with missing rods, not replaced by solid dummy/filler rods, are an exception based upon the criticality analysis done for these assemblies. They are, therefore, considered to be undamaged. However, these Maine Yankee assemblies must be preferentially loaded per Tables B2-6 and B2-7.

(continued)

DAMAGED FUEL (cont'd)

3. The SNF assembly has missing, displaced or damaged structural components such that either:
   - Radiological and/or criticality safety is adversely affected (e.g., significantly changed rod pitch); or
   - The assembly cannot be handled by normal means (i.e., crane and grapple).

   Note: PWR assemblies with the following structural defects meet UMS system-related functional requirements and are, therefore, classified as undamaged.
   - Grid, grid strap, and/or grid strap spring damage in PWR assemblies such that the unsupported length of the fuel rod does not exceed 60 inches.
4. Any SNF assembly that contains fuel rods for which reactor operating records (or other records or tests) cannot support the conclusion that they do not contain gross breaches.

   Note: Breached fuel rods with minor cladding defects (i.e, pinhole leaks or hairline cracks that will not permit significant release of particulate matte from the spent fuel rod) meet UMS system-related functional requirements and are, therefore, classified as undamaged.
5. The SNF assembly is no longer in the form of an intact fuel bundle (e.g., consists of or contains debris such as loose fuel pellets or rod segments).

FUEL DEBRIS

An intact or a partial fuel rod or an individual intact or partial fuel pellet not contained in a fuel rod. For Site Specific (MY) contents fuel debris is inserted into a 9 × 9 array of tubes in a lattice that has approximately the same dimensions as a standard fuel assembly. FUEL DEBRIS is stored in a MAINE YANKEE FUEL CAN. BWR Fuel Debris must be loaded into a BWR DFC. BWR Fuel Debris are limited to the equivalent of an UNDAMAGED BWR fuel assembly per DFC.

(continued)

GROSSLY BREACHED SPENT FUEL ROD	A breach in the spent fuel cladding that is larger than a pinhole or hairline crack. A gross cladding breach may be established by visual examination with the capability to determine if the fuel pellet can be seen through the cladding, or through a review of reactor operating records indicating the presence of heavy metal isotopes.
HIGH BURNUP FUEL	A fuel assembly meeting the definition of a standard fuel assembly with an assembly average burnup between 45,000 and 60,000 MWd/MTU.
INDEPENDENT SPENT FUEL STORAGE INSTALLATION (ISFSI)	The facility within the perimeter fence licensed for storage of spent fuel within NAC-UMS® SYSTEMs (see also 10 CFR 72.3).
INITIAL PEAK PLANAR-AVERAGE ENRICHMENT	THE INITIAL PEAK PLANAR-AVERAGE ENRICHMENT is the maximum planar-average enrichment at any height along the axis of the fuel assembly. The INITIAL PEAK PLANAR-AVERAGE ENRICHMENT may be higher than the bundle (assembly) average enrichment.
INTACT FUEL (ASSEMBLY OR ROD)	Any fuel that can fulfill all fuel-specific and system-related functions and that is not breached.
LOADING OPERATIONS	LOADING OPERATIONS include all licensed activities on a NAC-UMS® SYSTEM while it is being loaded with fuel assemblies. LOADING OPERATIONS begin when the first fuel assembly is placed in the CANISTER and end when the NAC-UMS® SYSTEM is secured on the transporter. LOADING OPERATIONS does not include post-storage operations, i.e., CANISTER transfer operations between the TRANSFER CASK and the CONCRETE CASK or transport cask after STORAGE OPERATIONS.

(continued)

MAINE YANKEE FUEL CAN	A specially designed stainless steel screened can sized to hold UNDAMAGED FUEL, CONSOLIDATED FUEL, DAMAGED FUEL or FUEL DEBRIS. The screens preclude the release of gross particulate from the can into the canister cavity. The MAINE YANKEE FUEL CAN may only be loaded in a Class 1 canister.
NAC-UMS® SYSTEM	NAC-UMS® SYSTEM includes the components approved for loading and storage of spent fuel assemblies at the ISFSI. The NAC-UMS® SYSTEM consists of a CONCRETE CASK, a TRANSFER CASK, and a CANISTER.
OPERABLE	An OPERABLE CONCRETE CASK heat removal system transfers sufficient heat away from the fuel assemblies such that the fuel cladding and CANISTER component temperatures do not exceed applicable limits. The CONCRETE CASK heat removal system is considered OPERABLE if the difference between the ISFSI ambient temperature and the average outlet air temperature is ≤102ºF for the PWR canister or ≤92ºF for the BWR canister, or if all four air inlet and outlet screens are visually verified to be unobstructed. Failing this, a CONCRETE CASK heat removal system may be declared OPERABLE if an engineering evaluation determines the CONCRETE CASK has adequate heat transfer capabilities to assure continued spent fuel and CANISTER integrity.

(continued)

SITE SPECIFIC FUEL	Spent fuel configurations that are unique to a site or reactor due to the addition of other components or reconfiguration of the fuel assembly at the site. It includes fuel assemblies, which hold nonfuel-bearing components, such as a control element assembly, a burnable poison rod insert, a solid stainless steel rod insert, an in-core instrument thimble or a flow mixer, or which are modified as required by expediency in reactor operations, research and development or testing. Modification may consist of individual fuel rod removal, fuel rod replacement of similar or dissimilar material or enrichment, the installation, removal or replacement of burnable poison rods or solid stainless steel rods, or containerizing damaged fuel. Site specific fuel includes irradiated fuel assemblies designed with variable enrichments and/or axial blankets, fuel that is consolidated and fuel that exceeds design basis fuel parameters.
STANDARD FUEL	Irradiated fuel assemblies having the same configuration as when originally fabricated consisting generally of the end fittings, fuel rods, guide tubes, and integral hardware. For PWR fuel, a flow mixer, an in-core instrument thimble or a burnable poison rod insert is considered to be a component of standard fuel. For BWR fuel, the channel is considered to be integral hardware. The design basis fuel characteristics and analysis are based on the STANDARD FUEL configuration.
STORAGE OPERATIONS	STORAGE OPERATIONS include all licensed activities that are performed at the ISFSI, while an NAC-UMS® SYSTEM containing spent fuel is located on the storage pad within the ISFSI perimeter.
TRANSFER CASK	TRANSFER CASK is a shielded lifting device that holds the CANISTER during LOADING and UNLOADING OPERATIONS and during closure welding, vacuum drying, leak testing, and non-destructive examination of the CANISTER closure welds. The TRANSFER CASK is also used to transfer the CANISTER into and from the CONCRETE CASK and into the transport cask. TRANSFER CASK refers to either the standard or advanced transfer cask.

TRANSFER OPERATIONS	TRANSFER OPERATIONS include all licensed activities involved in transferring a loaded CANISTER from a CONCRETE CASK to another CONCRETE CASK or to a TRANSPORT CASK.
TRANSPORT OPERATIONS	TRANSPORT OPERATIONS include all licensed activities involved in moving a loaded NAC-UMS® CONCRETE CASK and CANISTER to and from the ISFSI. TRANSPORT OPERATIONS begin when the NAC-UMS® SYSTEM is first secured on the transporter and end when the NAC-UMS® SYSTEM is at its destination and no longer secured on the transporter.
TRANSPORTABLE STORAGE CANISTER (CANISTER)	TRANSPORTABLE STORAGE CANISTER is the sealed container that consists of a tube and disk fuel basket in a cylindrical canister shell that is welded to a baseplate, shield lid with welded port covers, and structural lid. The CANISTER provides the confinement boundary for the confined spent fuel.
UNDAMAGED FUEL	Spent nuclear fuel that can meet all fuel specific and system-related functions. UNDAMAGED FUEL is spent nuclear fuel that is not DAMAGED FUEL and does not contain assembly structural defects that adversely affect radiological and/or criticality safety. As such, UNDAMAGED FUEL may contain: a) BREACHED SPENT FUEL RODS (i.e, rods with minor defects up to hairline cracks or pinholes) but can not contain grossly breached fuel rods; b) Grid, grid strap, and/or grid spring damage in PWR assemblies, provided that the unsupported length of the fuel rod does not exceed 60 inches.

(continued)

UNLOADING OPERATIONS	UNLOADING OPERATIONS include all licensed activities on a NAC-UMS® SYSTEM to be unloaded of the contained fuel assemblies. UNLOADING OPERATIONS begin when the NAC-UMS® SYSTEM is no longer secured on the transporter and end when the last fuel assembly is removed from the NAC-UMS® SYSTEM.
VERTICAL CONCRETE CASK (CONCRETE CASK)	VERTICAL CONCRETE CASK is the cask that receives and holds the sealed CANISTER. It provides the gamma and neutron shielding and convective cooling of the spent fuel confined in the CANISTER.

A 1.0 USE AND APPLICATION

A 1.2 Logical Connectors

PURPOSE

The purpose of this section is to explain the meaning of logical connectors.

Logical connectors are used in Technical Specifications (TS) to discriminate between, and yet connect, discrete Conditions, Required Actions, Completion Times, Surveillances, and Frequencies. The only logical connectors that appear in Technical Specifications are "AND" and "OR." The physical arrangement of these connectors constitutes logical conventions with specific meanings.

BACKGROUND

Several levels of logic may be used to state Required Actions. These levels are identified by the placement (or nesting) of the logical connectors and by the number assigned to each Required Action. The first level of logic is identified by the first digit of the number assigned to a Required Action and the placement of the logical connector in the first level of nesting (i.e., left justified with the number of the Required Action). The successive levels of logic are identified by additional digits of the Required Action number and by successive indentations of the logical connectors.

When logical connectors are used to state a Condition, Completion Time, Surveillance, or Frequency, only the first level of logic is used; the logical connector is left justified with the statement of the Condition, Completion Time, Surveillance, or Frequency.

(continued)

EXAMPLES The following examples illustrate the use of logical connectors.

EXAMPLES <u>EXAMPLE 1.2-1</u>

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. LCO not met	A.1 Verify. . . <u>AND</u> A.2 Restore. . .	

In this example, the logical connector "<u>AND</u>" is used to indicate that when in Condition A, both Required Actions A.1 and A.2 must be completed.

(continued)

EXAMPLES (continued)

EXAMPLE 1.2-2

ACTIONS

CONDITION	REQUIRED ACTION		COMPLETION TIME
A. LCO not met	A.1	Stop. . .	
	OR		
	A.2.1	Verify. . .	
	AND		
	A.2.2		
	A.2.2.1	Reduce. . .	
		OR	
	A.2.2.2	Perform. . .	
	OR		
	A.3	Remove. . .	

This example represents a more complicated use of logical connectors. Required Actions A.1, A.2, and A.3 are alternative choices, only one of which must be performed as indicated by the use of the logical connector "OR" and the left justified placement. Any one of these three Actions may be chosen. If A.2 is chosen, then both A.2.1 and A.2.2 must be performed as indicated by the logical connector "AND." Required Action A.2.2 is met by performing A.2.2.1 or A.2.2.2. The indented position of the logical connector "OR" indicated that A.2.2.1 and A.2.2.2 are alternative choices, only one of which must be performed.

A 1.0 USE AND APPLICATION

A 1.3 Completion Times

PURPOSE	The purpose of this section is to establish the Completion Time convention and to provide guidance for its use.
BACKGROUND	Limiting Conditions for Operations (LCOs) specify the lowest functional capability or performance levels of equipment required for safe operation of the NAC-UMS® SYSTEM. The ACTIONS associated with an LCO state conditions that typically describe the ways in which the requirements of the LCO can fail to be met. Specified with each stated Condition are Required Action(s) and Completion Time(s).
DESCRIPTION	The Completion Time is the amount of time allowed for completing a Required Action. It is referenced to the time of discovery of a situation (e.g., equipment or variable not within limits) that requires entering an ACTIONS Condition, unless otherwise specified, provided that the NAC-UMS® SYSTEM is in a specified Condition stated in the Applicability of the LCO. Prior to the expiration of the specified Completion Time, Required Actions must be completed. An ACTIONS Condition remains in effect and the Required Actions apply until the Condition no longer exists or the NAC-UMS® SYSTEM is not within the LCO Applicability. Once a Condition has been entered, subsequent subsystems, components, or variables expressed in the Condition, discovered to be not within limits, will not result in separate entry into the Condition, unless specifically stated. The Required Actions of the Condition continue to apply to each additional failure, with Completion Times based on initial entry into the Condition.

(continued)

EXAMPLES

The following examples illustrate the use of Completion Times with different types of Conditions and changing Conditions.

EXAMPLE 1.3-1

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
B. Required Action and associated Completion Time not met	B.1 Perform Action B.1 AND B.2 Perform Action B.2	12 hours 36 hours

Condition B has two Required Actions. Each Required Action has its own Completion Time. Each Completion Time is referenced to the time that Condition B is entered.

The Required Actions of Condition B are to complete action B.1 within 12 hours AND complete action B.2 within 36 hours. A total of 12 hours is allowed for completing action B.1 and a total of 36 hours (not 48 hours) is allowed for completing action B.2 from the time that Condition B was entered. If action B.1 is completed within six hours, the time allowed for completing action B.2 is the next 30 hours because the total time allowed for completing action B.2 is 36 hours.

(continued)

EXAMPLES (continued)

EXAMPLE 1.3-2

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. One System not within limit	A.1 Restore System to within limit	7 days
B. Required Action and associated Completion Time not met	B.1 Complete action B.1 AND B.2 Complete action B.2	12 hours 36 hours

When a System is determined not to meet the LCO, Condition A is entered. If the System is not restored within seven days, Condition B is also entered, and the Completion Time clocks for Required Actions B.1 and B.2 start. If the System is restored after Condition B is entered, Conditions A and B are exited; therefore, the Required Actions of Condition B may be terminated.

(continued)

EXAMPLES (continued)

EXAMPLE 1.3-3

ACTIONS

---NOTE-----------------------------------
Separate Condition entry is allowed for each component.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. LCO not met	A.1 Restore compliance with LCO	4 hours
B. Required Action and associated Completion Time not met	B.1 Complete action B.1 AND B.2 Complete action B.2	6 hours 12 hours

The Note above the ACTIONS table is a method of modifying how the Completion Time is tracked. If this method of modifying how the Completion Time is tracked was applicable only to a specific Condition, the Note would appear in that Condition rather than at the top of the ACTIONS Table.

The Note allows Condition A to be entered separately for each component, and Completion Times to be tracked on a per component basis. When a component is determined to not meet the LCO, Condition A is entered and its Completion Time starts. If subsequent components are determined to not meet the LCO, Condition A is entered for each component and separate Completion Times are tracked for each component.

(continued)

EXAMPLES (continued)

EXAMPLE 1.3-3

IMMEDIATE COMPLETION TIME

When "Immediately" is used as a Completion Time, the Required Action should be pursued without delay and in a controlled manner.

A 1.0 USE AND APPLICATION

A 1.4 Frequency

PURPOSE

The purpose of this section is to define the proper use and application of Frequency requirements.

DESCRIPTION

Each Surveillance Requirement (SR) has a specified Frequency in which the Surveillance must be met in order to meet the associated Limiting Condition for Operation (LCO). An understanding of the correct application of the specified Frequency is necessary for compliance with the SR.

Each “specified Frequency” is referred to throughout this section and each of the Specifications of Section 3.0, Surveillance Requirement (SR) Applicability. The “specified Frequency” consists of requirements of the Frequency column of each SR.

Situations where a Surveillance could be required (i.e., its Frequency could expire), but where it is not possible or not desired that it be performed until sometime after the associated LCO is within its Applicability, represent potential SR 3.0.4 conflicts. To avoid these conflicts, the SR (i.e., the Surveillance or the Frequency) is stated such that it is only “required” when it can be and should be performed. With an SR satisfied, SR 3.0.4 imposes no restriction.

The use of “met” or “performed” in these instances conveys specific meanings. A Surveillance is “met” only after the acceptance criteria are satisfied. Known failure of the requirements of a Surveillance, even without a Surveillance specifically being “performed,” constitutes a Surveillance not “met.”

(continued)

EXAMPLES The following examples illustrate the various ways that Frequencies are specified.

EXAMPLE 1.4-1

SURVEILLANCE REQUIREMENTS

SURVEILLANCE	FREQUENCY
Verify pressure within limit	12 hours

Example 1.4-1 contains the type of SR most often encountered in the Technical Specifications (TS). The Frequency specifies an interval (12 hours) during which the associated Surveillance must be performed at least one time. Performance of the Surveillance initiates the subsequent interval. Although the Frequency is stated as 12 hours, SR 3.0.2 allows an extension of the time interval to 1.25 times the interval specified in the Frequency for operational flexibility. The measurement of this interval continues at all times, even when the SR is not required to be met per SR 3.0.1 (such as when the equipment or variables are outside specified limits, or the facility is outside the Applicability of the LCO). If the interval specified by SR 3.0.2 is exceeded while the facility is in a condition specified in the Applicability of the LCO, the LCO is not met in accordance with SR 3.0.1.

If the interval as specified by SR 3.0.2 is exceeded while the facility is not in a condition specified in the Applicability of the LCO for which performance of the SR is required, the Surveillance must be performed within the Frequency requirements of SR 3.0.2, prior to entry into the specified condition. Failure to do so would result in a violation of SR 3.0.4.

(continued)

EXAMPLE 1.4-2

SURVEILLANCE REQUIREMENTS

SURVEILLANCE	FREQUENCY
Verify flow is within limits	Once within 12 hours prior to starting activity AND 24 hours thereafter

Example 1.4-2 has two Frequencies. The first is a one time performance Frequency, and the second is of the type shown in Example 1.4-1. The logical connector "AND" indicates that both Frequency requirements must be met. Each time the example activity is to be performed, the Surveillance must be performed within 12 hours prior to starting the activity.

The use of "once" indicates a single performance will satisfy the specified Frequency (assuming no other Frequencies are connected by "AND"). This type of Frequency does not qualify for the 25% extension allowed by SR 3.0.2.

"Thereafter" indicates future performances must be established per SR 3.0.2, but only after a specified condition is first met (i.e., the "once" performance in this example). If the specified activity is canceled or not performed, the measurement of both intervals stops. New intervals start upon preparing to restart the specified activity.

A 2.0 [Reserved]

A 3.0 LIMITING CONDITION FOR OPERATION (LCO) APPLICABILITY

LCO 3.0.1	LCOs shall be met during specified conditions in the Applicability, except as provided in LCO 3.0.2.
LCO 3.0.2	Upon failure to meet an LCO, the Required Actions of the associated Conditions shall be met, except as provided in LCO 3.0.5. If the LCO is met or is no longer applicable prior to expiration of the specified Completion Time(s), completion of the Required Action(s) is not required, unless otherwise stated.
LCO 3.0.3	Not applicable to a NAC-UMS® SYSTEM.
LCO 3.0.4	When an LCO is not met, entry into a specified condition in the Applicability shall not be made except when the associated ACTIONS to be entered permit continued operation in the specified condition in the Applicability for an unlimited period of time. This Specification shall not prevent changes in specified conditions in the Applicability that are required to comply with ACTIONS or that are related to the unloading of an NAC-UMS® SYSTEM. Exceptions to this Condition are stated in the individual Specifications. These exceptions allow entry into specified conditions in the Applicability where the associated ACTIONS to be entered allow operation in the specified conditions in the Applicability only for a limited period of time.
LCO 3.0.5	Equipment removed from service or not in service in compliance with ACTIONS may be returned to service under administrative control solely to perform testing required to demonstrate it meets the LCO or that other equipment meets the LCO. This is an exception to LCO 3.0.2 for the System to return to service under administrative control to perform the testing.

A 3.0 SURVEILLANCE REQUIREMENT (SR) APPLICABILITY

SR 3.0.1

SRs shall be met during the specified conditions in the Applicability for individual LCOs, unless otherwise stated in the SR. Failure to meet a Surveillance, whether such failure is experienced during the performance of the Surveillance or between performances of the Surveillance, shall be a failure to meet the LCO. Failure to perform a Surveillance within the specified Frequency shall be a failure to meet the LCO, except as provided in SR 3.0.3. Surveillances do not have to be performed on equipment or variables outside specified limits.

SR 3.0.2

The specified Frequency for each SR is met if the Surveillance is performed within 1.25 times the interval specified in the Frequency, as measured from the previous performance or as measured from the time a specified condition of the Frequency is met.

For Frequencies specified as "once," the above interval extension does not apply. If a Completion Time requires periodic performance on a "once per…" basis, the above Frequency extension applies to each performance after the initial performance.

Exceptions to this Specification are stated in the individual Specifications.

SR 3.0.3

If it is discovered that a Surveillance was not performed within its specified Frequency, then compliance with the requirement to declare the LCO not met may be delayed from the time of discovery up to 24 hours or up to the limit of the specified Frequency, whichever is less. This delay period is permitted to allow performance of the Surveillance.

If the Surveillance is not performed within the delay period, the LCO must immediately be declared not met, and the applicable Condition(s) must be entered.

(continued)

SR 3.0.3 (continued)	When the Surveillance is performed within the delay period and the Surveillance is not met, the LCO must immediately be declared not met, and the applicable Condition(s) must be entered.
SR 3.0.4	Entry into a specified Condition in the Applicability of an LCO shall not be made, unless the LCO's Surveillances have been met within their specified Frequency. This provision shall not prevent entry into specified conditions in the Applicability that are required to comply with Actions or that are related to the unloading of a NAC-UMS® SYSTEM.

A 3.1 NAC-UMS® SYSTEM Integrity

A 3.1.1 CANISTER Maximum Time in Vacuum Drying

LCO 3.1.1 The following limits for vacuum drying time shall be met, as appropriate:

1. The time duration from completion of draining the CANISTER through completion of vacuum dryness testing and the completion of LCO A 3.1.3 shall not exceed the following time limits:

PWR

Total Heat Load (L) (kW)	Time Limit (Hours)	Total Heat Load (L) (kW)	Time Limit (Hours)
$20 < L \leq 23$	27	$11 < L \leq 14$	40
$17.6 < L \leq 20$	30	$8 < L \leq 11$	52
$14 < L \leq 17.6$	33	$L \leq 8$	103

BWR

Total Heat Load (L) (kW)	Time Limit (Hours)	Total Heat Load (L) (kW)	Time Limit (Hours)
$20 < L \leq 23$	25	$11 < L \leq 14$	45
$17 < L \leq 20$	27	$8 < L \leq 11$	72
$14 < L \leq 17$	33	$L \leq 8$	600

(continued)

2. The time duration from the end of 24 hours of in-pool cooling or of forced air cooling of the CANISTER through completion of vacuum dryness testing and the completion of LCO A 3.1.3 shall not exceed the following limits:

PWR Forced Air		PWR In-Pool	
Total Heat Load (L) (kW)	Time Limit (Hours)	Total Heat Load (L) (kW)	Time Limit (Hours)
20 < L ≤ 23	3	20 < L ≤ 23	12
17.6 < L ≤ 20	6	17.6 < L ≤ 20	15
14 < L ≤ 17.6	9	14 < L ≤ 17.6	18
11 < L ≤ 14	16	11 < L ≤ 14	24
8 < L ≤ 11	27	8 < L ≤ 11	36
L ≤ 8	78	L ≤ 8	87

BWR Forced Air		BWR In-Pool	
Total Heat Load (L) (kW)	Time Limit (Hours)	Total Heat Load (L) (kW)	Time Limit (Hours)
20 < L ≤ 23	2	20 < L ≤ 23	10
17 < L ≤ 20	3	17 < L ≤ 20	11
14 < L ≤ 17	8	14 < L ≤ 17	17
11 < L ≤ 14	18	11 < L ≤ 14	26
L ≤ 11	41	L ≤ 11	52

Note: A CANISTER loaded with a fuel assembly having a burnup >45 GWd/MTU is limited to a total of nine (9) cooling/vacuum drying cycles performed in accordance with LCO 3.1.1.2.

APPLICABILITY: During LOADING OPERATIONS

(continued)

ACTIONS

---------------------------------------NOTE--

Separate Condition entry is allowed for each NAC-UMS® SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. LCO time limits not met	A.1 Fill CANISTER with helium	2 hours
	AND	
	A.2.1.1 Place TRANSFER CASK with helium filled loaded CANISTER in spent fuel pool.	2 hours
	AND	
	A.2.1.2 Maintain TRANSFER CASK and CANISTER in spent fuel pool for a minimum of 24 hours	26 hours
	OR	
	A.2.2.1 Commence supplying air to the TRANSFER CASK annulus fill/drain lines at a rate of 375 CFM and a maximum temperature of 76ºF	2 hours
	AND	
	A.2.2.2 Maintain airflow for a minimum of 24 hours	26 hours

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.1.1	Monitor elapsed time from completion of CANISTER draining operations until completion of LCO A 3.1.3.	As required to meet the time limit
SR 3.1.1.2	Monitor elapsed time from the end of in-pool cooling or of forced-air cooling until completion of LCO A 3.1.3.	As required to meet the time limit

A 3.1 NAC-UMS® SYSTEM Integrity

A 3.1.2 CANISTER Vacuum Drying Pressure

LCO 3.1.2	The CANISTER vacuum drying pressure, ≤10 mm of mercury (Hg), shall be held for a minimum of 10 minutes with the vacuum pump isolated and turned off, with the pressure remaining ≤10 mm of Hg during the 10-minute period.
APPLICABILITY:	During LOADING OPERATIONS

ACTIONS

---NOTE---
Separate Condition entry is allowed for each NAC-UMS® SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. CANISTER vacuum drying pressure limit not met	A.1 Establish CANISTER cavity vacuum drying pressure within limit	25 days
B. Required Action and associated Completion Time not met	B.1 Remove all fuel assemblies from the NAC-UMS® SYSTEM	5 days

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.2.1	Verify CANISTER cavity vacuum drying pressure is within limits	Prior to TRANSPORT OPERATIONS.

A 3.1 NAC-UMS® SYSTEM Integrity

A 3.1.3 CANISTER Helium Backfill Pressure

LCO 3.1.3 The CANISTER helium backfill pressure shall be 0 (+1, -0) psig.

APPLICABILITY: During LOADING OPERATIONS

ACTIONS

---NOTE---
Separate Condition entry is allowed for each NAC-UMS® SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. CANISTER helium backfill pressure limit not met	A.1 Establish CANISTER helium backfill pressure within limit	25 days
B. Required Action and associated Completion Time not met	B.1 Remove all fuel assemblies from the NAC-UMS® SYSTEM	5 days

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.3.1	Verify CANISTER helium backfill pressure is within limit	Prior to TRANSPORT OPERATIONS.

A 3.1 NAC-UMS® SYSTEM Integrity

A 3.1.4 CANISTER Maximum Time in TRANSFER CASK

LCO 3.1.4

The total cumulative time a loaded and helium filled CANISTER may remain in TRANSFER CASK is limited to 600 hours. The following intermediate time limits for loaded and helium filled CANISTER time in TRANSFER CASK, without forced air or in-pool cooling, shall apply between cooling cycles. Canisters with total heat loads below those with intermediate limits are only limited by the 600 cumulative hours.

Total PWR Heat Load (L)(kW)	Time Limit (Hours)
$20 < L \leq 23$	20

Total BWR Heat Load (L)(kW)	Time Limit (Hours)
$20 < L \leq 23$	16
$17 < L \leq 20$	30

APPLICABILITY: During LOADING OPERATIONS, TRANSFER OPERATIONS, and UNLOADING OPERATIONS.

(continued)

ACTIONS

---NOTE---
Separate Condition entry is allowed for each NAC-UMS® SYSTEM.

CONDITION	REQUIRED ACTION		COMPLETION TIME
A. ----NOTE ----- All time spent in Condition A is part of the 600 hour cumulative limit ------------------- Intermediate time limit not met	A.1.1	Place TRANSFER CASK with CANISTER in spent fuel pool	2 hours
	AND		
	A.1.2	Maintain TRANSFER CASK and CANISTER in spent fuel pool for a minimum of 24 hours	26 hours
	OR		
	A.2.1	Commence supplying air to the TRANSFER CASK annulus fill/drain lines at a rate of 375 CFM and a maximum temperature of 76ºF	2 hours
	AND		
	A.2.2	Maintain airflow for a minimum of 24 hours	26 hours
B. 600 hour cumulative time limit not met	B.1	Load CANISTER into CONCRETE CASK	5 days
	OR		
	B.2	Load CANISTER into TRANSPORT CASK	5 days
	OR		
	B.3	Remove all fuel assemblies from the NAC-UMS® SYSTEM	5 days

(continued)

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.4.1	Monitor elapsed time for compliance with LCO 3.1.4	As required to meet the time limit

A 3.1 NAC-UMS® SYSTEM Integrity

A 3.1.5 CANISTER Helium Leak Rate

LCO 3.1.5 There shall be no indication of a helium leak at a test sensitivity of 1×10^{-7} cm^3/sec (helium) through the CANISTER shield lid to CANISTER shell confinement weld to demonstrate a helium leak rate equal to or less than 2×10^{-7} cm^3/sec (helium).

APPLICABILITY: During LOADING OPERATIONS

ACTIONS

---NOTE---

Separate Condition entry is allowed for each NAC-UMS® SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. CANISTER helium leak rate limit not met	A.1 Establish CANISTER helium leak rate within limit	25 days
B. Required Action and associated Completion Time not met	B.1 Remove all fuel assemblies from the NAC-UMS® SYSTEM	5 days

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.5.1	Verify CANISTER helium leak rate is within limit	Once prior to TRANSPORT OPERATIONS.

A 3.1 NAC-UMS® SYSTEM

A 3.1.6 CONCRETE CASK Heat Removal System

LCO 3.1.6 The CONCRETE CASK Heat Removal System shall be OPERABLE.

APPLICABILITY: During STORAGE OPERATIONS

ACTIONS

---NOTE---

Separate Condition entry is allowed for each NAC-UMS® SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. CONCRETE CASK heat removal system inoperable	A.1 Ensure adequate heat removal to prevent exceeding short-term temperature limits AND A.2 Restore CONCRETE CASK Heat Removal System to OPERABLE status	Immediately 25 days
B. Required Actions A.1 or A.2 and associated Completion Times not met	B.1 Perform an engineering evaluation to determine that the CONCRETE CASK Heat Removal System is OPERABLE OR B.2 Place the NAC-UMS SYSTEM in a safe condition	5 days 5 days

(continued)

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.6.1	Verify the difference between the ISFSI ambient temperature and the average outlet air temperature of at least two outlet vents (at least two vents must be located 180° apart from each other) is ≤102ºF for the PWR canister or ≤ 92ºF for the BWR canister <u>OR</u> Visually verify all four air inlet and outlet screens are unobstructed	24 hours 24 hours
SR 3.1.6.2	Verify the difference between the ISFSI ambient temperature and the average outlet air temperature of at least two outlet vents (at least two vents must be located 180° apart from each other) is ≤ 102ºF for the PWR canister or ≤ 92ºF for the BWR canister	Once between 5 and 30 days after STORAGE OPERATIONS begin

[DELETED]

A 3.2 NAC-UMS® SYSTEM Radiation Protection

A 3.2.1 CANISTER Surface Contamination

LCO 3.2.1 Removable contamination on the exterior surfaces of the CANISTER shall not exceed:

a. 10,000 dpm/100 cm^2 from beta and gamma sources; and

b. 100 dpm/100 cm^2 from alpha sources.

APPLICABILITY: During LOADING OPERATIONS

ACTIONS

---NOTE---
Separate Condition entry is allowed for each NAC-UMS® SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. CANISTER removable surface contamination limits not met	A.1 Restore CANISTER removable surface contamination to within limits	Prior to TRANSPORT OPERATIONS

(continued)

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.2.1.1	Verify by either direct or indirect methods that the removable contamination on the exterior surfaces of the CANISTER is within limits	Once, prior to TRANSPORT OPERATIONS

A 3.2 NAC-UMS® SYSTEM Radiation Protection

A 3.2.2 CONCRETE CASK Average Surface Dose Rates

LCO 3.2.2 The average surface dose rates of each CONCRETE CASK shall not exceed the following limits unless required ACTIONS A.1 and A.2 are met.

a. 50 mrem/hour (neutron + gamma) on the side (on the concrete surfaces);

b. 50 mrem/hour (neutron + gamma) on the top;

c. 100 mrem/hour (neutron + gamma) at air inlets and outlets.

APPLICABILITY: Prior to STORAGE OPERATIONS

ACTIONS

---NOTE---
Separate Condition entry is allowed for each NAC-UMS® SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. CONCRETE CASK average surface dose rate limits not met	A.1 Administratively verify correct fuel loading AND	24 hours

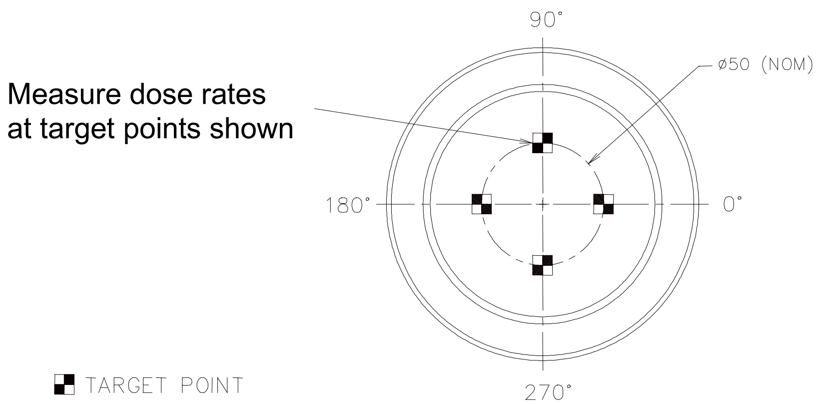
(continued)

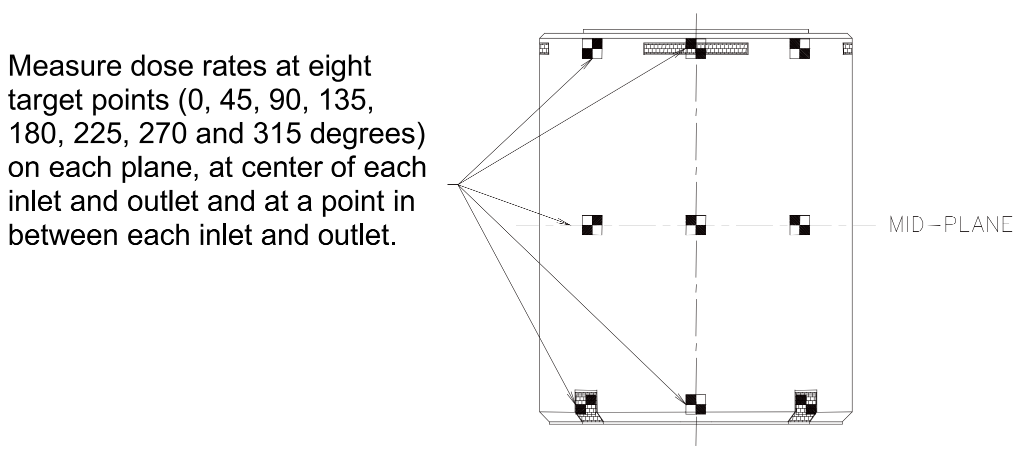
CONDITION	REQUIRED ACTION	COMPLETION TIME
	A.2 Perform analysis to verify compliance with the ISFSI offsite radiation protection requirements of 10 CFR 20 and 10 CFR 72	7 days
B. Required Action and associated Completion Time not met.	B.1 Remove all fuel assemblies from the NAC-UMS® SYSTEM	30 days

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.2.2.1	Verify average surface dose rates of CONCRETE CASK loaded with a CANISTER containing fuel assemblies are within limits. Dose rates shall be measured at the locations shown in Figure A3-1.	Prior to STORAGE OPERATIONS

Figure A3-1 CONCRETE CASK Surface Dose Rate Measurement





A 3.3 NAC-UMS® SYSTEM Criticality Control

A 3.3.1 Dissolved Boron Concentration

LCO 3.3.1 The dissolved boron concentration in the water in the CANISTER cavity shall be ≥ 1,000 ppm.

APPLICABILITY: During LOADING OPERATIONS and UNLOADING OPERATIONS with water and at least one fuel assembly in the CANISTER that exceeds the enrichment limits in Table B2-2 for fuel assemblies taking no boron credit.

ACTIONS

---NOTE--
Separate Condition entry is allowed for each NAC-UMS® SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. Dissolved boron concentration not met.	A.1 Suspend loading of fuel assemblies into CANISTER and any other actions that increase reactivity	Immediately
	AND	
	A.2 Initiate action to restore boron concentration to within limit	Immediately
	AND	
	A.3.1 Restore boron concentration to within limit	24 hours
	OR	
	A.3.2 Remove all fuel assemblies that exceed the enrichment limits of Table B2-2 for fuel assemblies taking no boron credit	24 hours

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.3.1.1	Verify the dissolved boron concentration is met using two independent measurements.	Once within 4 hours prior to commencing LOADING or UNLOADING OPERATIONS. <u>AND</u> Every 48 hours thereafter while the CANISTER is in the spent fuel pool or while water is in the CANISTER, except when no water is being introduced into the CANISTER cavity.

A 4.0 [Reserved]

A 5.0 ADMINISTRATIVE CONTROLS AND PROGRAMS

A 5.1 Training Program

A training program for the NAC-UMS® Universal Storage System shall be developed under the general licensee's systematic approach to training (SAT). Training modules shall include comprehensive instructions for the operation and maintenance of the NAC-UMS® Universal Storage System and the independent spent fuel storage installation (ISFSI).

A 5.2 Pre-Operational Testing and Training Exercises

A dry run training exercise on loading, closure, handling, unloading, and transfer of the NAC-UMS® Storage System shall be conducted by the licensee prior to the first use of the system to load spent fuel assemblies. The training exercise shall not be conducted with spent fuel in the CANISTER. The dry run may be performed in an alternate step sequence from the actual procedures, but all steps must be performed. The dry run shall include, but is not limited to the following:

a. Moving the CONCRETE CASK into its designated loading area
b. Moving the TRANSFER CASK containing the empty CANISTER into the spent fuel pool
c. Loading one or more dummy fuel assemblies into the CANISTER, including independent verification
d. Selection and verification of fuel assemblies requiring preferential loading
e. Installing the shield lid
f. Removal of the TRANSFER CASK from the spent fuel pool
g. Closing and sealing of the CANISTER to demonstrate pressure testing, vacuum drying, helium backfilling, welding, weld inspection and documentation, and leak testing
h. TRANSFER CASK movement through the designated load path
i. TRANSFER CASK installation on the CONCRETE CASK
j. Transfer of the CANISTER to the CONCRETE CASK

(continued)

A 5.2 Pre-Operational Testing and Training Exercises (continued)

k. CONCRETE CASK shield plug and lid installation
l. Transport of the CONCRETE CASK to the ISFSI
m. CANISTER unloading, including reflooding and weld removal or cutting
n. CANISTER removal from the CONCRETE CASK

Appropriate mockup fixtures may be used to demonstrate and/or to qualify procedures, processes or personnel in welding, weld inspection, vacuum drying, helium backfilling, leak testing and weld removal or cutting.

A 5.3 Special Requirements for the First System Placed in Service

The heat transfer characteristics and performance of the NAC-UMS® SYSTEM will be recorded by air inlet and outlet temperature measurements of the first system placed in service with a heat load equal to or greater than 10 kW. A letter report summarizing the results of the measurements will be submitted to the NRC in accordance with 10 CFR 72.4 within 30 days of placing the loaded cask on the ISFSI pad. The report will include a comparison of the calculated temperatures of the NAC-UMS® SYSTEM heat load to the measured temperatures. A report is not required to be submitted for the NAC-UMS® SYSTEMs that are subsequently loaded, provided that the performance of the first system placed in service with a heat load $\geq$ 10 kW is demonstrated by the comparison of the calculated and measured temperatures.

A 5.4 [DELETED]

(continued)

A 5.5 Radioactive Effluent Control Program

The program implements the requirements of 10 CFR 72.126.

a. The NAC-UMS® SYSTEM does not create any radioactive materials or have any radioactive waste treatment systems. Therefore, specific operating procedures for the control of radioactive effluents are not required. LCO 3.1.5, CANISTER Helium Leak Rate, provides assurance that there are no radioactive effluents from the NAC-UMS® SYSTEM.

b. This program includes an environmental monitoring program. Each general license user may incorporate NAC-UMS® SYSTEM operations into their environmental monitoring program for 10 CFR Part 50 operations.

A 5.6 NAC-UMS® SYSTEM Transport Evaluation Program

This program provides a means for evaluating various transport configurations and transport route conditions to ensure that the design basis drop limits are met. For lifting of the loaded TRANSFER CASK or CONCRETE CASK using devices that are integral to a structure governed by 10 CFR Part 50 regulations, 10 CFR 50 requirements apply. This program is not applicable when the TRANSFER CASK or CONCRETE CASK is in the fuel building or is being handled by a device providing support from underneath (i.e., on a rail car, heavy haul trailer, air pads, etc.).

Pursuant to 10 CFR 72.212, this program shall evaluate the site specific transport route conditions.

a. The lift height above the transport surface shall not exceed the limits in Table A5-1.

(continued)

A 5.6 NAC-UMS® SYSTEM Transport Evaluation Program (continued)

b. For site-specific transport conditions that are not bounded by Section 11.2.4 of the NAC-UMS® Final Safety Analysis Report, the program may evaluate the site-specific conditions to ensure that the impact loading due to site-specific drop events does not exceed 60g. This alternative analysis shall be commensurate with the drop analyses described in the Final Safety Analysis Report for the NAC-UMS® SYSTEM. The program shall ensure that these alternative analyses are documented and controlled.

c. The TRANSFER CASK and CONCRETE CASK may be lifted to those heights necessary to perform cask handling operations, including CANISTER transfer, provided the lifts are made with structures and components designed in accordance with the criteria specified in Section B3.5 of Appendix B to CoC No. 1015, as applicable.

A 5.7 [Deleted]

Table A5-1 TRANSFER CASK and CONCRETE CASK Lifting Requirements

Item	Orientation	Loaded Cask Lifting Height Limit
TRANSFER CASK	Horizontal	Not Permitted
TRANSFER CASK	Vertical	None Established[1]
CONCRETE CASK	Horizontal	Not Permitted
CONCRETE CASK	Vertical	< 24 inches

Note:
1. See Technical Specification A5.6(c).

APPENDIX B

APPROVED CONTENTS AND DESIGN FEATURES FOR THE NAC-UMS® SYSTEM

AMENDMENT 8

Appendix B
Table of Contents

1.0 [Reserved]

B 2.0 APPROVED CONTENTS

B 2.1 Fuel Specifications and Loading Conditions

The NAC-UMS® System is designed to provide passive dry storage of canistered PWR and BWR spent fuel. The system requires few operating controls. The principal controls and limits for the NAC-UMS® SYSTEM are satisfied by the selection of fuel for storage that meets the Approved Contents presented in this section and in Tables B2-1 through B2-5 for the standard NAC-UMS® SYSTEM design basis spent fuels.

This section also permits the loading of fuel assemblies that are unique to specific reactor sites. SITE SPECIFIC FUEL assembly configurations are either shown to be bounded by the analysis of the standard NAC-UMS® System design basis fuel assembly configuration of the same type (PWR or BWR), or are shown to be acceptable contents by specific evaluation of the configuration.

The separate specific evaluation may establish different limits, which are maintained by administrative controls for preferential loading. The preferential loading controls allow the loading of unique configurations as compared to the standard NAC-UMS® System design basis spent fuels.

Unless specifically excepted, SITE SPECIFIC FUEL must meet all of the controls and limits specified for the NAC-UMS® System.

If any Fuel Specification or Loading Conditions of this section are violated, the following actions shall be completed:

- The affected fuel assemblies shall be placed in a safe condition.
- Within 24 hours, notify the NRC Operations Center.
- Within 60 days, submit a special report in accordance with the applicable requirements of 10 CFR 72.75(g).

(continued)

B 2.1.1 Fuel to be Stored in the NAC-UMS® SYSTEM

UNDAMAGED FUEL and DAMAGED FUEL ASSEMBLIES meeting the limits specified in Tables B2-1 through B2-15 may be stored in the NAC-UMS® SYSTEM. DAMAGED Fuel is limited to SITE SPECIFIC FUEL and select BWR fuel assembly types. BWR fuel assembly types allowed as DAMAGED FUEL are shown in Table B2-3 and must be loaded into a Class 5DF CANISTER.

B 2.1.2 Maine Yankee SITE SPECIFIC FUEL Preferential Loading

The estimated Maine Yankee SITE SPECIFIC FUEL inventory is shown in Table B2-6. As shown in this table, certain of the Maine Yankee fuel configurations must be preferentially loaded in specific basket fuel tube positions.

Corner positions are used for CONSOLIDATED FUEL, certain HIGH BURNUP FUEL and DAMAGED FUEL or FUEL DEBRIS loaded in a MAINE YANKEE FUEL CAN, for fuel assemblies with missing fuel rods, burnable poison rods or fuel assemblies with fuel rods that have been replaced by hollow zirconium alloy rods. Designation for placement in corner positions results primarily from shielding or criticality evaluations of these fuel configurations. CONSOLIDATED FUEL is conservatively designated for a corner position, even though analysis shows that these lattices could be loaded in any basket position. Corner positions are positions 3, 6, 19, and 22 in Figure B2-1.

Preferential loading is also used for HIGH BURNUP FUEL not loaded in the MAINE YANKEE FUEL CAN. This fuel is assigned to peripheral locations, positions 1, 2, 3, 6, 7, 12, 13, 18, 19, 22, 23, and 24 in Figure B2-1. The interior locations, positions 4, 5, 8, 9, 10, 11, 14, 15, 16, 17, 20, and 21, must be loaded with fuel that has lower burnup and/or longer cool times to maintain the design basis heat load (23 kW per canister).

One of the two loading patterns (Standard or Preferential) shown in Table B2-8 must be used to load each canister. For the Standard loading pattern, the heat load of each fuel assembly is limited to 0.958 kW. For the Preferential loading pattern, the heat load of the fuel assemblies at the basket periphery locations is limited to 1.05 kW, and the heat load of the fuel assemblies at the basket interior locations is limited to 0.867 kW. Once selected, all of the spent fuel in that canister must be loaded in accordance with that pattern. Within a pattern, mixing of enrichment and cool time is allowed, but no mixing of loading patterns is permitted. Choosing a Preferential pattern restricts the interior fuel to the cool times shown in the Preferential (I) column, and the peripheral fuel to the cool times shown in the Preferential (P) column.

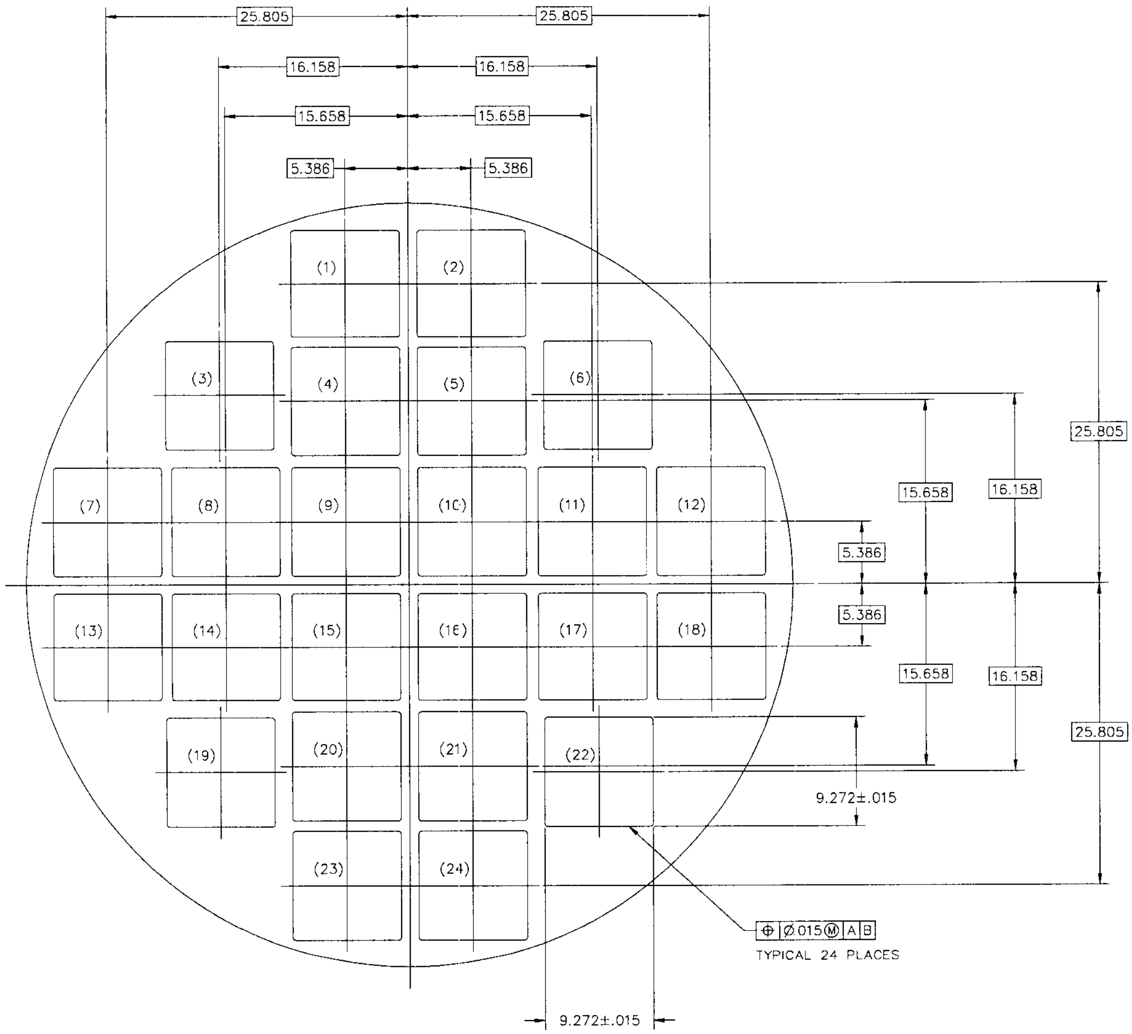
(continued)

B 2.1.2 Maine Yankee SITE SPECIFIC FUEL Preferential Loading (continued)

Fuel assemblies with a control element assembly (CEA) inserted will be loaded in a Class 2 canister and basket due to the increased length of the assembly with the CEA installed. However, these assemblies are not restricted as to loading position within the basket. Fuel assemblies with non-fuel items installed in corner guide tubes of the fuel assembly must also have a flow mixer installed and must be loaded in a basket corner fuel position in a Class 2 canister.

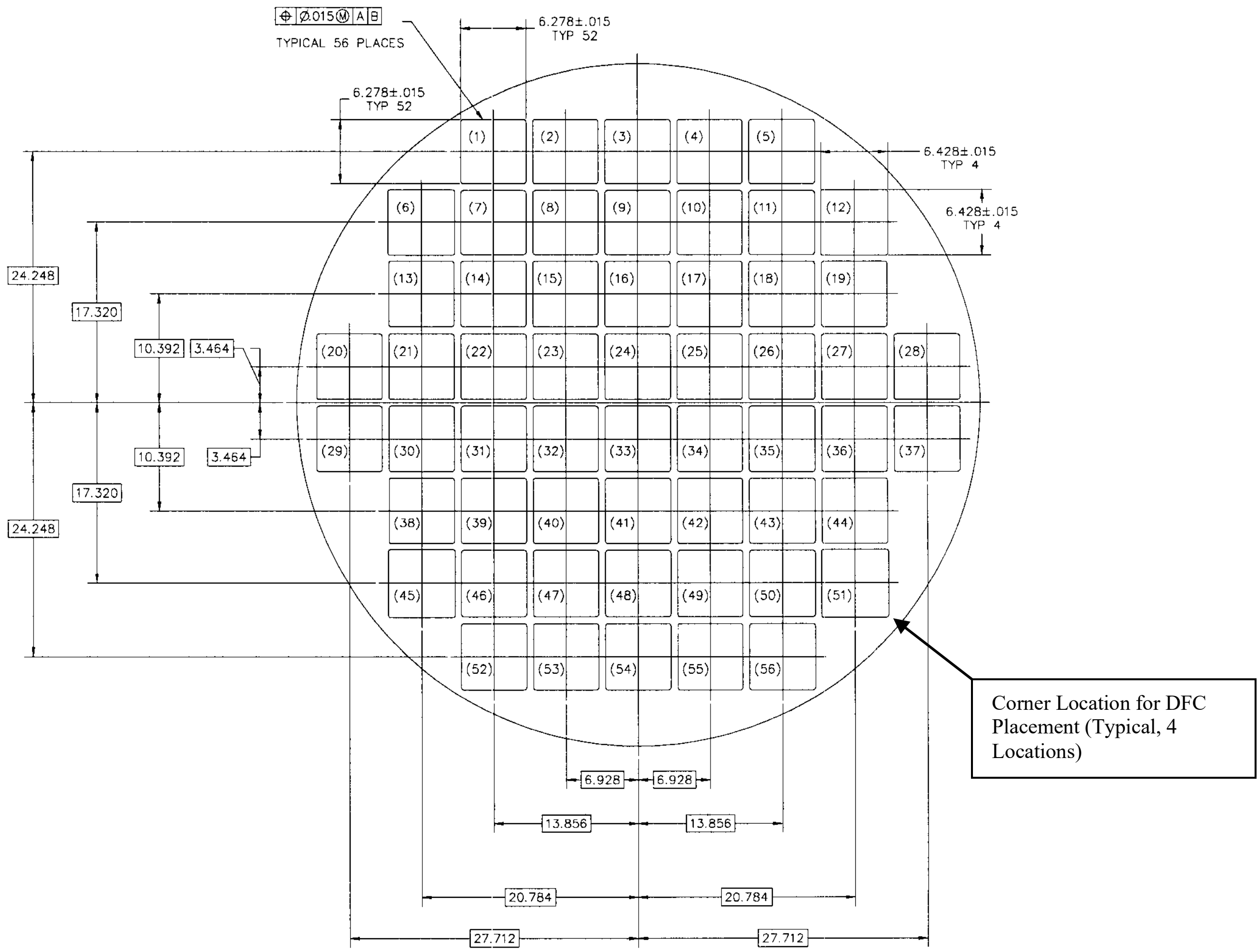
The Transportable Storage Canister loading procedures indicate that loading of a fuel configuration with removed fuel or poison rods, CONSOLIDATED FUEL, or a MAINE YANKEE FUEL CAN with DAMAGED FUEL, FUEL DEBRIS or HIGH BURNUP FUEL, is administratively controlled in accordance with Section B 2.1.

Figure B2-1 PWR Basket Fuel Loading Positions and Minimum Flux Trap Definition



Note: Variations in the dimensions due to fabrication error are permitted provided the minimum flux trap thickness specified in this figure is maintained and no more than two affected (out-of-tolerance) disk openings are adjacent to each other.

Figure B2-2 BWR Basket Fuel Loading Positions DFC Locations and Minimum Flux Trap Definition



Note: Variations in the dimensions due to fabrication error are permitted provided the minimum flux trap thickness specified in this figure is maintained and no more than two affected (out-of-tolerance) disk openings are adjacent to each other.

Figure B2-3 Preferential BWR Fuel Assembly Load Locations -Three Outer Location Possibilities for Higher Enrichment Fuel Assemblies

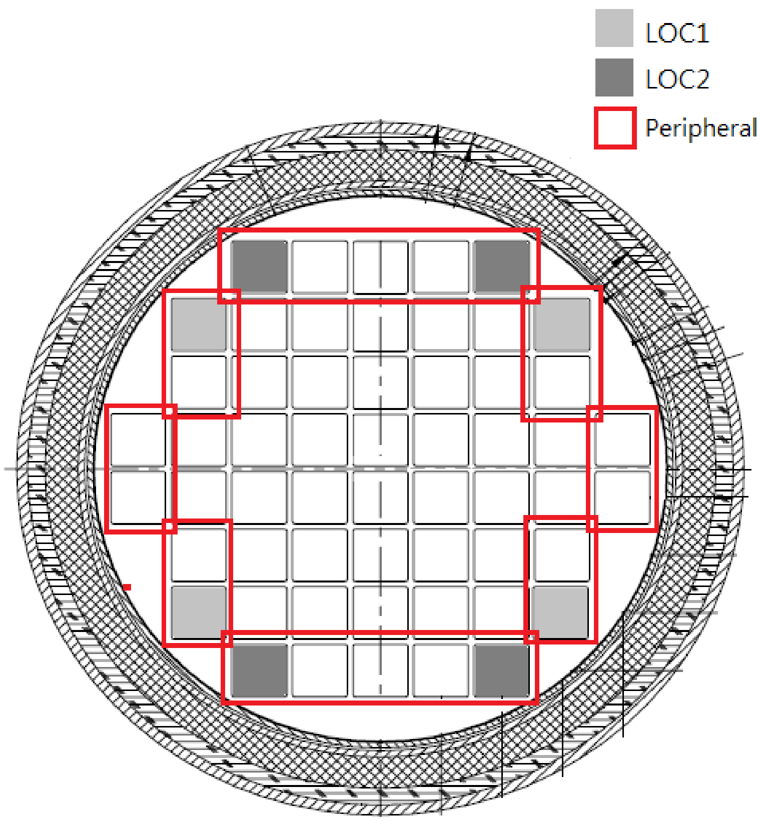


Table B2-1
Fuel Assembly Limits

I. NAC-UMS® CANISTER: PWR FUEL

A. Allowable Contents

1. Uranium oxide PWR UNDAMAGED FUEL ASSEMBLIES listed in Table B2-2 and meeting the following specifications:

a. Cladding Type:	Zirconium alloy with thickness as specified in Table B2-2 for the applicable fuel assembly class.
b. Enrichment, Post-irradiation Cooling Time and Average Burnup Per Assembly:	Maximum enrichment limits are shown in Table B2-2. For variable enrichment fuel assemblies, maximum enrichments represent peak rod enrichments. Combined minimum enrichment, maximum burnup and minimum cool time limits are shown in Table B2-4.
c. Assembly Average Burnup:	Value calculated by averaging the burnup over the entire fuel region (UO_2) of an individual fuel assembly. The maximum assembly average burnup is 60,000 MWd/MTU.
d. Peak Average Rod Burnup:	Value calculated by averaging the burnup in a rod over the length of the rod, then using the highest burnup calculated for any rod as the peak average rod burnup. The maximum peak average rod burnup is 62,500 MWd/MTU.
e. Decay Heat Per Assembly:	≤ 958.3 watts †
f. Nominal Fresh Fuel Assembly Length (in.):	≤ 178.3
g. Nominal Fresh Fuel Assembly Width (in.):	≤ 8.54
h. Fuel Assembly Weight (lbs.):	≤ 1,602 ‡

† Decay heat may be higher for site-specific configurations. A site-specific maximum decay heat of 1.05 kW is specified in Section B 2.1.2.

‡ Includes the weight of nonfuel-bearing components.

B. Quantity per CANISTER: Up to 24 PWR UNDAMAGED FUEL ASSEMBLIES.

C. PWR UNDAMAGED FUEL ASSEMBLIES may contain a flow mixer (thimble plug), an in-core instrument thimble, a burnable poison rod insert (Class 1 and Class 2 contents) consistent with Table B2-2, or solid stainless steel rods (inserted in the guide tubes).

D. PWR UNDAMAGED FUEL ASSEMBLIES shall not contain a control element assembly, except as permitted for SITE-SPECIFIC FUEL.

Table B2-1
Fuel Assembly Limits (continued)

E. Stainless steel spacers may be used in CANISTERS to axially position PWR UNDAMAGED FUEL ASSEMBLIES that are shorter than the available cavity length to facilitate handling.

F. Unenriched fuel assemblies are not authorized for loading.

G. The minimum length of the PWR UNDAMAGED FUEL ASSEMBLY internal structure and bottom end fitting and/or spacers shall ensure that the minimum distance to the fuel region from the base of the CANISTER is 3.2 inches.

H. PWR UNDAMAGED FUEL ASSEMBLIES with one or more grid spacers missing or damaged such that the unsupported length of the fuel rods does not exceed 60 inches. End fitting damage including damaged or missing hold-down springs is allowed, as long as the assembly can be handled safely by normal means.

I. PWR UNDAMAGED FUEL ASSEMBLIES not containing the nominal number of fuel rods specified in Table B2-2 must contain solid filler rods that displace a volume equal to, or greater than, that of the fuel rod that the filler rod replaces. SITE-SPECIFIC FUEL may contain missing fuel rods or hollow rods without replacement by solid filler rods provided the loading restrictions listed in Table B2-7 are met.

II. NAC-UMS® CANISTER: BWR FUEL

A. Allowable Contents

1. Uranium oxide BWR UNDAMAGED and DAMAGED FUEL ASSEMBLIES listed in Table B2-3 and meeting the following specifications:

a. Cladding Type:	Zirconium alloy with thickness as specified in Table B2-3 for the applicable fuel assembly class.
b. Enrichment:	Maximum INITIAL PEAK PLANAR-AVERAGE ENRICHMENTS are shown in Table B2-3 and Table B2-13 thru B2-15. Combined minimum enrichment, maximum burnup and minimum cool time limits are shown in Table B2-5, and Tables B2-10 thru Tables B2-12.
c. Decay Heat per Assembly:	$\leq$ 410.7 watts
d. Post-irradiation Cooling Time and Average Burnup Per Assembly:	As specified in Table B2-5, and Tables B2-10 thru Tables B2-12 for the applicable fuel assembly class.
e. Nominal Fresh Fuel Design Assembly Length (in.):	$\leq$ 176.1

Table B2-1
Fuel Assembly Limits (continued)

f.	Nominal Fresh Fuel Design Assembly Width (in.):	≤ 5.51
g.	Fuel Assembly Weight (lbs):	≤ 702, including channels

B. Quantity per CANISTER: Up to 56 BWR UNDAMAGED FUEL ASSEMBLIES. When loading DAMAGED FUEL up to four damaged fuel assemblies may be loaded.

C. BWR FUEL ASSEMBLIES can be unchanneled or channeled with zirconium alloy channels.

D. BWR FUEL ASSEMBLIES with stainless steel channels shall not be loaded.

E. Stainless steel fuel spacers may be used in CANISTERS to axially position BWR FUEL ASSEMBLIES that are shorter than the available cavity length to facilitate handling.

F. With the exception of the low burnup assemblies identified when applying Table B2-12 for the assembly types authorized by Table B2-3 unenriched fuel assemblies are not authorized for loading.

G. The minimum length of the BWR UNDAMAGED FUEL ASSEMBLY internal structure and bottom end fitting and/or spacers shall ensure that the minimum distance to the fuel region from the base of the CANISTER is 6.2 inches.

H. BWR UNDAMAGED FUEL ASSEMBLIES not containing the nominal number of fuel rods specified in Table B2-3 must contain solid filler rods that displace a volume equal to, or greater than, that of the fuel rod that the filler rod replaces. BWR DAMAGED FUEL ASSEMBLIES may contain less than the nominal number of fuel rods specified in Table B2-3 without filler rods.

Table B2-2 PWR Fuel Assembly Characteristics

Fuel Class	Vendor[1]	Array	Max. MTU	W/O Boron Max. wt % ^{235}U[3]	With Boron Max. wt % ^{235}U[4]	No. of Fuel Rods	No. of Water Holes	Max. Pitch (in)	Min. Rod Dia. (in)	Min. Clad Thick (in)	Max. Pellet Dia.(in)	Max. Active Length (in)	Min. Guide Tube Thick (in)
1	CE	14×14	0.404	4.7	5.0	176	5	0.590	0.438	0.024	0.380	137.0	0.034
1	Ex/ANF	14×14	0.369	5.0	5.0	179	17	0.556	0.424	0.030	0.351	142.0	0.034
1	WE	14×14	0.362	5.0	5.0	179	17	0.556	0.400	0.024	0.345	144.0	0.034
1	WE	14×14	0.415	5.0	5.0	179	17	0.556	0.422	0.022	0.368	145.2	0.034
1	WE, Ex/ANF	15×15	0.465	4.4	5.0	204	21	0.563	0.422	0.024	0.366	144.0	0.015
1	Ex/ANF	17×17	0.413	4.4	5.0	264	25	0.496	0.360	0.025	0.303	144.0	0.016
1	WE	17×17	0.468	4.5	5.0	264	25	0.496	0.374	0.022	0.323	144.0	0.015
1	WE	17×17	0.429	4.3	5.0	264	25	0.496	0.360	0.022	0.309	144.0	0.015
2	B&W	15×15	0.481	4.4	5.0	208	17	0.568	0.430	0.026	0.369	144.0	0.016
2	B&W	17×17	0.466	4.4	5.0	264	25	0.502	0.379	0.024	0.324	143.0	0.017
3	CE	16×16	0.442	4.8	5.0	236	5	0.506	0.382	0.023	0.3255	150.0	0.035
1	Ex/ANF[2]	14×14	0.375	5.0	- -	179	17	0.556	0.417	0.030	0.351	144.0	0.036
1	CE[2]	15×15	0.432	4.2	- -	216	9[5]	0.550	0.418	0.026	0.358	132.0	----
1	Ex/ANF[2]	15×15	0.431	4.2	- -	216	9[5]	0.550	0.417	0.030	0.358	131.8	----
1	CE[2]	16×16	0.403	4.8	- -	236	5	0.506	0.382	0.023	0.3255	136.7	0.035

Note: Parameters shown are nominal pre-irradiation values.

1. Vendor ID indicates the source of assembly base parameters, which are nominal, pre-irradiation values. Loading of assemblies meeting above limits is not restricted to the vendor(s) listed.
2. 14×14, 15×15 and 16×16 fuel manufactured for Prairie Island, Palisades and St. Lucie 2 cores, respectively. These are not generic fuel assemblies provided to multiple reactors.
3. Maximum initial enrichment without boron credit. Assemblies meeting this limit may contain a flow mixer (thimble plug), an ICI thimble, a burnable poison rod insert, or solid stainless steel rods (inserted in guide tubes).
4. Maximum initial enrichment with credit for a minimum soluble boron concentration of 1000 ppm in the spent fuel pool water. Assemblies meeting this limit may contain a flow mixer (thimble plug).
5. Nine nonfuel locations, which may be filled by solid nonfuel rods.

Table B2-3 BWR Fuel Assembly Characteristics

Fuel Class[1]	Vendor[4]	Array	Fuel Identifier	Max. MTU	Max. wt % ^{235}U	No. of Fuel Rods	Max. Pitch (in)	Min. Rod Dia. (in)	Min. Clad Thick (in)	Max. Pellet Dia.(in)	Max. Active Length (in)[2]
4	Ex/ANF	7 × 7	--	0.196	4.5	48	0.738	0.570	0.036	0.490	144.0
4	Ex/ANF	8 × 8	--	0.177	4.7	63	0.641	0.484	0.036	0.405	145.2
4	Ex/ANF	9 × 9	--	0.173	4.4	79	0.572	0.424	0.030	0.357	145.2
4	GE	7 × 7	--	0.199	4.5	49	0.738	0.570	0.036	0.488	144.0
4	GE	7 × 7	--	0.198	4.5	49	0.738	0.563	0.032	0.487	144.0
4	GE	8 × 8	--	0.173	4.5	60	0.640	0.484	0.032	0.410	145.2
4	GE	8 × 8	--	0.179	4.5	62	0.640	0.483	0.032	0.410	145.2
4	GE	8 × 8	--	0.186	4.7	63	0.640	0.493	0.034	0.416	144.0
5/DF	Ex/ANF	8 × 8	ex08b[6]	0.1845	Note 5	62	0.641	0.484	0.035	0.4055	150.0
5	Ex/ANF	9 × 9	--	0.167	4.4	74[3]	0.572	0.424	0.030	0.357	150.0
5/DF	Ex/ANF	9 × 9	ex09c[6]	0.1817	Note 5	79[3]	0.572	0.424	0.030	0.357	150.0
5	GE	7 × 7	--	0.193	4.7	49	0.738	0.563	0.037	0.477	146.0
5	GE	7 × 7	--	0.198	4.5	49	0.738	0.563	0.032	0.487	144.0
5/DF	GE	8 × 8	ge08i[6]	0.1825	Note 5	60	0.640	0.483	0.032	0.410	150.0
5/5DF	GE	8 × 8	ge08k[6]	0.1886	Note 5	62	0.640	0.483	0.032	0.410	150.0
5/5DF	GE	8 × 8	ge09n[6]	0.192	Note 5	63	0.640	0.493	0.034	0.416	146.0
5	GE	9 × 9	--	0.186	4.5	74[3]	0.566	0.441	0.028	0.376	150.0
5	GE	9 × 9	--	0.198	4.6	79[3]	0.566	0.441	0.028	0.376	150.0
5	--	9 x 9	B9_72A[6]	0.1803	Note 5	72	0.572	0.433	0.02.	0.374	150.0.
5	--	10 x 10	B10_91A[6]	0.1906	Note 5	91[3]	0.51	0.3957	0.02385	0.342	150.0.
5	--	10 x10	B10_92A[6]	0.1966	Note 5	92[3]	0.51	0.404	0.026	0.3455	150.0

Note: Parameters shown are nominal pre-irradiation values.

1. All fuel rods are zirconium alloy clad.
2. 150-inch active fuel length assemblies contain 6” natural uranium blankets on top and bottom.
3. Shortened active fuel length in some rods.
4. Vendor ID indicates the source of assembly base parameters, which are nominal, pre-irradiation values. Loading of assemblies meeting above limits is not restricted to the vendor(s) listed.
5. Maximum allowed enrichments are dependent on undamaged uniform or damaged configuration or preferential loading. See Tables B2-9 thru B2-11.
6. Fuel assemblies are allowed maximum assembly average burnup of 60 GWd/MTU and may be loaded as DAMAGED FUEL. Remaining fuel assemblies are limited to 45 GWd/MTU and must be UNDAMAGED.

Table B2-4 Minimum Cooling Time Versus Burnup/Initial Enrichment for PWR Fuel

Minimum Initial Enrichment	**Assembly Average Burnup ≤30 GWd/MTU Minimum Cooling Time [years]**				**30< Assembly Average Burnup ≤35 GWd/MTU Minimum Cooling Time [years]**			
wt % ^{235}U (E)	**14×14**	**15×15**	**16×16**	**17×17**	**14×14**	**15×15**	**16×16**	**17×17**
1.9 ≤ E < 2.1	5	5	5	5	7	7	5	7
2.1 ≤ E < 2.3	5	5	5	5	7	6	5	6
2.3 ≤ E < 2.5	5	5	5	5	6	6	5	6
2.5 ≤ E < 2.7	5	5	5	5	6	6	5	6
2.7 ≤ E < 2.9	5	5	5	5	6	5	5	5
2.9 ≤ E < 3.1	5	5	5	5	5	5	5	5
3.1 ≤ E < 3.3	5	5	5	5	5	5	5	5
3.3 ≤ E < 3.5	5	5	5	5	5	5	5	5
3.5 ≤ E < 3.7	5	5	5	5	5	5	5	5
3.7 ≤ E < 3.9	5	5	5	5	5	5	5	5
3.9 ≤ E < 4.1	5	5	5	5	5	5	5	5
4.1 ≤ E < 4.3	5	5	5	5	5	5	5	5
4.3 ≤ E < 4.5	5	5	5	5	5	5	5	5
4.5 ≤ E < 4.7	5	5	5	5	5	5	5	5
4.7 ≤ E < 4.9	5	5	5	5	5	5	5	5
E ≥ 4.9	5	5	5	5	5	5	5	5
Minimum Initial Enrichment	**35< Assembly Average Burnup ≤40 GWd/MTU Minimum Cooling Time [years]**				**40< Assembly Average Burnup ≤45 GWd/MTU Minimum Cooling Time [years]**			
wt % ^{235}U (E)	**14×14**	**15×15**	**16×16**	**17×17**	**14×14**	**15×15**	**16×16**	**17×17**
1.9 ≤ E < 2.1	10	10	7	10	15	15	11	15
2.1 ≤ E < 2.3	9	9	6	9	14	13	9	13
2.3 ≤ E < 2.5	8	8	6	8	12	12	8	12
2.5 ≤ E < 2.7	8	7	6	7	11	11	7	11
2.7 ≤ E < 2.9	7	7	6	7	10	10	7	10
2.9 ≤ E < 3.1	7	6	6	7	9	9	7	9
3.1 ≤ E < 3.3	6	6	6	6	9	8	7	8
3.3 ≤ E < 3.5	6	6	6	6	8	8	7	8
3.5 ≤ E < 3.7	6	6	6	6	7	8	7	7
3.7 ≤ E < 3.9	6	6	6	6	7	8	7	7
3.9 ≤ E < 4.1	6	6	6	6	7	7	7	7
4.1 ≤ E < 4.3	5	6	6	6	6	7	7	7
4.3 ≤ E < 4.5	5	6	6	6	6	7	7	7
4.5 ≤ E < 4.7	5	6	5	6	6	7	6	7
4.7 ≤ E < 4.9	5	6	5	6	6	7	6	7
E ≥ 4.9	5	6	5	6	6	7	6	7

Table B2-4 Minimum Cooling Time Versus Burnup/Initial Enrichment for PWR Fuel (continued)

Minimum Initial Enrichment	**45< Assembly Average Burnup ≤50 GWd/MTU Minimum Cooling Time [years]**				**50< Assembly Average Burnup ≤55 GWd/MTU Minimum Cooling Time [years]**			
wt % ^{235}U (E)	**14×14**	**15×15**	**16×16**	**17×17**	**14×14**	**15×15**	**16×16**	**17×17**
1.9 ≤ E < 2.1	21	21	18	21	27	27	25	27
2.1 ≤ E < 2.3	19	19	16	19	25	25	23	25
2.3 ≤ E < 2.5	17	17	14	17	23	24	21	24
2.5 ≤ E < 2.7	16	16	12	16	21	22	19	22
2.7 ≤ E < 2.9	14	14	11	14	20	20	17	20
2.9 ≤ E < 3.1	13	13	9	13	18	18	15	18
3.1 ≤ E < 3.3	12	12	9	12	17	17	13	17
3.3 ≤ E < 3.5	11	11	9	11	15	15	12	15
3.5 ≤ E < 3.7	10	10	8	10	14	14	11	14
3.7 ≤ E < 3.9	9	10	8	9	13	13	11	13
3.9 ≤ E < 4.1	9	10	8	9	12	13	11	12
4.1 ≤ E < 4.3	8	10	8	9	11	13	10	12
4.3 ≤ E < 4.5	8	9	8	9	10	13	10	12
4.5 ≤ E < 4.7	7	9	8	9	10	12	10	12
4.7 ≤ E < 4.9	7	9	8	9	9	12	10	12
E ≥ 4.9	7	9	8	9	9	12	10	11
Minimum Initial Enrichment	**55< Assembly Average Burnup ≤60 GWd/MTU Minimum Cooling Time [years]**							
wt % ^{235}U (E)	**14×14**	**15×15**	**16×16**	**17×17**				
1.9 ≤ E < 2.1	33	34	32	34				
2.1 ≤ E < 2.3	31	32	30	32				
2.3 ≤ E < 2.5	29	30	28	30				
2.5 ≤ E < 2.7	28	28	26	28				
2.7 ≤ E < 2.9	26	26	24	26				
2.9 ≤ E < 3.1	24	24	22	24				
3.1 ≤ E < 3.3	22	23	20	23				
3.3 ≤ E < 3.5	21	21	18	21				
3.5 ≤ E < 3.7	19	19	17	20				
3.7 ≤ E < 3.9	18	18	15	18				
3.9 ≤ E < 4.1	17	18	14	17				
4.1 ≤ E < 4.3	15	17	14	16				
4.3 ≤ E < 4.5	14	17	14	16				
4.5 ≤ E < 4.7	13	17	14	16				
4.7 ≤ E < 4.9	12	17	13	16				
E ≥ 4.9	12	16	13	15				

Table B2-5 Minimum Cooling Time Versus Burnup/Initial Enrichment for BWR Fuel

Minimum Initial Enrichment	Assembly Average Burnup ≤30 GWd/MTU Minimum Cooling Time [years]			30< Assembly Average Burnup ≤35 GWd/MTU Minimum Cooling Time [years]		
wt % ^{235}U (E)	**7×7**	**8×8**	**9×9**	**7×7**	**8×8**	**9×9**
1.9 ≤ E < 2.1	5	5	5	8	7	7
2.1 ≤ E < 2.3	5	5	5	6	6	6
2.3 ≤ E < 2.5	5	5	5	6	5	6
2.5 ≤ E < 2.7	5	5	5	5	5	5
2.7 ≤ E < 2.9	5	5	5	5	5	5
2.9 ≤ E < 3.1	5	5	5	5	5	5
3.1 ≤ E < 3.3	5	5	5	5	5	5
3.3 ≤ E < 3.5	5	5	5	5	5	5
3.5 ≤ E < 3.7	5	5	5	5	5	5
3.7 ≤ E < 3.9	5	5	5	5	5	5
3.9 ≤ E < 4.1	5	5	5	5	5	5
4.1 ≤ E < 4.3	5	5	5	5	5	5
4.3 ≤ E < 4.5	5	5	5	5	5	5
4.5 ≤ E ≤ 4.7	5	5	5	5	5	5

Minimum Initial Enrichment	35< Assembly Average Burnup ≤40 GWd/MTU Minimum Cooling Time [years]			40< Assembly Average Burnup ≤45 GWd/MTU Minimum Cooling Time [years]		
wt % ^{235}U (E)	**7×7**	**8×8**	**9×9**	**7×7**	**8×8**	**9×9**
1.9 ≤ E < 2.1	16	14	15	26	24	25
2.1 ≤ E < 2.3	13	12	12	23	21	22
2.3 ≤ E < 2.5	11	9	10	20	18	19
2.5 ≤ E < 2.7	9	8	8	18	16	17
2.7 ≤ E < 2.9	8	7	7	15	13	14
2.9 ≤ E < 3.1	7	6	6	13	11	12
3.1 ≤ E < 3.3	6	6	6	11	10	10
3.3 ≤ E < 3.5	6	5	6	9	8	9
3.5 ≤ E < 3.7	6	5	6	8	7	7
3.7 ≤ E < 3.9	6	5	5	7	6	7
3.9 ≤ E < 4.1	5	5	5	7	6	7
4.1 ≤ E < 4.3	5	5	5	7	6	6
4.3 ≤ E < 4.5	5	5	5	6	6	6
4.5 ≤ E ≤ 4.7	5	5	5	6	6	6

Table B2-6 Maine Yankee Site Specific Fuel Canister Loading Position Summary

Site Specific Spent Fuel Configurations[1]	**Est. Number of Assemblies**[2]	**Canister Loading Position**
Total Number of Fuel Assemblies[3]	1,434	Any
Inserted Control Element Assembly (CEA)	168	Any
Inserted In-Core Instrument (ICI) Thimble	138	Any
Consolidated Fuel	2	Corner[4]
Fuel Rod Replaced by Rod Enriched to 1.95 wt %	3	Any
Fuel Rod Replaced by Stainless Steel Rod or Zirconium Alloy Rod	18	Any
Fuel Rods Removed	10	Corner[4]
Variable Enrichment[6]	72	Any
Variable Enrichment and Axial Blanket[6]	68	Any
Burnable Poison Rod Replaced by Hollow Zirconium Alloy Rod	80	Corner[4]
Damaged Fuel in MAINE YANKEE FUEL CAN	12	Corner[4]
Burnup between 45,000 and 50,000 MWD/MTU	90	Periphery[5]
MAINE YANKEE FUEL CAN	As Required	Corner[4]
Inserted Start-up Source	4	Corner[4]
Inserted CEA Finger Tip or ICI String Segment	1	Corner[4]

1. All spent fuel, including that held in a Maine Yankee fuel can, must conform to the loading limits presented in Tables B2-8 and B2-9 for cool time.
2. The number of fuel assemblies in some categories may vary depending on future fuel inspections.
3. Includes these site specific spent fuel configurations and standard fuel assemblies. Standard fuel assemblies may be loaded in any canister position.
4. Basket corner positions are positions 3, 6, 19, and 22 in Figure B2-1. Corner positions are also periphery positions.
5. Basket periphery positions are positions 1, 2, 3, 6, 7, 12, 13, 18, 19, 22, 23, and 24 in Figure B2-1. Periphery positions include the corner positions.
6. Variably enriched fuel assemblies have a maximum burnup of less than 30,000 MWD/MTU and enrichments greater than 1.9 wt %. The minimum required cool time for these assemblies is 5 years.

Table B2-7 Maine Yankee Site Specific Fuel Limits

A. Allowable Contents
   1. Combustion Engineering 14 × 14 PWR UNDAMAGED FUEL ASSEMBLIES meeting the specifications presented in Tables B2-1, B2-2 and B2-4.
   2. PWR UNDAMAGED FUEL ASSEMBLIES may contain inserted Control Element Assemblies (CEA), In-Core Instrument (ICI) Thimbles or Flow Mixers. CEAs or Flow Mixers may not be inserted in damaged fuel assemblies, consolidated fuel assemblies or assemblies with irradiated stainless steel replacement rods. Fuel assemblies with a CEA or Flow Mixer inserted must be loaded in a Class 2 CANISTER and cannot be loaded in a Class 1 CANISTER. Fuel assemblies without an inserted CEA or CEA Plug, including those with inserted ICI Thimbles, must be loaded in a Class 1 CANISTER.
   3. PWR UNDAMAGED FUEL ASSEMBLIES with fuel rods replaced with stainless steel or zirconium alloy rods or with uranium oxide rods nominally enriched up to 1.95 wt %.
   4. PWR UNDAMAGED FUEL ASSEMBLIES with fuel rods having variable enrichments with a maximum fuel rod enrichment up to 4.21 wt % ^{235}U and that also have a maximum planar average enrichment up to 3.99 wt % ^{235}U.
   5. PWR UNDAMAGED FUEL ASSEMBLIES with annular axial end blankets. The axial end blanket enrichment may be up to 2.6 wt % ^{235}U.
   6. PWR UNDAMAGED FUEL ASSEMBLIES with solid filler rods or burnable poison rods occupying up to 16 of 176 fuel rod positions.
   7. PWR UNDAMAGED FUEL ASSEMBLIES with one or more grid spacers missing or damaged such that the unsupported length of the fuel rods does not exceed 60 inches or with end fitting damage, including damaged or missing hold-down springs, as long as the assembly can be handled safely by normal means.

B. Allowable Contents requiring preferential loading based on shielding, criticality or thermal constraints. The preferential loading requirement for these fuel configurations is as described in Table B2-6.
   1. PWR UNDAMAGED FUEL ASSEMBLIES with up to 176 fuel rods missing from the fuel assembly lattice.
   2. PWR UNDAMAGED FUEL ASSEMBLIES with a burnup between 45,000 and 50,000 MWd/MTU that must be loaded in accordance with Tables B2-6 and B2-8.
   3. PWR UNDAMAGED FUEL ASSEMBLIES with a burnable poison rod replaced by a hollow zirconium alloy rod.

Table B2-7 Maine Yankee Site Specific Fuel Limits (continued)

4. UNDAMAGED FUEL ASSEMBLIES with a start-up source in a center guide tube. The assembly must be loaded in a basket corner position and must be loaded in a Class 1 CANISTER. Only one (1) start-up source may be loaded in any fuel assembly or any CANISTER.
5. PWR UNDAMAGED FUEL ASSEMBLIES with CEA ends (finger tips) and/or ICI segment inserted in corner guide tube positions. The assembly must also have a CEA plug installed. The assembly must be loaded in a basket corner position and must be loaded in a Class 2 CANISTER.
6. UNDAMAGED FUEL ASSEMBLIES may be loaded in a MAINE YANKEE FUEL CAN.
7. FUEL enclosed in a MAINE YANKEE FUEL CAN. The MAINE YANKEE FUEL CAN can only be loaded in a Class 1 CANISTER. The contents that must be loaded in the MAINE YANKEE FUEL CAN are:

   a) PWR fuel assemblies with up to two UNDAMAGED or DAMAGED FUEL rods inserted in each fuel assembly guide tube or with up to two burnable poison rods inserted in each guide tube. The rods inserted in the guide tubes cannot be from a different fuel assembly. The maximum number of rods in the fuel assembly (fuel rods plus inserted rods, including burnable poison rods) is 176.

   b) A DAMAGED FUEL ASSEMBLY with up to 100% of the fuel rods classified as damaged and/or damaged or missing assembly hardware components. A DAMAGED FUEL ASSEMBLY cannot have an inserted CEA or other nonfuel component.

   c) Individual UNDAMAGED or DAMAGED FUEL rods in a rod type structure, which may be a guide tube, to maintain configuration control.

   d) FUEL DEBRIS consisting of fuel rods with exposed fuel pellets or individual intact or partial fuel pellets not contained in fuel rods.

Table B2-7 Maine Yankee Site Specific Fuel Limits (continued)

e) CONSOLIDATED FUEL lattice structure with a 17 × 17 array formed by grids and top and bottom end fittings connected by four solid stainless steel rods. Maximum contents are 289 fuel rods having a total lattice weight ≤ 2,100 pounds. A CONSOLIDATED FUEL lattice cannot have an inserted CEA or other nonfuel component. Only one CONSOLIDATED FUEL lattice may be stored in any CANISTER.

C. Unenriched fuel assemblies are not authorized for loading.

D. A canister preferentially loaded in accordance with Table B2-8 may only contain fuel assemblies selected from the same loading pattern.

Table B2-8 Loading Table for Maine Yankee CE 14 × 14 Fuel with No Non-Fuel Material – Required Cool Time in Years Before Assembly is Acceptable

Enrichment	Burnup ≤ 30 GWD/MTU - Minimum Cool Time [years] for		
	Standard[1]	Preferential (I)[2]	Preferential (P)[3]
1.9 ≤ E < 2.1	5	5	5
2.1 ≤ E < 2.3	5	5	5
2.3 ≤ E < 2.5	5	5	5
2.5 ≤ E < 2.7	5	5	5
2.7 ≤ E < 2.9	5	5	5
2.9 ≤ E < 3.1	5	5	5
3.1 ≤ E < 3.3	5	5	5
3.3 ≤ E < 3.5	5	5	5
3.5 ≤ E < 3.7	5	5	5
3.7 ≤ E ≤ 4.2	5	5	5
Enrichment	30 < Burnup ≤ 35 GWD/MTU – Minimum Cool Time [years] for		
	Standard[1]	Preferential (I)[2]	Preferential (P)[3]
1.9 ≤ E < 2.1	5	5	5
2.1 ≤ E < 2.3	5	5	5
2.3 ≤ E < 2.5	5	5	5
2.5 ≤ E < 2.7	5	5	5
2.7 ≤ E < 2.9	5	5	5
2.9 ≤ E < 3.1	5	5	5
3.1 ≤ E < 3.3	5	5	5
3.3 ≤ E < 3.5	5	5	5
3.5 ≤ E < 3.7	5	5	5
3.7 ≤ E ≤ 4.2	5	5	5
Enrichment	35 < Burnup ≤ 40 GWD/MTU - Minimum Cool Time [years] for		
	Standard[1]	Preferential (I)[2]	Preferential (P)[3]
1.9 ≤ E < 2.1	7	7	5
2.1 ≤ E < 2.3	6	6	5
2.3 ≤ E < 2.5	6	6	5
2.5 ≤ E < 2.7	5	6	5
2.7 ≤ E < 2.9	5	6	5
2.9 ≤ E < 3.1	5	6	5
3.1 ≤ E < 3.3	5	6	5
3.3 ≤ E < 3.5	5	6	5
3.5 ≤ E < 3.7	5	6	5
3.7 ≤ E ≤ 4.2	5	6	5

1. “Standard” loading pattern: allowable decay heat = 0.958 kW per assembly
2. “Preferential” loading pattern, interior basket locations: allowable heat decay = 0.867 kW per assembly
3. “Preferential” loading pattern, periphery basket locations: allowable heat decay = 1.05 kW per assembly

Table B2-8 Loading Table for Maine Yankee CE 14 × 14 Fuel with No Non-Fuel Material – Required Cool Time in Years Before Assembly is Acceptable (Continued)

Enrichment	40 < Burnup ≤ 45 GWD/MTU - Minimum Cool Time [years] for		
	Standard[1]	**Preferential (I)[2]**	**Preferential (P)[3]**
1.9 ≤ E < 2.1	11	11	6
2.1 ≤ E < 2.3	9	9	6
2.3 ≤ E < 2.5	8	8	6
2.5 ≤ E < 2.7	7	7	6
2.7 ≤ E < 2.9	7	7	6
2.9 ≤ E < 3.1	6	7	6
3.1 ≤ E < 3.3	6	7	5
3.3 ≤ E < 3.5	6	7	5
3.5 ≤ E < 3.7	6	7	5
3.7 ≤ E ≤ 4.2	6	7	5
Enrichment	**45 < Burnup ≤ 50 GWD/MTU - Minimum Cool Time [years] for**		
	Standard[1]	**Preferential (I)[2]**	**Preferential (P)[3]**
1.9 ≤ E < 2.1	Not allowed	Not allowed	7
2.1 ≤ E < 2.3	Not allowed	Not allowed	7
2.3 ≤ E < 2.5	Not allowed	Not allowed	7
2.5 ≤ E < 2.7	Not allowed	Not allowed	7
2.7 ≤ E < 2.9	Not allowed	Not allowed	7
2.9 ≤ E < 3.1	Not allowed	Not allowed	7
3.1 ≤ E < 3.3	Not allowed	Not allowed	7
3.3 ≤ E < 3.5	Not allowed	Not allowed	6
3.5 ≤ E < 3.7	Not allowed	Not allowed	6
3.7 ≤ E ≤ 4.2	Not allowed	Not allowed	6

1. "Standard" loading pattern: allowable decay heat = 0.958 kW per assembly
2. "Preferential" loading pattern, interior basket locations: allowable heat decay = 0.867 kW per assembly
3. "Preferential" loading pattern, periphery basket locations: allowable heat decay = 1.05 kW per assembly

Table B2-9 Loading Table for Maine Yankee CE 14 × 14 Fuel Containing CEA Cooled to Indicated Time

Enrichment	≤ 30 GWD/MTU Burnup - Minimum Cool Time in Years for				
	No CEA (Class 2)	5 Year CEA	10 Year CEA	15 Year CEA	20 Year CEA
1.9 ≤ E < 2.1	5	5	5	5	5
2.1 ≤ E < 2.3	5	5	5	5	5
2.3 ≤ E < 2.5	5	5	5	5	5
2.5 ≤ E < 2.7	5	5	5	5	5
2.7 ≤ E < 2.9	5	5	5	5	5
2.9 ≤ E < 3.1	5	5	5	5	5
3.1 ≤ E < 3.3	5	5	5	5	5
3.3 ≤ E < 3.5	5	5	5	5	5
3.5 ≤ E < 3.7	5	5	5	5	5
3.7 ≤ E ≤ 4.2	5	5	5	5	5
Enrichment	30 < Burnup ≤ 35 GWD/MTU - Minimum Cool Time in Years for				
	No CEA (Class 2)	5 Year CEA	10 Year CEA	15 Year CEA	20 Year CEA
1.9 ≤ E < 2.1	5	5	5	5	5
2.1 ≤ E < 2.3	5	5	5	5	5
2.3 ≤ E < 2.5	5	5	5	5	5
2.5 ≤ E < 2.7	5	5	5	5	5
2.7 ≤ E < 2.9	5	5	5	5	5
2.9 ≤ E < 3.1	5	5	5	5	5
3.1 ≤ E < 3.3	5	5	5	5	5
3.3 ≤ E < 3.5	5	5	5	5	5
3.5 ≤ E < 3.7	5	5	5	5	5
3.7 ≤ E ≤ 4.2	5	5	5	5	5
Enrichment	35 < Burnup ≤ 40 GWD/MTU - Minimum Cool Time in Years for				
	No CEA (Class 2)	5 Year CEA	10 Year CEA	15 Year CEA	20 Year CEA
1.9 ≤ E < 2.1	7	7	7	7	7
2.1 ≤ E < 2.3	6	6	6	6	6
2.3 ≤ E < 2.5	6	6	6	6	6
2.5 ≤ E < 2.7	5	6	5	5	5
2.7 ≤ E < 2.9	5	6	5	5	5
2.9 ≤ E < 3.1	5	6	5	5	5
3.1 ≤ E < 3.3	5	5	5	5	5
3.3 ≤ E < 3.5	5	5	5	5	5
3.5 ≤ E < 3.7	5	5	5	5	5
3.7 ≤ E ≤ 4.2	5	5	5	5	5
Enrichment	40 < Burnup ≤ 45 GWD/MTU - Minimum Cool Time in Years for				
	No CEA (Class 2)	5 Year CEA	10 Year CEA	15 Year CEA	20 Year CEA
1.9 ≤ E < 2.1	11	11	11	11	11
2.1 ≤ E < 2.3	9	9	9	9	9
2.3 ≤ E < 2.5	8	8	8	8	8
2.5 ≤ E < 2.7	7	7	7	7	7
2.7 ≤ E < 2.9	7	7	7	7	7
2.9 ≤ E < 3.1	6	6	6	6	6
3.1 ≤ E < 3.3	6	6	6	6	6
3.3 ≤ E < 3.5	6	6	6	6	6
3.5 ≤ E < 3.7	6	6	6	6	6
3.7 ≤ E ≤ 4.2	6	6	6	6	6

Table B2-10 Loading Table for 10x10 Burnup BWR Fuel

Minimum Initial Assembly Avg. Enrichment, E (wt% ^{235}U)	Minimum Cooling Time (years) (Based on Assembly Average Burnup, B, Expressed in GWd/MTU)				
	30 < B ≤ 34	34 < B ≤ 38	38 < B ≤ 39	39 < B ≤ 40	40 < B ≤ 41
1.9 ≤ E < 2.1	-	-	-	-	-
2.1 ≤ E < 2.3	5.0	-	-	-	-
2.3 ≤ E < 2.5	5.0	5.0	-	-	-
2.5 ≤ E < 2.7	5.0	5.0	5.0	5.3	5.5
2.7 ≤ E < 2.9	5.0	5.0	5.0	5.2	5.4
2.9 ≤ E < 3.1	5.0	5.0	5.0	5.1	5.3
3.1 ≤ E < 3.3	5.0	5.0	5.0	5.0	5.2
3.3 ≤ E < 3.5	5.0	5.0	5.0	5.0	5.2
3.5 ≤ E < 3.7	5.0	5.0	5.0	5.0	5.1
3.7 ≤ E < 3.9	5.0	5.0	5.0	5.0	5.0
3.9 ≤ E < 4.1	5.0	5.0	5.0	5.0	5.0
4.1 ≤ E < 4.3	5.0	5.0	5.0	5.0	5.0
4.3 ≤ E < 4.5	5.0	5.0	5.0	5.0	5.0
4.5 ≤ E < 4.7	5.0	5.0	5.0	5.0	5.0
4.7 ≤ E < 4.9	5.0	5.0	5.0	5.0	5.0
E ≥ 4.9	5.0	5.0	5.0	5.0	5.0

Minimum Initial Assembly Avg. Enrichment, E (wt% ^{235}U)	Minimum Cooling Time (years) (Based on Assembly Average Burnup, B, Expressed in GWd/MTU)				
	41 < B ≤ 42	42 < B ≤ 43	43 < B ≤ 44	44 < B ≤ 45	
1.9 ≤ E < 2.1	-	-	-	-	
2.1 ≤ E < 2.3	-	-	-	-	
2.3 ≤ E < 2.5	-	-	-	-	
2.5 ≤ E < 2.7	5.7	5.9	6.2	-	
2.7 ≤ E < 2.9	5.6	5.8	6.1	6.4	
2.9 ≤ E < 3.1	5.5	5.7	6.0	6.2	
3.1 ≤ E < 3.3	5.5	5.7	5.9	6.1	
3.3 ≤ E < 3.5	5.4	5.6	5.8	6.0	
3.5 ≤ E < 3.7	5.3	5.5	5.7	5.9	
3.7 ≤ E < 3.9	5.2	5.5	5.7	5.9	
3.9 ≤ E < 4.1	5.2	5.4	5.6	5.8	
4.1 ≤ E < 4.3	5.1	5.3	5.5	5.7	
4.3 ≤ E < 4.5	5.0	5.3	5.5	5.7	
4.5 ≤ E < 4.7	5.0	5.2	5.4	5.6	
4.7 ≤ E < 4.9	5.0	5.2	5.4	5.6	
E ≥ 4.9	5.0	5.1	5.3	5.5	

Table B2-11 Loading Table for High Burnup BWR Fuel

Minimum Initial Assembly Avg. Enrichment, E (wt% ^{235}U)	45 < Assembly Average Burnup ≤ 46 GWd/MTU Minimum Cooling Time (years)		
	8×8	9×9	10×10
1.9 ≤ E < 2.1	-	-	-
2.1 ≤ E < 2.3	-	-	-
2.3 ≤ E < 2.5	-	-	-
2.5 ≤ E < 2.7	-	-	-
2.7 ≤ E < 2.9	6.1	6.7	6.7
2.9 ≤ E < 3.1	6.0	6.6	6.5
3.1 ≤ E < 3.3	5.9	6.5	6.4
3.3 ≤ E < 3.5	5.8	6.4	6.3
3.5 ≤ E < 3.7	5.7	6.2	6.2
3.7 ≤ E < 3.9	5.7	6.1	6.1
3.9 ≤ E < 4.1	5.6	6.0	6.0
4.1 ≤ E < 4.3	5.5	6.0	5.9
4.3 ≤ E < 4.5	5.5	5.9	5.9
4.5 ≤ E < 4.7	5.4	5.9	5.8
4.7 ≤ E < 4.9	5.4	5.8	5.8
E ≥ 4.9	5.3	5.8	5.7

Table B2-11 Loading Table for High Burnup BWR Fuel

Minimum Initial Assembly Avg. Enrichment,E (wt% ^{235}U)	46 < Assembly Average Burnup ≤ 47 GWd/MTU Minimum Cooling Time (years)			47 < Assembly Average Burnup ≤ 48 GWd/MTU Minimum Cooling Time (years)		
	8×8	9×9	10×10	8×8	9×9	10×10
1.9 ≤ E < 2.1	-	-	-	-	-	-
2.1 ≤ E < 2.3	-	-	-	-	-	-
2.3 ≤ E < 2.5	-	-	-	-	-	-
2.5 ≤ E < 2.7	-	-	-	-	-	-
2.7 ≤ E < 2.9	6.4	7.0	6.9	6.7	7.4	7.3
2.9 ≤ E < 3.1	6.3	6.9	6.8	6.6	7.2	7.2
3.1 ≤ E < 3.3	6.1	6.8	6.7	6.4	7.1	7.0
3.3 ≤ E < 3.5	6.0	6.6	6.6	6.3	6.9	6.9
3.5 ≤ E < 3.7	5.9	6.5	6.5	6.2	6.8	6.8
3.7 ≤ E < 3.9	5.9	6.4	6.4	6.1	6.7	6.7
3.9 ≤ E < 4.1	5.8	6.3	6.3	6.0	6.6	6.6
4.1 ≤ E < 4.3	5.7	6.3	6.2	5.9	6.5	6.5
4.3 ≤ E < 4.5	5.7	6.2	6.1	5.9	6.5	6.4
4.5 ≤ E < 4.7	5.6	6.1	6.0	5.8	6.4	6.3
4.7 ≤ E < 4.9	5.6	6.0	6.0	5.8	6.3	6.3
E ≥ 4.9	5.5	6.0	5.9	5.7	6.2	6.2

Minimum Initial Assembly Avg. Enrichment,E (wt% ^{235}U)	48 < Assembly Average Burnup ≤ 49 GWd/MTU Minimum Cooling Time (years)			49 < Assembly Average Burnup ≤ 50 GWd/MTU Minimum Cooling Time (years)		
	8×8	9×9	10×10	8×8	9×9	10×10
1.9 ≤ E < 2.1	-	-	-	-	-	-
2.1 ≤ E < 2.3	-	-	-	-	-	-
2.3 ≤ E < 2.5	-	-	-	-	-	-
2.5 ≤ E < 2.7	-	-	-	-	-	-
2.7 ≤ E < 2.9	7.0	7.8	7.7	-	-	-
2.9 ≤ E < 3.1	6.8	7.6	7.5	7.1	8.0	7.9
3.1 ≤ E < 3.3	6.7	7.4	7.4	7.0	7.8	7.8
3.3 ≤ E < 3.5	6.6	7.3	7.2	6.9	7.7	7.6
3.5 ≤ E < 3.7	6.5	7.1	7.1	6.8	7.5	7.5
3.7 ≤ E < 3.9	6.4	7.0	7.0	6.6	7.4	7.3
3.9 ≤ E < 4.1	6.3	6.9	6.9	6.6	7.3	7.2
4.1 ≤ E < 4.3	6.2	6.8	6.8	6.5	7.1	7.1
4.3 ≤ E < 4.5	6.1	6.7	6.7	6.4	7.0	7.0
4.5 ≤ E < 4.7	6.0	6.7	6.6	6.3	6.9	6.9
4.7 ≤ E < 4.9	5.9	6.6	6.5	6.2	6.9	6.8
E ≥ 4.9	5.9	6.5	6.5	6.1	6.8	6.7

Table B2-11 Loading Table for High Burnup BWR Fuel (cont.)

Minimum Initial Assembly Avg. Enrichment,E (wt% ^{235}U)	50 < Assembly Average Burnup ≤ 51 GWd/MTU Minimum Cooling Time (years)			51 < Assembly Average Burnup ≤ 52 GWd/MTU Minimum Cooling Time (years)		
	8×8	9×9	10×10	8×8	9×9	10×10
1.9 ≤ E < 2.1	-	-	-	-	-	-
2.1 ≤ E < 2.3	-	-	-	-	-	-
2.3 ≤ E < 2.5	-	-	-	-	-	-
2.5 ≤ E < 2.7	-	-	-	-	-	-
2.7 ≤ E < 2.9	-	-	-	-	-	-
2.9 ≤ E < 3.1	7.5	8.5	8.4	7.9	8.9	8.8
3.1 ≤ E < 3.3	7.3	8.2	8.2	7.7	8.7	8.6
3.3 ≤ E < 3.5	7.2	8.0	8.0	7.6	8.5	8.4
3.5 ≤ E < 3.7	7.0	7.9	7.8	7.4	8.3	8.3
3.7 ≤ E < 3.9	6.9	7.8	7.7	7.3	8.2	8.1
3.9 ≤ E < 4.1	6.8	7.6	7.6	7.1	8.0	7.9
4.1 ≤ E < 4.3	6.7	7.5	7.5	7.0	7.9	7.8
4.3 ≤ E < 4.5	6.6	7.4	7.3	6.9	7.8	7.7
4.5 ≤ E < 4.7	6.6	7.3	7.2	6.8	7.7	7.6
4.7 ≤ E < 4.9	6.5	7.2	7.1	6.7	7.6	7.5
E ≥ 4.9	6.4	7.1	7.0	6.7	7.5	7.4

Minimum Initial Assembly Avg. Enrichment,E (wt% ^{235}U)	52 < Assembly Average Burnup ≤ 53 GWd/MTU Minimum Cooling Time (years)			53 < Assembly Average Burnup ≤ 54 GWd/MTU Minimum Cooling Time (years)		
	8×8	9×9	10×10	8×8	9×9	10×10
1.9 ≤ E < 2.1	-	-	-	-	-	-
2.1 ≤ E < 2.3	-	-	-	-	-	-
2.3 ≤ E < 2.5	-	-	-	-	-	-
2.5 ≤ E < 2.7	-	-	-	-	-	-
2.7 ≤ E < 2.9	-	-	-	-	-	-
2.9 ≤ E < 3.1	8.3	9.5	9.4	8.7	10.0	9.9
3.1 ≤ E < 3.3	8.1	9.2	9.1	8.5	9.8	9.7
3.3 ≤ E < 3.5	7.9	9.0	8.9	8.3	9.5	9.4
3.5 ≤ E < 3.7	7.8	8.8	8.7	8.1	9.3	9.2
3.7 ≤ E < 3.9	7.6	8.6	8.5	8.0	9.1	9.0
3.9 ≤ E < 4.1	7.5	8.5	8.4	7.8	8.9	8.8
4.1 ≤ E < 4.3	7.4	8.3	8.2	7.7	8.8	8.7
4.3 ≤ E < 4.5	7.2	8.2	8.1	7.6	8.6	8.5
4.5 ≤ E < 4.7	7.1	8.0	7.9	7.5	8.5	8.4
4.7 ≤ E < 4.9	7.0	7.9	7.8	7.4	8.3	8.3
E ≥ 4.9	6.9	7.8	7.8	7.2	8.2	8.1

Table B2-11 Loading Table for High Burnup BWR Fuel (cont.)

Minimum Initial Assembly Avg. Enrichment,E (wt% ^{235}U)	54 < Assembly Average Burnup ≤ 55 GWd/MTU			55 < Assembly Average Burnup ≤ 56 GWd/MTU		
	Minimum Cooling Time (years)			Minimum Cooling Time (years)		
	8×8	9×9	10×10	8×8	9×9	10×10
1.9 ≤ E < 2.1	-	-	-	-	-	-
2.1 ≤ E < 2.3	-	-	-	-	-	-
2.3 ≤ E < 2.5	-	-	-	-	-	-
2.5 ≤ E < 2.7	-	-	-	-	-	-
2.7 ≤ E < 2.9	-	-	-	-	-	-
2.9 ≤ E < 3.1	-	-	-	-	-	-
3.1 ≤ E < 3.3	9.0	10.4	10.3	9.5	11.1	11.0
3.3 ≤ E < 3.5	8.8	10.1	10.0	9.2	10.8	10.7
3.5 ≤ E < 3.7	8.6	9.9	9.8	9.0	10.5	10.4
3.7 ≤ E < 3.9	8.4	9.6	9.5	8.8	10.2	10.1
3.9 ≤ E < 4.1	8.2	9.4	9.3	8.7	10.0	9.9
4.1 ≤ E < 4.3	8.0	9.2	9.1	8.5	9.8	9.7
4.3 ≤ E < 4.5	7.9	9.1	9.0	8.3	9.6	9.5
4.5 ≤ E < 4.7	7.8	8.9	8.8	8.2	9.4	9.3
4.7 ≤ E < 4.9	7.7	8.8	8.7	8.0	9.3	9.2
E ≥ 4.9	7.6	8.7	8.6	7.9	9.1	9.0

Minimum Initial Assembly Avg. Enrichment,E (wt% ^{235}U)	56 < Assembly Average Burnup ≤ 57 GWd/MTU			57 < Assembly Average Burnup ≤ 58 GWd/MTU		
	Minimum Cooling Time (years)			Minimum Cooling Time (years)		
	8×8	9×9	10×10	8×8	9×9	10×10
1.9 ≤ E < 2.1	-	-	-	-	-	-
2.1 ≤ E < 2.3	-	-	-	-	-	-
2.3 ≤ E < 2.5	-	-	-	-	-	-
2.5 ≤ E < 2.7	-	-	-	-	-	-
2.7 ≤ E < 2.9	-	-	-	-	-	-
2.9 ≤ E < 3.1	-	-	-	-	-	-
3.1 ≤ E < 3.3	10.0	11.8	11.6	10.7	12.5	12.4
3.3 ≤ E < 3.5	9.8	11.5	11.3	10.4	12.1	12.0
3.5 ≤ E < 3.7	9.5	11.2	11.1	10.1	11.8	11.7
3.7 ≤ E < 3.9	9.3	10.9	10.8	9.8	11.6	11.4
3.9 ≤ E < 4.1	9.1	10.7	10.5	9.6	11.3	11.2
4.1 ≤ E < 4.3	8.9	10.4	10.3	9.4	11.1	10.9
4.3 ≤ E < 4.5	8.8	10.2	10.0	9.2	10.8	10.7
4.5 ≤ E < 4.7	8.6	10.0	9.9	9.0	10.6	10.5
4.7 ≤ E < 4.9	8.5	9.8	9.7	8.9	10.4	10.3
E ≥ 4.9	8.3	9.7	9.5	8.8	10.2	10.1

Table B2-11 Loading Table for High Burnup BWR Fuel (cont.)

Minimum Initial Assembly Avg. Enrichment,E (wt% ^{235}U)	58 < Assembly Average Burnup ≤ 59 GWd/MTU Minimum Cooling Time (years)			59 < Assembly Average Burnup ≤ 60 GWd/MTU Minimum Cooling Time (years)		
	8×8	9×9	10×10	8×8	9×9	10×10
1.9 ≤ E < 2.1	-	-	-	-	-	-
2.1 ≤ E < 2.3	-	-	-	-	-	-
2.3 ≤ E < 2.5	-	-	-	-	-	-
2.5 ≤ E < 2.7	-	-	-	-	-	-
2.7 ≤ E < 2.9	-	-	-	-	-	-
2.9 ≤ E < 3.1	-	-	-	-	-	-
3.1 ≤ E < 3.3	11.3	13.3	13.1	-	-	-
3.3 ≤ E < 3.5	11.0	12.9	12.8	11.6	13.7	13.5
3.5 ≤ E < 3.7	10.7	12.6	12.4	11.3	13.4	13.2
3.7 ≤ E < 3.9	10.4	12.3	12.1	11.1	13.0	12.9
3.9 ≤ E < 4.1	10.2	11.9	11.8	10.8	12.7	12.6
4.1 ≤ E < 4.3	9.9	11.7	11.6	10.5	12.4	12.2
4.3 ≤ E < 4.5	9.7	11.5	11.3	10.3	12.1	12.0
4.5 ≤ E < 4.7	9.5	11.3	11.1	10.0	11.9	11.8
4.7 ≤ E < 4.9	9.4	11.1	10.9	9.9	11.7	11.5
E ≥ 4.9	9.2	10.9	10.7	9.7	11.5	11.4

Table B2-12 BWR 8x8, 9x9, and 10x10 Low Enriched Minimum Enrichment Allowed as a Function of Burnup (5-year Minimum Cool Time)

Maximum Assembly Average Burnup [GWd/MTU]	Minimum Enrichment [wt.% ^{235}U]
5	0.711
10	1.3
15	1.5
20	1.7
25	1.9

Table B2-13 Undamaged Fuel Maximum Initial Enrichment

Fuel Type	75% Neutron Absorber Credit Enrichment (^{235}U wt%)	90% Neutron Absorber Credit Enrichment (^{235}U wt%)
ge08n	4.80	5.00
ge08k	4.70	4.90
ge08i	4.70	4.90
ex08b	4.70	4.90
ex09c	4.60	4.70
B9_72A	4.50	4.70
B10_91A	4.50	4.70
B10_92A	4.40	4.60

Table B2-14 Maximum Initial Enrichment with four BWR DFCs loaded with Damaged Fuel

Fuel Type	Maximum Initial Enrichment (^{235}U wt%)	
	75% Neutron Absorber Credit	90% Neutron Absorber Credit
ge08n	4.80	5.00
ge08k	4.70	4.90
ge08i	4.60*	4.90
ex08b	4.70	4.90
ex09c	4.50*	4.70
B9_72A	4.40*	4.60*
B10_91A	4.40*	4.60*
B10_92A	4.40	4.60

*Maximum initial enrichment is 0.1% lower than undamaged uniform loading

Table B2-15 Summary of Preferentially Loaded Fuel Enrichment Combinations – Undamaged BWR Fuel

Outer Locations*	Outer Locations Maximum Enrichment (^{235}U wt%)	Remaining Locations Maximum Enrichment (^{235}U wt%)
LOC1 (Option 1)	4.6	4.5
LOC1 (Option 2)	5.0	4.4
LOC2 (Option 1)	4.6	4.5
LOC2 (Option 2)	5.0	4.4
Peripheral (Option 1)	4.6	4.5
Peripheral (Option 2)	5.0	4.4

*The preferential loading locations are defined in Figure B2-3
Note: Preferential load patterns are only evaluated for 75% absorber credit.

B 3.0 DESIGN FEATURES

B 3.1 Site

B 3.1.1 Site Location

The NAC-UMS® SYSTEM is authorized for general use by 10 CFR 50 license holders at various site locations under the provisions of 10 CFR 72, Subpart K.

B 3.2 Design Features Important for Criticality Control

B 3.2.1 CANISTER

a) Minimum ^{10}B loading in the neutron absorbers:
   1. PWR – 0.025g/cm^2
   2. BWR – 0.011g/cm^2
b) Minimum length of UNDAMAGED FUEL ASSEMBLY internal structure and bottom end fitting and/or spacers shall ensure the minimum distance to the fuel region from the base of the CANISTER is:
   1. PWR – 3.2 inches
   2. BWR – 6.2 inches
c) Soluble boron concentration in the PWR fuel pool and CANISTER water:
   1. Fuel meeting the enrichment limits in Table B2–2 without boron - 0 ppm.
   2. Fuel meeting the enrichment limits in Table B2–2 with boron ≥ 1000 ppm.
d) Minimum water temperature for PWR fuel to ensure boron is soluble:
   1. Temperature should be 5 - 10°F higher than the minimum needed to ensure solubility.
e) Minimum flux trap (structural disk web) thickness is specified per Figure B2-1 (PWR) and Figure B2-2 (BWR).

(continued)

B 3.3 Codes and Standards

The American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), 1995 Edition with Addenda through 1995, is the governing Code for the NAC-UMS® CANISTER.

The American Concrete Institute Specifications ACI-349 (1985) and ACI-318 (1995) govern the NAC-UMS® CONCRETE CASK design and construction, respectively.

The American National Standards Institute ANSI N14.6 (1993) and NUREG-0612 govern the NAC-UMS® TRANSFER CASK design, operation, fabrication, testing, inspection and maintenance.

B 3.3.1 Exceptions to Codes, Standards, and Criteria

Table B3-1 lists exceptions to the ASME Code for the design of the NAC-UMS® SYSTEM.

B 3.3.2 Construction/Fabrication Exceptions to Codes, Standards, and Criteria

Proposed alternatives to ASME Code, Section III, 1995 Edition with Addenda, through 1995, including exceptions listed in Specification B3.3.1, may be used when authorized by the Director of the Office of Nuclear Material Safety and Safeguards or designee. The request for such alternatives should demonstrate that:

1. The proposed alternatives would provide an acceptable level of quality and safety, or
2. Compliance with the specified requirements of ASME Code, Section III, 1995 Edition with Addenda through 1995, would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

Requests for exceptions shall be submitted in accordance with 10 CFR 72.4.

Table B3-1 List of ASME Code Exceptions for the NAC-UMS® SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification and Compensatory Measures
CANISTER	NB-1100	Statement of requirements for Code stamping of components.	CANISTER is designed and will be fabricated in accordance with ASME Code, Section III, Subsection NB to the maximum practical extent, but Code stamping is not required. The completion of an ASME Design Specification, Design Report and Overpressure Protection Report is not required.
CANISTER	NB-2000	Requirements for materials to be supplied by ASME-approved material supplier.	Materials will be supplied by NAC-approved suppliers with Certified Material Test Reports (CMTRs) in accordance to NB-2000 requirements.
CANISTER	NB-2500	Repairs to pressure-retaining material from which a defect(s) has been removed are to be examined by magnetic particle or dye penetrant methods. If the depth of the repair exceeds the lesser of 3/8-inch or 10% of the section thickness, examination is to be by radiography.	In accordance with ASME Code Case N-595-4, a loaded CANISTER shell examination of a weld repair of material within 1/2-inch of a closure weld may be done by progressive magnetic particle or dye penetrant examination methods for each weld layer ≤ 1/4-inch and final surface.
CANISTER Shield Lid and Structural Lid Welds	NB-4243	Full penetration welds required for Category C joints (flat head to main shell per NB-3352.3).	Shield lid and structural lid to CANISTER shell welds are not full penetration welds. These field welds are performed independently to provide a redundant closure.
CANISTER Structural Lid Weld	NB-4421	Requires removal of backing ring.	Structural lid to CANISTER shell weld uses a backing ring that is not removed. The backing ring permits completion of the groove weld; it is not considered in any analyses; and it has no detrimental effect on the CANISTER's function.

Table B3-1 List of ASME Code Exceptions for the NAC-UMS® SYSTEM (continued)

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification and Compensatory Measures
CANISTER Vent Port Cover and Drain Port Cover to Shield Lid Welds; Shield Lid to Canister Shell Weld	NB-5230	Radiographic (RT) or ultrasonic (UT) examination required.	Root and final surface liquid penetrant examination to be performed per ASME Code Section V, Article 6, with acceptance in accordance with ASME Code, Section III, NB-5350.
CANISTER Structural Lid to Shell Weld	NB-5230	Radiographic (RT) or ultrasonic (UT) examination required.	The CANISTER structural lid to CANISTER shell closure weld is performed in the field following fuel assembly loading. The structural lid-to-shell weld will be verified by either ultrasonic (UT) or progressive liquid penetrant (PT) examination. If progressive PT examination is used, at a minimum, it must include the root and final layers and each approximately 3/8 inch of weld depth. If UT examination is used, it will be followed by a final surface PT examination. For either UT or PT examination, the maximum, undetectable flaw size is demonstrated to be smaller than the critical flaw size. The critical flaw size is determined in accordance with ASME Code, Section XI methods. The examination of the weld will be performed by qualified personnel per ASME Code Section V, Articles 5 (UT) and 6 (PT) with acceptance per ASME Code Section III, NB-5332 (UT) per 1995 Addenda, and NB-5350 for (PT).

Table B3-1 List of ASME Code Exceptions for the NAC-UMS® SYSTEM (continued)

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification and Compensatory Measures
CANISTER Vessel and Shield Lid	NB-6111	All completed pressure retaining systems shall be pressure tested.	The CANISTER shield lid to shell weld is performed in the field following fuel assembly loading. The CANISTER is then pneumatically (air/nitrogen/ helium-over-water) pressure tested as defined in Chapter 9 and described in Chapter 8. Accessibility for leakage inspections precludes a Code compliant hydrostatic test. The shield lid-to-shell weld is also leak tested to the leak-tight criteria of ANSI N14.5. The vent port and drain port cover welds are examined by root and final PT examination. The structural lid weld is examined by progressive PT or UT and final surface PT.
CANISTER Vessel	NB-7000	Vessels are required to have overpressure protection.	No overpressure protection is provided. The function of the CANISTER is to confine radioactive contents under normal, off-normal, and accident conditions of storage. The CANISTER vessel is designed to withstand a maximum internal pressure considering 100% fuel rod failure and maximum accident temperatures.
CANISTER Vessel	NB-8000	States requirements for nameplates, stamping and reports per NCA-8000.	The NAC-UMS® SYSTEM is marked and identified in accordance with 10 CFR 72 requirements. Code stamping is not required. The QA data package will be in accordance with NAC's approved QA program. The completion of an ASME Design Specification, Design Report and Overpressure Protection Report is not required.

Table B3-1 List of ASME Code Exceptions for the NAC-UMS® SYSTEM (continued)

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification and Compensatory Measures
CANISTER Basket Assembly	NG-2000	Requires materials to be supplied by ASME approved material supplier.	Materials to be supplied by NAC-approved suppliers with CMTRs in accordance with NG-2000 requirements.
CANISTER Basket Assembly	NG-8000	States requirements for nameplates, stamping and reports per NCA-8000.	The NAC-UMS® SYSTEM will be marked and identified in accordance with 10 CFR 72 requirements. No Code stamping is required. The CANISTER basket data package will be in accordance with NAC's approved QA program.
CANISTER Vessel and Basket Assembly Material	NB-2130/ NG-2130	States requirements for certification of material organizations and materials to NCA-3861 and NCA-3862, respectively.	The NAC-UMS® CANISTER and Basket Assembly component materials are procured in accordance with the specifications for materials in ASME Code Section II with Certified Material Test Reports. The component materials will be obtained from NAC approved Suppliers in accordance with NAC's approved QA program.

B 3.4 Site Specific Parameters and Analyses

This section presents site-specific parameters and analytical bases that must be verified by the NAC-UMS® SYSTEM user. The parameters and bases presented in Section B.3.4.1 are those applied in the design basis analysis. The parameters and bases used in the evaluation of SITE SPECIFIC FUEL are presented in the appropriate sections below.

B 3.4.1 Design Basis Site Specific Parameters and Analyses

The design basis site-specific parameters and analyses that require verification by the NAC-UMS® SYSTEM user are:

1. The temperature of 76°F is the maximum average yearly temperature. The 3-day average ambient temperature shall be 106°F or less.

2. The allowed temperature extremes, averaged over a 3-day period, shall be greater than –40°F and less than 133°F.

3. a) The design basis earthquake horizontal and vertical seismic acceleration levels at the top surface of the ISFSI pad or at the center of gravity of the loaded concrete cask on the ISFSI pad are bounded by the values shown:

Configuration	Coefficient of Friction	Horizontal g-level in each of Two Orthogonal Directions	Corresponding Vertical g-level
Standard	0.35	0.26g	0.26g
Standard	0.40	0.29g	0.29g

Note: For a condition of a degraded coefficient of friction, site-specific analysis may be performed in accordance with 3.4.1(3)(b).

b) Alternatively, the design basis earthquake motion of the ISFSI pad may be limited so that the acceleration g-load resulting from the collision of two sliding casks remains bounded by the accident condition analyses presented in Chapter 11 of the FSAR.

Site-specific analysis by the cask user shall demonstrate that a cask does not slide off the ISFSI pad.

(continued)

B 3.4.1 Design Basis Site Specific Parameters and Analyses (continued)

4. The analyzed flood condition of 15 fps water velocity and a height of 50 feet of water (full submergence of the loaded cask) are not exceeded.

5. The potential for fire and explosion shall be addressed, based on site-specific considerations. This includes the condition that the fuel tank of the cask handling equipment used to move the loaded CONCRETE CASK onto or from the ISFSI site contains no more than 50 gallons of fuel.

6 In cases where engineered features (i.e., berms, shield walls) are used to ensure that requirements of 10 CFR 72.104(a) are met, such features are to be considered important to safety and must be evaluated to determine the applicable Quality Assurance Category on a site specific basis.

7. TRANSFER CASK OPERATIONS shall only be conducted with surrounding air temperatures ≥ 0°F.

8. The VERTICAL CONCRETE CASK shall only be lifted by the lifting lugs with surrounding air temperatures ≥ 0°F.

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B 3.4.2 Maine Yankee Site Specific Parameters and Analyses

The design basis site-specific parameters and analyses that require verification by Maine Yankee are:

1. The temperature of 76°F is the maximum average yearly temperature. The 3-day average ambient temperature shall be 106°F or less.

2. The allowed temperature extremes, averaged over a 3-day period, shall be greater than –40°F and less than 133°F.

3. The design basis earthquake horizontal and vertical seismic acceleration levels at the top surface of the ISFSI pad are bounded by the values shown:

Configuration	Coefficient of Friction	Horizontal g-level in each of Two Orthogonal Directions[1]	Corresponding Vertical g-level (upward)
Maine Yankee	0.50	0.38	0.38 × 0.667 = 0.253g

[1] Earthquake loads are applied to the center of gravity of the concrete cask on the ISFSI pad.

4. The analyzed flood condition of 15 fps water velocity and a height of 50 feet of water (full submergence of the loaded cask) are not exceeded.

5. The potential for fire and explosion shall be addressed, based on site-specific considerations. This includes the condition that the fuel tank of the cask handling equipment used to move the loaded CONCRETE CASK onto or from the ISFSI site contains no more than 50 gallons of fuel.

6. Physical testing shall be conducted to demonstrate that the coefficient of friction between the concrete cask and ISFSI pad surface is at least 0.5.

(continued)

B 3.4.2 Maine Yankee Site Specific Parameters and Analyses (continued)

7. In addition to the requirements of 10 CFR 72.212(b)(2)(ii), the ISFSI pad(s) and foundation shall meet the design basis earthquake horizontal and vertical seismic acceleration levels at the top surface of the ISFSI pad as specified in B 3.4.2 (3).

   The surface of the ISFSI pad shall have a broom finish or brushed surface as defined in ACI 116R-90 and described in Sections 7.12 and 7.13.4 of ACI 302.1R.

8. In cases where engineered features (i.e., berms, shield walls) are used to ensure that requirements of 10 CFR 72.104(a) are met, such features are to be considered important to safety and must be evaluated to determine the applicable Quality Assurance Category on a site specific basis.

9. TRANSFER CASK OPERATIONS shall only be conducted with surrounding air temperatures ≥ 0°F.

B 3.5 CANISTER HANDLING FACILITY (CHF)

B 3.5.1 TRANSFER CASK and CANISTER Lifting Devices

Movements of the TRANSFER CASK and CANISTER outside of the 10 CFR 50 licensed facilities, when loaded with spent fuel are not permitted unless the movements are made with a CANISTER HANDLING FACILITY designed, operated, fabricated, tested, inspected and maintained in accordance with the guidelines of NUREG-0612, “Control of Heavy Loads at Nuclear Power Plants” and the below clarifications. This Technical Specification does not apply to handling heavy loads under a 10 CFR 50 license.

B 3.5.2 CANISTER HANDLING FACILITY Structure Requirements

B 3.5.2.1 CANISTER Station and Stationary Lifting Devices

1. The weldment structure of the CANISTER HANDLING FACILITY shall be designed to comply with the stress limits of ASME Code, Section III, Subsection NF, Class 3 for linear structures. The applicable loads, load combinations, and associated service condition definitions are provided in Table B3-2. All compression loaded members shall satisfy the buckling criteria of ASME Code, Section III, Subsection NF.

2. If a portion of the CANISTER HANDLING FACILITY structure is constructed of reinforced concrete, then the factored load combinations set forth in ACI-318 (1995) for the loads defined in Table B3-2 shall apply.

3. The TRANSFER CASK and CANISTER lifting device used with the CANISTER HANDLING FACILITY shall be designed, fabricated, operated, tested, inspected and maintained in accordance with NUREG-0612, Section 5.1.

(continued)

B 3.5.2.1 CANISTER HANDLING Station and Stationary Lifting Devices (continued)

4. The CHF design shall incorporate an impact limiter for CANISTER lifting and movement if a qualified single failure proof crane is not used. The impact limiter must be designed and fabricated to ensure that, if a CANISTER is dropped, the confinement boundary of the CANISTER would not be breached.

B 3.5.2.2 Mobile Lifting Devices

If a mobile lifting device is used as the lifting device, in lieu of a stationary lifting device, it shall meet the guidelines of NUREG-0612, Section 5.1, with the following clarifications:

1. Mobile lifting devices shall have a minimum safety factor of two over the allowable load table for the lifting device in accordance with the guidance of NUREG-0612, Section 5.1.6(1)(a) and shall be capable of stopping and holding the load during a Design Basis Earthquake (DBE) event.
2. Mobile lifting devices shall conform to the requirements of ANSI B30.5, “Mobile and Locomotive Cranes,” in lieu of the requirements of ANSI B30.2, “Overhead and Gantry Cranes.”
3. Mobile cranes are not required to meet the requirements of NUREG-0612, Section 5.1.6(2) for new cranes.

Table B3-2 Load Combinations and Service Condition Definitions for the CANISTER HANDLING FACILITY (CHF) Structure

Load Combination	ASME Section III Service Condition for Definition of Allowable Stress	Comment
D* D + S	Level A	All primary load bearing members must satisfy Level A stress limits
D + M + W'[1] D + F D + E D + Y	Level D	Factor of safety against overturning shall be ≥ 1.1

D = Crane hook dead load
D* = Apparent crane hook dead load
S = Snow and ice load for the CHF site
M = Tornado missile load of the CHF site[1]
W' = Tornado wind load for the CHF site[1]
F = Flood load for the CHF site
E = Seismic load for the CHF site
Y = Tsunami load for the CHF site

Note:

1. Tornado missile load may be reduced or eliminated based on a PRA for the CHF site.

Enclosure 2

Supporting Calculation

for the

NAC-UMS FSAR
Amendment 8
Revision 19A
(Docket No 72-1015)

NAC International

December 2019

List of Calculations

1. **EA790-2520 R00**
2. **EA790-2521 R00**
3. **EA790-2522 R00**
4. **EA790-3007 R01**
5. **EA790-3312 R00**
6. **EA790-3507 R07**
7. **EA790-4601 R00**
8. **EA790-4602 R00**
9. **EA790-4603 R00**
10. **EA790-4604 R00**
11. **EA790-4605 R00**
12. **EA790-5601 R00**
13. **EA790-5602 R00**

CALCULATIONS WITHHELD IN THEIR ENTIRETY PER 10 CFR 2.390

Enclosure 3

List of Changes

for the

NAC-UMS FSAR
Amendment 8
Revision 19A
(Docket No 72-1015)

NAC International

December 2019

List of Changes for the NAC-UMS FSAR, Amendment 8, Revision 19A

Chapter/Page/ Figure/Table	Description of Change
Note: The List of Effective Pages and the Chapter Table of Contents, List of Figures and List of Tables have been revised accordingly to reflect the list of changes detailed below.	
Chapter 1	
Pages 1-4 thru 1-6	Modified Table 1-1 where indicated.
Page 1-8	Modified Table 1-1 where indicated.
Page 1-9	Text flow changes.
Page 1.2-2	Modified text at the end of the third paragraph of Section 1.2.1.1 where indicated.
Pages 1.2-5 thru 1.2-6	Modified text in the first and fourth paragraphs of Section 1.2.1.2.2 where indicated.
Pages 1.2-7 thru 1.2-10	Text flow changes.
Page 1.2-21	Added a row to the bottom of page 1 of Table 1.2-1 where indicated.
Page 1.2-24	Modified Table 1.2-2 where indicated.
Page 1.2-26	Modified Table 1.2-4 where indicated.
Page 1.3-1	Modified text in Section 1.3.1 where indicated.
Pages 1.8-1 thru 1.8-2	Modified Section 1.8.1 where indicated.
Chapter 2	
Page 2-2	Modified Table 2-1 where indicated.
Page 2.1-1	Modified the first and last paragraphs of Section 2.1 where indicated.
Page 2.1.2-1	Modified the last paragraph of Section 2.1.2 where indicated.
Page 2.1.2-2	Modified Table 2.1.2-1 throughout, where indicated.
Pages 2.3-5 thru 2.3-7	Modified Section 2.3.4 and subsections throughout, where indicated.
Page 2.3-8	Text flow changes.
Pages 2.3-16 thru 2.3-17	Modified Table 2.3-1 where indicated.
Page 2.3-20	Added new page to the end of Table 2.3-1.
Chapter 3	
Page 3.1-3	Modified text in both paragraphs on the page where indicated.
Page 3.2-3	Replaced Table 3.2-2.
Page 3.2-4	Replaced Table 3.2-3.
Pages 3.9-1 thru 3.9-15	Added new Section 3.9.

Chapter/Page/ Figure/Table	Description of Change
Chapter 4	
Page 4.4-1	Modified last sentence of Section 4.4 where indicated.
Page 4.4.1-2	Modified text in the last paragraph on the page where indicated.
Page 4.4.1-18	Added paragraph to the end of the text for Section 4.4.1.2 where indicated.
Page 4.4.1-23	Added new Figure 4.4.1.2-5.
Page 4.4.1-24	Moved Table 4.4.1.2-1 to page with Table 4.4.1-2 as a text flow change.
Page 4.4.1-35	Modified the first paragraph of Section 4.4.1.5 where indicated.
Page 4.4.1-38	Modified last sentence of the first paragraph of Section 4.4.1.6.
Page 4.4.3-2	Added text to the end of Section 4.4.3.
Pages 4.4.3-3 thru 4.4.3-5	Text flow changes.
Page 4.4.5-3	Modified text in the middle of the first paragraph of Section 4.4.5.2 where indicated; added second paragraph to Section 4.4.5.2.
Page 4.4.5-5	Modified tables 4.4.5-4, 4.4.5-5 and 4.4.5-6 where indicated.
Chapter 5	
Pages 5.8-1 thru 5.8.3-4	Added new Section 5.8.
Chapter 6	
Pages 6.1-3 thru 6.1-4	Updated text throughout Section 6.1 where indicated.
Pages 6.1-5 thru 6.1-6	Text flow changes.
Page 6.1-7	Replaced Table 6.1-2
Page 6.4-14	Modified text in the first and third paragraphs of Section 6.4.3.2 where indicated.
Page 6.4-15	Modified text in the first and third paragraphs of Section 6.4.3.3 where indicated.
Page 6.5-1	Modified text near the end of Section 6.5 where indicated.
Pages 6.5.50 thru 6.5-81	Added new Section 6.5.3.
Pages 6.7-1 thru 6.7-30	Added new Section 6.7.
Page 6.8-1	Re-numbered Section.
Page 6.8-2	Added Reference number 21.
Pages 6.9-1 thru 6.9-66	Modified text in Section 6.9 and updated figure numbers throughout section where indicated.
Chapter 7 – no changes	
Chapter 8 – no changes	

Chapter/Page/ Figure/Table	Description of Change
<u>Chapter 9</u>	
Pages 9.1-7 thru 9.1-9	Editorial changes deleting empty spaces causing text flow.
Pages 9.1-10 thru 9.1-19	Added new Section 9.1.6.4.
Page 9.1-20	Text flow changes.
<u>Chapter 10</u>	
Page 10.2-1	Modified text in the second paragraph of Section 10.2 where indicated; added note to embedded table in Section 10.2.1.
Page 10.2-2	Modified text in the first paragraph on the page where indicated.
Page 10.3-1	Added paragraph at the beginning of Section 10.3 where indicated.
Pages 10.3-2 thru 10.3-3	Text flow changes.
Page 10.4-1	Added paragraph at the beginning of Section 10.4 where indicated.
Page 10.4-2	Text flow changes.
Pages 10.6-1 thru 10.6-3	Added new Section 10.6.
Page 10.7-1	Editorial: renumbered Section 10.7 heading.
<u>Chapter 11</u>	
Page 11.2.16-1	Modified Section 11.2.16 where indicated.
Pages 11.2.16-10 thru 11.2.16-16	Added new Section 11.2.16.2.
Page 11.2.16-17	Renumbered and modified Section 11.2.16.3 where indicated.
Page 11.3-5	Added reference number 64.
<u>Chapter 12</u>	
Page 12-4	Modified Table 12-1 where indicated.
<u>Chapter 13 – no changes</u>	

Enclosure 4

List of Drawing Changes

for the

NAC-UMS
Amendment 8
(Docket No 72-1015)

NAC International

December 2019

List of Drawing Changes, NAC-UMS SAR, Revision 19A

Drawing 790-561, Sheet 1 thru 4 of 4, Revision 16

1. All sheets, removed scale and weights

Sheet 2:

2. Zone E5, revised dimension to "6.0-7.5", was "7.5".
3. Zone D8, removed dimension "7.5".

Drawing 790-562, Sheet 1 of 8, Revision 20

Sheet 1:

1. 1.Revised Note 6 to “Concrete shall develop a compressive strength (Fc’) of 4000 psi using Type I or Type I/II Portland cement. For BWR damaged fuel, high burnup fuel and BWR 10x10 fuel, concrete shall use 1-inch maximum size aggregate and have an average density of 145 PCF with no single density measurement being less than 142 PCF. For other cask configurations, concrete may use maximum aggregate size of 1 2/3 in and a minimum concrete density of 140 PCF. Optional 1.5 PCY Fibermesh may be added. “

   Was, “Concrete shall develop a compressive strength (FC') of 4000 psi using Type 2 Portland Cement , 1 1/2 in. maximum size aggregate. Concrete density shall be 140 pcf minimum. Optimal 1.5 PCY Fibermesh may be added.”

Drawing 790-570, Sheet 2 of 3, Revision 6

Sheet 2:

1. Zone C6-C7, revised title for Assembly 97 to "Fuel Basket Assembly - DF", was "Fuel Basket Assembly".
2. Revised drawing title to "Fuel Basket Assembly, 56 Element BWR & BWR DF NAC-UMS®", was "Fuel Basket Assembly, 56 Element BWR NAC-UMS®".

Drawing 790-570, Sheets 1 thru 3 of 3, Revision 5

Sheet 1 of 3:

1. Zone A4-6, revised delta note 2, "Assembly -99, -98, -97 to be freely inserted into canister, during final assembly. Alternate assembly in canister optional." was "Assembly -99, -98 to be freely inserted into canister, during final assembly. Alternate assembly in canister optional.”
2. Revised BOM, added assembly "97 ASSY".
3. Added item 25, quantity Assy 97 - “1”, name - “Bottom Weldment", and drawing no. – “790-671-99”.
4. Added item 26, quantity Assy 97 – “1”, name - “Top Weldment", and drawing no. – “790-672-99”.
5. All sheets, removed scale and weights.
6. BOM, items 5, 6, 8, 9, and 13-20, revised item names to include "Neutron Absorber". Removed references to "Boral".
7. Zone F6, added sheet box “3”.
8. Zone F3, added sheet box “3”.

9. Zone E2, added sheet box “3”.

Sheet 2 of 3:

10. Added assembly "97 Fuel Basket Assembly" on sheet 2. Moved DETAIL A-A, DETAIL B-B, and DETAIL C-C to sheet 3.

Drawing 790-575, Sheet 1 thru 2 of 2, Revision 11

Sheet 1:

1. Note 1, revised to "Areal density of neutron absorber sheet as specified in the certificate of compliance.
2. B.O.M. items 3 & 4, revised material description to "Metallic Composite" was "BORAL".
3. All sheets, removed scale and weights from title block and view titles.

Drawing 790-582, Sheets 1 thru 2 of 2, Revision 13

Sheet 1 of 2:

1. Zone C5/C6, added delta note 9, "For Assy 94, Item 6 thickness to be 1.75 +.04/-.01."
2. Zone C3/C4, added dimension "190.65+.13/-.00 -94"
3. Zone C1, added delta note 9 symbol next to dimension "(1.75)".
4. Zone A8, added assembly title "94 Shell Weldment"
5. Zone A5/A6, modified delta note 2, "Optional engraved stripe – for Assy -99, 96, 95 angle is 35°±5° for Assy -98, 97, 94 angle is 40°±5° engrave stripe 1.0 wide X .03 deep and fill with weather resistant yellow paint." was "Optional engraved stripe – for Assy -99, 96, 95 angle is 35°±5° for Assy -98, 97 angle is 40°±5° engrave stripe 1.0 wide X .03 deep and fill with weather resistant yellow paint."
6. Revised BOM: added assembly "94 Assy". Added Item 8, name - "Shell", material - "304L St. Stl.", spec - "ASME SA240", and description - "5/8 plate".
7. All sheets, removed scale and weights.
8. Zone F6, added part balloon "8".

Sheet 2 of 2:

9. Zone C4, added dimension "190.65 +.13/-.00 -94"
10. Zone C1, added delta note 9 symbol next to dimension "(1.75)"
11. Zone A5, added assembly title balloon "94 Shell Weldment"
12. Zone F6, added part balloon "8".

Drawing 790-583, Sheets 1 of 1, Revision 9

1. Zone C5, added assembly title “94 Drain Tube Assembly”
2. Zone E4, added text “181.1 – 8” to dimension.
3. Zone F3, added Item 8 balloon callout.
4. B.O.M., added 94 Assy column consisting of items 1 and 7 with qty “1”.
5. B.O.M., added item 8, Qty “1” for Assy 94, Name “Tube”, Material “304 St. Stl.”, Spec “COML”, Description “1 OD X .035 Wall Tube”. Include delta notes 3 and 5 attached to B.O.M., Item 8.
6. Revised delta note 1 to include dimension “(181.5) -8”

7. Revised delta note 3 to “Minor surface indentations and/or dimensional deviations are acceptable for items 2-6 and 8, tube.”, was “Minor surface indentations and/or dimensional deviations are acceptable for items 2-6, tube.”

Drawing 790-585, Sheet 1 of 3, Revision 25

1. B.O.M., revised title of Item 25 to "Fuel Basket Assy - DF", was "Fuel Basket Assy".

Drawing 790-585, Sheet 1 thru 2 of 3, Revision 24

Sheet 1:

1. B.O.M., added Item 28, Qty “1” for Assy 94, Name “Drain Tube Assy”, Drawing “790-583-94”.
2. B.O.M., revised Item 14, delete Qty “1” from Assy 94.

Sheet 2:

3. Zone B3/4, added balloon item 28 callout to balloons 11-15.

Drawing 790-585, Sheet 1 thru 3 of 3, Revision 23

Sheet 1 of 3:

1. Zone D5/D6, added delta note 22, "For the BWR DF TSC (Assembly 94) the DFCs (Item 26) shall be oriented as shown with the neutron absorbers facing the interior of the basket assembly. The top flange corner relief provides clearance for the drain tube assembly (item 14) and indication of the DFC orientation.”
2. Zone D5/D6, updated delta note 21, "For assemblies 98, 97, and 94 (BWR) weld size is (1/2), for Assy 99, 96, and 95 (PWR) minimum weld depth of bevel is .36" for a weld size of (3/8) nominal to (5/16) minimum." was "For assemblies 98, and 97 (BWR) weld size is (1/2), for Assy 99, 96, and 95 (PWR) minimum weld depth of bevel is .36" for a weld size of (3/8) nominal to (5/16) minimum."
3. Zone C5/C6, updated delta note 20, "For assemblies 98, 97, and 94 (BWR) weld size is (7/8), for Assy 99, 96, and 95 (PWR) weld size is (3/4)."
4. BOM, added item "25”, quantity Assy 94 - ”1”, name – “Fuel Basket Assy", and drawing no. – “790-570-97”.
5. BOM, added item “26”, quantity Assy 94 – “4”, name – “Damaged Fuel Can Assy”, and drawing no. – “790-601-99”.
6. BOM, added item “27”, quantity Assy 94 – “1”, name – “Shell Weldment”, and drawing no. – “790-582-94”.
7. All sheets, removed scale and weights.

Sheet 2 of 3:

8. Zone F1, added item balloon "27"
9. Zone C8, added "DETAIL D-D" callout.
10. Zone C8, added delta note "22"
11. Zone C6, added item balloon "26"
12. Zone F4/C4, added section cut "C-C"
13. Zone C3, added item balloon "25"
14. Zone C3, added dimension "(190.65) -94".
15. Zone A7, added section view "SECTION C-C"

16. Zone A5, Added detail view "DETAIL D-D"

Drawing 790-590, Sheet 1 thru 2 of 2 Revision 9

Sheet 1 of 2:

1. Zone E4-6, added assembly balloon "93 Loaded Vertical Concrete Cask"
2. Zone D4, revised detail view "DETAIL D-D; Scaled; Optional configurations (4X Item 21 req'd for each); shown with optional baffle assembly and stand. (Reference drawing 790-561-98)" was "DETAIL D-D; Scale: 1/2; Optional configurations; (4X Item 21 req'd for each)"
3. Zone C6, added item balloon "22"
4. Zone A7, revised scale on Detail D-D to "Scaled" was "Scale: 1/4"
5. BOM, added item "22", quantity assy 93 – "1", name – "TSC Assembly", drawing no. – "790-585-94".
6. BOM, added assembly "93"
7. All sheets, removed scale and weights.

Drawing 790-601, Sheets 1 and 4 of 5, Revision 1P

Sheet 1:

1. Zone A8/B8, removed "." from delta notes 2, 3, and 5.

Sheet 4:

2. Zone E8, added delta note "3" next to item balloon "6".
3. Zone E3, added delta note "3" next to item balloon "6".

Drawing 790-601, Sheets 1 and 4 of 5, Revision 0P

Initial Issue.

Drawing 790-601, Sheets 1 and 4 of 5, Revision 0NP

Initial Issue.

Drawing 790-605, Sheet 1 thru 2 of 2, Revision 12

Sheet 1:

1. Note 1, revised to "Areal density of neutron absorber sheet as specified in the certificate of compliance."
2. B.O.M. items 3 & 4. Revised material description to "Metallic Composite" was "BORAL"
3. All sheets, removed scale and weights.

Drawing 790-671, Sheet 1 of 1, Revision 1

1. Revised title to "Bottom Weldment, Fuel Basket, 56 Element BWR DF, NAC-UMS®", was "Bottom Weldment, Fuel Basket, 56 Element BWR NAC-UMS®"

Drawing 790-672, Sheet 1 of 1, Revision 1

1. Revised title of drawing to "Top Weldment, fuel Basket, 56 Element BWR DF, NAC-UMS®", was "Top Weldment, fuel Basket, 56 Element BWR NAC-UMS®".

Enclosure 5

FSAR Changed Pages

for the

NAC-UMS
Amendment 8
(Docket No 72-1015)

NAC International

December 2019

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Revision 19A

NAC-UMS

Universal MPC System

FINAL SAFETY ANALYSIS REPORT

for the UMS Universal Storage System

Non-Proprietary Version

Docket No. 72-1015

NAC INTERNATIONAL

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Chapter 7

Chapter 8

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Chapter 13

Table 1-1 Terminology

Universal Storage System	The storage component of the Universal MPC System (UMS®) designed by NAC for the storage and transportation of spent nuclear fuel.
Universal Transport Cask	The packaging consisting of a Universal Transport Cask body with a closure lid and energy-absorbing impact limiters. The Universal Transport Cask is used to transport a Transportable Storage Canister containing spent fuel. The cask body provides the primary containment boundary during transport.
Air Pad Rig Set (Air Pallet)	A device used to lift the Vertical Concrete Cask by using high volume air.
Assembly Defect	Any change in the physical as-built condition of the assembly, with the exception of normal in-reactor changes such as elongation from irradiation growth or assembly bow. Example of assembly defects include: (a) missing rods, (b) broken or missing grids or grid straps (spacer), and (c) missing or broken grid springs, etc. An assembly with a defect is damaged only if it cannot meet its fuel-specific and system-related functions.
Breached Spent Fuel Rod	Spent fuel with cladding defects that permit the release of gas from the interior of the fuel rod. A fuel rod breach may be a minor defect (i.e., hairline crack or pinhole), allowing the rod to be classified as undamaged, or be a gross breach requiring a damaged fuel classification.
Confinement System	The components of the Transportable Storage Canister intended to retain the radioactive material during storage.
Consolidated Fuel	A nonstandard fuel configuration in which the individual undamaged fuel rods from one or more fuel assemblies are placed in a single container or a lattice structure that is dimensionally similar to a fuel assembly. Consolidated Fuel is stored in a Maine Yankee Fuel Can.
Contents	Twenty-four PWR fuel assemblies, or fifty-six BWR fuel assemblies. The fuel assemblies may be configured as Site Specific Fuel. The fuel assemblies are contained in a Transportable Storage Canister.

Table 1-1 Terminology (Continued)

Damaged Fuel	Spent nuclear fuel (SNF) that cannot fulfill its fuel-specific or system-related function. Damaged fuel must be placed in a Damaged Fuel Can (DFC) unless otherwise noted. Spent fuel is classified as damaged under the following conditions.

1) There is visible deformation of the rods in the SNF assembly.

   Note: This is not referring to the uniform bowing that occurs in the reactor; this refers to bowing that significantly opens up the lattice spacing.

2) Individual fuel rods are missing from the assembly and the missing rods are not replaced by dummy rods that displace a volume equal to, or greater than, the original fuel rods.

   Note: Maine Yankee fuel assemblies with missing fuel rods, not replaced by filler rods, do not require placement into a Maine Yankee Fuel Can, but must be preferentially loaded.

3) The SNF assembly has missing, displaced or damaged structural components such that either:

   - Radiological and/or criticality safety is adversely affected (e.g., significantly changed rod pitch); or
   - The assembly cannot be handled by normal means (i.e., crane and grapple).

   Note: Fuel assemblies with the following structural defects meet UMS system-related functional requirements and are, therefore, classified as undamaged.

   - Grid, grid strap, and/or grid strap spring damage in PWR assemblies such that the unsupported length of the fuel rod does not exceed 60 inches.

4) Any SNF assembly that contains fuel rods for which reactor operating records (or other records or tests) cannot support the conclusion that they do not contain gross breaches.

   Note: Breached fuel rods with minor cladding defects (i.e, pinhole leaks or hairline cracks that will not permit significant release of particulate matter from the spent fuel rod) meet UMS system-related functional requirements and are, therefore, classified as undamaged.

Table 1-1 Terminology (Continued)

Damaged Fuel (cont'd)	5) The SNF assembly is no longer in the form of an intact fuel bundle (e.g., consists of or contains debris such as loose fuel pellets or rod segments).
BWR Damaged Fuel Basket (BWR DF Basket)	A structure like a Fuel Basket but with four corner fuel tubes replaced by a BWR Damaged Fuel Can (DFC). Upper and lower bottom weldments contain larger openings to accommodate the DFC.
Fuel Basket (Basket)	The structure located within the Transportable Storage Canister that provides structural support, criticality control, and primary heat transfer paths for the fuel assemblies.
- **Support Disk**	The primary lateral load-bearing component of the fuel basket. The PWR support disk is a circular stainless steel plate with 24 square holes machined in a symmetrical pattern. The BWR support disk is a circular carbon steel plate with 56 square holes machined in a symmetrical pattern. Each square hole is a location for a fuel tube.
- **Heat Transfer Disk**	A circular aluminum plate with 24 (PWR basket) or 56 (BWR basket) square holes machined in a symmetrical pattern. The heat transfer disk enhances heat transfer in the fuel basket.
- **Fuel Tube**	A stainless steel tube having a square cross-section. One fuel tube is inserted through each square hole in the support disks and heat transfer disks. Fuel assemblies are loaded into the fuel tubes. A fuel tube may have neutron absorber material enclosed by a stainless steel sheet on one or more of its external faces, depending on fuel type and the position of the fuel tube in the basket.
- **Tie Rod**	A stainless steel rod used to align, retain, and support the support disks and the heat transfer disks in the fuel basket structure. The tie rods extend from the top weldment to the bottom weldment.
- **Spacer**	Installed on the tie rod between the support disks (BWR only) or between the support disks and top and bottom weldments (BWR and PWR) to properly position the disks and provide axial support for the support disks.

Table 1-1 Terminology (Continued)

- Split Spacer	Spacers installed on the tie rod between the support disks and the heat transfer disks to properly position the disks and provide axial support for the support disks and the heat transfer disks.
Grossly Breached Spent Fuel Rod	A breach in the spent fuel cladding that is larger than a pinhole or hairline crack. A gross cladding breach may be established by visual examination with the capability to determine if the fuel pellet can be seen through the cladding, or through a review of reactor operating records indicating the presence of heavy metal isotopes.
Heavy Haul Trailer	The trailer used to transport the empty or loaded Vertical Concrete Cask.
High Burnup Fuel	A fuel assembly meeting the definition of a standard fuel assembly with an assembly average burnup between 45,000 and 60,000 MWd/MTU.
Intact Fuel (Assembly or Rod)	Any fuel that can fulfill all fuel-specific and system-related functions and that is not breached.
Damaged Fuel Can (DFC) (Maine Yankee Fuel Can or BWR Damaged Fuel Can)	A specially designed stainless steel screened can sized to hold an undamaged fuel assembly, consolidated fuel, or damaged fuel. The can screens permit draining and drying, while precluding the release of gross particulates into the canister cavity. The Maine Yankee Fuel Can may only be loaded in a Class 1 Canister. The BWR Damaged Fuel Can may only be loaded in a Class 5 DF Canister.
Margin of Safety	An analytically determined value defined as the "factor of safety" minus 1. Factor of safety is also analytically determined, and is defined as the allowable stress or displacement of a material divided by its actual (calculated) value.
NS-4-FR or NS-3	Solid hydrogenous materials with neutron absorption capabilities.

Table 1-1 Terminology (Continued)

Site Specific Fuel	Spent fuel configurations that are unique to a site or reactor due to the addition of other components or reconfiguration of the fuel assembly at the site. It includes fuel assemblies, which hold nonfuel-bearing components, such as control components or instrument and plug thimbles, or which are modified as required by expediency in reactor operations, research and development or testing. Modification may consist of individual fuel rod removal, fuel rod replacement of similar or dissimilar material or enrichment, the installation, removal or replacement of burnable poison rods, or containerizing damaged (failed) fuel. Site specific fuel includes irradiated fuel assemblies designed with variable enrichments and/or axial blankets, fuel that is consolidated and fuel that exceeds design basis fuel parameters.
Shield Lid	A thick stainless steel disk that is located directly above the fuel basket. The shield lid comprises the first part of a double-welded closure system for the Transportable Storage Canister. The shield lid provides a containment/confinement boundary for storage and shielding for the contents.
- Drain Port	A penetration located in the shield lid to permit draining of the canister cavity.
- Vent Port	A penetration located in the shield lid to aid in draining and in vacuum drying and backfilling the canister with helium.
- Port Cover	The stainless steel covers that close the vent and drain ports, and that are welded in place following draining, drying, and backfilling operations.
- Quick Disconnect	The valved nipple used in the vent and drain ports to facilitate operations.

Table 1-1 Terminology (Continued)

Standard Fuel	Irradiated fuel assemblies with a burnup less than, or equal to, 45,000 MWd/MTU and having the same configuration as when originally fabricated consisting generally of the end fittings, fuel rods, guide tubes, and integral hardware. For PWR fuel, a flow mixer (thimble plug), an in-core instrument thimble, a burnable poison rod insert, or a solid stainless steel rod insert is considered to be a component of standard fuel. For BWR fuel, the channel is considered to be integral hardware.
Structural Lid	A thick stainless steel disk that is positioned on top of the shield lid and welded to the canister. The structural lid is the second part of a double-welded closure system for the Transportable Storage Canister. The structural lid provides a confinement boundary for storage, shielding for the contents, and canister lifting/handling capability.
Transfer Adapter	A carbon steel plate assembly that is positioned on to the top of the transport or concrete cask to facilitate installation and alignment of the transfer cask. It also provides the operating mechanism for the transfer cask bottom doors.
Transfer Cask	A shielded lifting device for handling of the Transportable Storage Canister during loading of spent fuel, canister closure operations, and transfer of the canister into or out of the Vertical Concrete Cask during storage, or into or out of the Universal Transport Cask during transportation. The transfer cask incorporates bottom doors that permit the vertical loading of the storage and transport casks. The transfer cask is provided in either the standard or the advanced configuration. The advanced configuration has a higher weight capacity.
- **Transfer Cask Lifting Trunnions**	Four low alloy steel trunnions used to lift and move the transfer cask in a vertical orientation.
Transportable Storage Canister (Canister)	The stainless steel cylindrical shell, bottom end plate, shield lid, and structural lid that contain the fuel basket structure and the contents.

Table 1-1 Terminology (Continued)

Undamaged Fuel	Spent nuclear fuel that can meet all fuel specific and system-related functions. Undamaged Fuel is spent nuclear fuel that is not Damaged Fuel, as defined herein, and does not contain assembly structural defects that adversely affect radiological and/or criticality safety. As such, Undamaged Fuel may contain: a) Breached spent fuel rods (i.e., rods with minor defects up to hairline cracks or pinholes) but can not contain grossly breached fuel rods; b) Grid, grid strap, and/or grid spring damage in PWR assemblies, provided that the unsupported length of the fuel rod does not exceed 60 inches.
Vertical Concrete Cask (Concrete Cask)	A concrete cylinder that contains the Transportable Storage Canister during storage. The Vertical Concrete Cask is formed around a steel inner liner and base and is closed by a shield plug and lid.
- Shield Plug	A thick carbon steel plug, which also contains a neutron shield material, installed in the top end of the Vertical Concrete Cask to reduce skyshine radiation.
- Lid	A thick carbon steel plate that serves as the bolted closure for the Vertical Concrete Cask. The lid precludes access to the canister and provides additional radiation shielding.
- Liner	A thick carbon steel shell that forms the annulus of the concrete cask. The liner serves as the inner form during concrete pouring and provides radiation shielding of the canister contents.
- Base	A carbon steel weldment that contains the air inlets, the concrete cask jacking points and the pedestal that supports the canister inside of the concrete cask.

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1.2 General Description of the Universal Storage System

The Universal Storage System provides long-term storage of any of three classes of PWR fuel or two classes of BWR fuel, and subsequent transport using a Universal Transport Cask (Docket 71-9270). During long-term storage, the system provides an inert environment; passive shielding, cooling, and criticality control; and a confinement boundary closed by welding. The structural integrity of the system precludes the release of contents in any of the design basis normal conditions and off-normal or accident events, thereby assuring public health and safety during use of the system.

1.2.1 Universal Storage System Components

The design and operation of the principal components of the Universal Storage System and the associated ancillary equipment are described in the following sections. The weights of the principal components are provided in Section 3.2.

The Universal Storage System consists of three principal components:

- Transportable Storage Canister (including PWR or BWR fuel basket),
- Vertical Concrete Cask, and
- Transfer Cask.

The design characteristics of these components are presented in Table 1.2-1.

Ancillary equipment needed to use the Universal Storage System are:

- Automated or manual welding equipment;
- An air pallet or hydraulic roller skid (used to move the concrete cask on and off the heavy haul trailer and to position the concrete cask on the storage pad);
- Suction pump, vacuum drying, helium backfill and leak detection equipment;
- A heavy haul trailer or transporter (for transport of concrete cask to the storage pad);
- An adapter plate and hardware to position the transfer cask with respect to the storage or transport cask; and
- A lifting yoke for the transfer cask and lifting slings for the canister and canister lids.

In addition to these items, the system requires utility services (electric, helium, air and water), common tools and fittings, and miscellaneous hardware.

1.2.1.1 Transportable Storage Canister

Three classes of Transportable Storage Canisters accommodate the PWR fuel assemblies, and two classes of Transportable Storage Canisters accommodate the BWR fuel assemblies. The canister is designed to be transported in the Universal Transport Cask. Transport conditions establish the design basis load conditions for the canister, except for canister lifting. The transport load conditions produce higher stresses in the canister than would be produced by the storage load conditions. Consequently, the canister design is conservative with respect to storage conditions. The evaluation of the canister for transport conditions is documented in the Safety Analysis Report for the Universal Transport Cask, Docket No. 71-9270.

The Transportable Storage Canister consists of a stainless steel canister that contains the fuel basket structure and contents. The canister is defined as confinement for the spent fuel during storage and is provided with a double welded closure system. The welded closure system prevents the release of contents in any design basis normal, off-normal or accident condition. The basket assembly in the canister provides the structural support and primary heat transfer path for the fuel assemblies while maintaining a subcritical configuration for all normal conditions of storage, off-normal events and hypothetical accident conditions. The PWR and BWR fuel basket assemblies are discussed in Section 1.2.1.2.

The major components of the Transportable Storage Canister are the shell and bottom, basket assembly, shield lid, and structural lid. The canister and the shield and structural lids provide a confinement boundary during storage, shielding, and lifting capability for the basket. The Transportable Storage Canister design parameters for the storage of the five classes of fuel are provided in Table 1.2-2. Note that a BWR DF transportable storage canister is provided to load Class 5 BWR fuel assemblies and up to four BWR Damaged Fuel Cans (DFCs).

The canister consists of a cylindrical, 5/8-inch thick Type 304L stainless steel shell with a 1.75-inch thick Type 304L stainless steel bottom plate and a Type 304 stainless steel shield lid support ring. A basket assembly is placed inside the canister. The shield lid assembly is a 7-inch thick Type 304 stainless steel disk that is positioned on the shield lid support ring above the basket assembly. The shield lid is welded to the canister after the canister is loaded and moved to the workstation for completion of canister closure activities. Two penetrations through the shield lid are provided for draining, vacuum drying, and backfilling the canister with helium. The drain pipe is threaded into the shield lid after the canister is moved to the workstation. The vent penetration in the shield lid is used to aid water removal and for vacuum drying and backfilling the

The Transportable Storage Canister is designed to facilitate filling with water and subsequent draining. Water fills and drains freely between the basket disks through three separate paths. One path is the gaps that exist between the disks and canister shell. The second path is through the gaps between the fuel tubes and disk that surrounds the fuel tubes. The third path is through three 1.3-inch diameter holes in each of the disks that are intended to provide additional paths for water flow between disks. The basket bottom weldment supports the fuel tubes above the canister bottom plate. The fuel tubes are open at the top and bottom ends, allowing the free flow of water from the bottom of the fuel tube. The bottom weldment is positioned by supports 1.0 inch above the canister bottom to facilitate water flow to the drain line. These design features ensure that water flows freely in the basket so that the canister fills and drains evenly.

1.2.1.2.2 BWR Fuel Basket

Like the PWR fuel basket, the BWR basket is contained within the stainless steel Transportable Storage Canister. The BWR fuel basket is also a right-circular cylinder configuration with square fuel tubes laterally supported by a series of support disks (40 disks for the Class 4 fuel basket and 41 disks for the Class 5 fuel basket). Note that a Class 5 BWR DF fuel basket is provided to load up to four Damaged Fuel Cans (DFCs) at corner slots. The basket design parameters for the storage of the two classes of BWR fuel are provided in Table 1.2-4. The support disks are retained by cylindrical spacers on tie rods at six locations. The top nut is torqued at installation to provide a solid load path in compression between the support disks. The support disks are fabricated of SA-533, Type B, Class 2 carbon steel and are coated with electroless nickel to inhibit corrosion and the formation of combustible gases during fuel loading. The disks are spaced axially at 3.8-inch center-to-center and contain square holes for the fuel tubes.

The top and bottom weldments are fabricated from Type 304 stainless steel, and are geometrically similar to the support disks. The fuel tubes are also fabricated from Type 304 stainless steel. Three types of tubes are designed to contain one BWR fuel assembly: tubes with neutron absorber on two sides, tubes with neutron absorber one side, and tubes with no neutron absorber. No credit is taken for the fuel tubes for structural strength of the basket or support of the fuel assemblies.

Each BWR fuel basket has a capacity of 56 BWR fuel assemblies in an aligned configuration. The fuel tubes in 52 positions have an inside square dimension of 5.90 inches. The inside dimension of the four fuel tubes located in the outside corners of the basket array is 6.05-inches square. The holes in the top weldment are 5.75 inches by 5.75 inches, except for the four enlarged holes, which are 5.90 inches-square. The holes in the bottom weldment are 5.63-inches

square. The basket design traps the fuel tube between the top and bottom weldments, thereby preventing axial movement of the fuel tube. The BWR DF basket is similar in design to the BWR fuel basket but has larger, 6.43-inches square, openings to allow storage of the BWR DFCs. The BWR DFC has a 6.30-inches inside square body and two neutron absorber sheets. The neutron absorbers are placed on adjacent DFC surfaces and face towards the basket center when the DFCs are placed in the basket. The support disk webs between the fuel tubes are 0.65-inch wide. The BWR fuel basket design also incorporates 17 Type 6061-T651 aluminum alloy heat transfer disks similar in design and function of those in the PWR baskets.

The BWR canister is also designed to facilitate filling with water and subsequent draining. Water fills and drains freely between the basket disks through three separate paths. One path is the gaps that exist between the disks and canister shell. The second path is through the gaps between the fuel tubes and disk that surrounds the fuel tubes. The third path is through three 1.3-inch diameter holes in each of the disks that are intended to provide additional paths for water flow between disks. The basket bottom weldment supports the fuel tubes above the canister bottom plate. The fuel tubes are open at the top and bottom ends, allowing the free flow of water from the bottom of the fuel tube. The bottom weldment is positioned by supports 1.0 inch above the canister bottom to facilitate water flow to the drain line. These design features ensure that water flows freely in the basket so that the canister fills and drains evenly.

1.2.1.3 Vertical Concrete Cask

The Vertical Concrete Cask is the storage overpack for the Transportable Storage Canister. Five concrete casks of different lengths are designed to store five canisters of different lengths containing one of three classes of PWR or of two classes of BWR fuel assemblies. The concrete cask provides structural support, shielding, protection from environmental conditions, and natural convection cooling of the canister during long-term storage. Table 1.2-5 lists the principal physical design parameters of the concrete cask.

The concrete cask is a reinforced concrete (Type II Portland cement) structure with a structural steel inner liner. The concrete wall and steel liner provide the neutron and gamma radiation shielding to reduce the average contact dose rate to less than 50 millirem per hour for design basis PWR or BWR fuel. Inner and outer reinforcing steel (rebar) assemblies are contained within the concrete. The reinforced concrete wall provides the structural strength to protect the canister and its contents in natural phenomena events such as tornado wind loading and wind driven missiles. The concrete cask incorporates reinforced chamfered corners at the edges to facilitate construction. The concrete cask is shown in Figure 1.2-1.

The Vertical Concrete Cask forms an annular air passage to allow the natural circulation of air around the canister to remove the decay heat from the spent fuel. The air inlets and outlets are steel-lined penetrations that take nonplanar paths to the concrete cask cavity to minimize radiation streaming. A baffle assembly directs inlet air upward and around the pedestal that supports the canister. The weldment structure includes the baffle assembly configuration, as shown in Drawing 790-561. The decay heat is transferred from the fuel assemblies to the tubes in the fuel basket and through the heat transfer disks to the canister wall. Heat flows by radiation and convection from the canister wall to the air circulating through the concrete cask annular air passage and is exhausted through the air outlets. This passive cooling system is designed to maintain the peak cladding temperature of the zirconium alloy-clad fuel well below acceptable limits during long-term storage. This design also maintains the bulk concrete temperature below 150°F and localized concrete temperatures below 200°F in normal operating conditions.

The top of the Vertical Concrete Cask is closed by a shield plug and lid. The shield plug is approximately 5 inches thick and incorporates carbon steel plate as gamma radiation shielding, and NS-4-FR or NS-3 as neutron radiation shielding. A carbon steel lid that provides additional gamma radiation shielding is installed and bolted in place above the shield plug. The shield plug and lid reduce skyshine radiation and provide a cover and seal to protect the canister from the environment and postulated tornado missiles. At the option of the user, a tamper-indicating seal wire and seal may be installed on two of the concrete cask lid bolts. An optional supplemental shielding fixture, shown in Drawing 790-613, may be installed in the air inlets to reduce the radiation dose rate at the base of the cask.

Fabrication of the concrete cask involves no unique or unusual forming, concrete placement, or reinforcement requirements. The concrete portion of the concrete cask is constructed by placing concrete between a reusable, exterior form and the inner metal liner. Reinforcing bars are used near the inner and outer concrete surfaces, to provide structural integrity. The inner liner and base of the concrete cask are shop fabricated. The principal fabrication specifications for the concrete cask are shown in Table 1.2-6.

1.2.1.4 Transfer Cask

The transfer cask is a heavy lifting device, which is designed, fabricated, and load-tested to meet the requirements of NUREG-0612 [11] and ANSI N14.6 [12]. The transfer cask can be provided in either a Standard or Advanced configuration. Canister handling, fuel loading and canister closing are operationally identical for either transfer cask configuration.

The transfer cask provides biological shielding when it contains a loaded canister and is used for the vertical transfer of the canister between work stations and the concrete cask, or transport cask.

Five transfer casks of either configuration, having different lengths, are designed to handle the five canisters of different lengths containing one of three classes of PWR fuel assemblies or two classes of BWR fuel assemblies. In addition, a Transfer Cask Extension may be used to extend the operational height, when using the standard transfer cask. This height extension allows a transfer cask designed for a specific canister class to be used with the next longer canister.

The transfer cask design incorporates a top retaining ring, which is bolted in place to prevent a loaded canister from being inadvertently lifted through the top of the transfer cask. The transfer cask has retractable bottom shield doors. During loading operations, the doors are closed and secured by door lock bolts/lock pins, so they cannot inadvertently open. During unloading, the doors are retracted using hydraulic cylinders to allow the canister to be lowered into a concrete cask for storage or into a transport cask. A typical transfer cask is shown in Figure 1.2-2. The principal design parameters of the transfer casks are shown in Table 1.2-7.

To minimize the potential for contamination of a canister or the inside of the transfer cask during loading operations in the spent fuel pool, clean water is circulated in the annular gap between the transfer cask interior surface and the canister exterior surface. Clean water is processed or filtered pool water, or any water external to the spent fuel pool that is compatible. The transfer cask has eight supply and two discharge lines passing through its wall. Normally, two of the lines are connected to allow clean water under pressure to flow into and through the annular gap to minimize potential for the intrusion of pool water when the canister is being loaded. Lines not used for clean water supply may be capped. The eight supply lines can also be used for the introduction of forced air at the bottom of the transfer cask to achieve cooling of the canister contents. This allows the canister to remain in the transfer cask for an extended period, if necessary, during canister closing operations.

Standard and Advanced Transfer Casks

The Standard and Advanced transfer casks are designed for lifting and handling in the vertical orientation only. The Standard transfer cask may be used to lift canisters weighing up to 88,000 pounds. The Advanced transfer cask is similar to the Standard transfer cask, except that the Advanced transfer cask incorporates a trunnion support plate that allows the Advanced transfer cask to lift canisters weighing up to 98,000 pounds. The Standard and Advanced transfer casks have four lifting trunnions, which allow for redundant load path lifting. Both transfer casks incorporate a multiwall (steel/lead/NS-4-FR/steel) design, and both designs have a maximum empty weight of approximately 121,500 pounds. The Standard and Advanced transfer cask designs are shown in Drawing 790-560.

1.2.1.5 Auxiliary Equipment

This section presents a brief description of the principal auxiliary equipment needed to operate the Universal Storage System in accordance with its design.

1.2.1.5.1 Transfer Adapter

The transfer adapter is a carbon steel table that is positioned on the top of the Vertical Concrete Cask or the Universal Transport Cask and mates the transfer cask to either of those casks. It has a large center hole that allows the Transportable Storage Canister to be raised or lowered through the plate into or out of the transfer cask. Rails are incorporated in the transfer adapter to guide and support the bottom shield doors of the transfer cask when they are in the open position. The transfer adapter also supports the hydraulic system and the actuators that open and close the transfer cask bottom doors.

1.2.1.5.2 Air Pad Rig Set

The air pad rig set (air pad set) is a commercially available device, sometimes referred to as an air pallet. When inflated, the air pad rig set lifts the concrete cask by using high volume air flow. The air pads employ a continuous, regulated air flow and a control system that equalizes lifting heights of the four air pads by regulating compressed air flow to each of the air pads. The compressed air supply creates an air film between the inflated air cushion and the supporting surface. The thin film of air allows the concrete cask to be lifted and moved. Once lifted, the cask can be moved by a suitable towing vehicle, such as a commercial tug or forklift.

1.2.1.5.3 Automatic Welding System

The automatic welding system consists of commercially available components with a customized weld head. The components include a welding machine, a remote pendant, a carriage, a drive motor and welding wire motor, and the weld head. The system is designed to make at least one weld pass automatically around the canister after its weld tip is manually positioned at the proper location. As a result, radiation exposure during canister closure is much less than would be incurred from manual welding.

1.2.1.5.4 Draining and Drying System

The draining and drying system consists of a suction pump and a vacuum pump. The suction pump is used to remove free water from the canister cavity. The vacuum pump is a two-stage

unit for drying the interior of the canister. The first stage is a large capacity or “roughing” pump intended to remove free water not removed by the suction pump. The second stage is a vacuum pump used to evacuate the canister interior of the small amounts of remaining moisture and establish the vacuum condition.

1.2.1.5.5 Lifting Jacks

Hydraulic jacks are installed at jacking pads in the air inlets at the bottom of the concrete cask to lift the cask so that the air pad set can be installed or removed. Four hydraulic jacks are provided, along with a control panel, an electric hydraulic oil pump, an oil reservoir tank and all hydraulic lines and fittings. The jacks are used to lift the cask approximately three inches. This permits installation of the air pad rig set under the concrete cask.

1.2.1.5.6 Heavy-Haul Trailer

The heavy-haul trailer is used to move the Vertical Concrete Cask. A special trailer is designed for transport of the empty or loaded concrete cask. The design incorporates a jacking system that facilitates raising the concrete cask to allow installation of the air pad set used to move the cask onto the storage pad. The trailer incorporates both reinforcing to increase the trailer load-bearing area and design features that reduce its turning radius. However, any commercial double-drop-frame trailer having a deck height approximately matching that of the storage pad could be used.

1.2.1.5.7 Transporter

A cask transporter may also be used to move an empty or loaded Vertical Concrete Cask. The typical design incorporates a vertical lifting system that raises the concrete cask using the Vertical Concrete Cask lifting lugs. The transporter may be a self-propelled, towed or pushed design.

1.2.1.5.8 Helium Leak Test Equipment

A helium leak detector and leak test fixtures are required to verify the integrity of the welds of the canister shield lid. The helium leak detector is the mass spectrometer type.

Table 1.2-1 Design Characteristics of the UMS® Universal Storage System

Design Characteristic	Value (in.)	Material
Transportable Storage Canister		
Shell thickness	0.625	Type 304L Stainless Steel
Shell bottom thickness	1.75	Type 304L Stainless Steel
Shield lid thickness	7	Type 304 Stainless Steel
Structural lid thickness	3	Type 304L Stainless Steel
Canister Fuel Basket		
Top weldment PWR thickness	1.25	Type 304 Stainless Steel
Bottom weldment PWR thickness	1.0	Type 304 Stainless Steel
Top and bottom weldment BWR thickness	1.0	Type 304 Stainless Steel
Support disks thickness		
- PWR	0.5	Type 17-4 PH Stainless Steel
- BWR	0.625	SA-533, Type B Class 2 Carbon Steel
Heat transfer disk thickness	0.5	Type 6061-T651 Aluminum Alloy
Fuel tube dimensions		
- PWR (inside)	8.8 × 8.8	Type 304 Stainless Steel Enclosing neutron absorber
- BWR Standard (inside)	5.9 × 5.9	Type 304 Stainless Steel Enclosing neutron absorber
- BWR Over-Sized Fuel (inside)	6.05 × 6.05	Type 304 Stainless Steel Enclosing neutron absorber
Spacer(s) diameter	2.875	Type 304 Stainless Steel
Tie rod diameter		
- PWR	1-5/8	Type 304 Stainless Steel
- BWR	1-5/8	Type 304 Stainless Steel
BWR Damaged Fuel Can (inside)	6.05 × 6.05	Type 304 Stainless Steel Enclosing neutron absorber

Table 1.2-1 Design Characteristics of the UMS® Universal Storage System (Continued)

Design Characteristic	Value (in.)	Material
Standard and Advanced Transfer Cask		
Outer Shell	1.25 × 85.3 dia.	ASTM A588 Low Alloy Steel
Inner Shell	0.75 × 67.8 dia.	ASTM A588 Low Alloy Steel
Retaining Ring	0.75 × 77.1 dia.	ASTM A588 Low Alloy Steel
Trunnions	10.0 dia.	A350 LF2 Low Alloy Steel
Bottom Plate	1.0 thick plate	ASTM A588 Low Alloy Steel
Top Plate	2.0 thick plate	ASTM A588 Low Alloy Steel
Shield Doors	9.0 thick	A350 LF2 Low Alloy Steel and NS-4-FR
Door Rails	9.4 × 6.5	A350 LF2 Low Alloy Steel
Gamma Shield	4.0 thick	ASTM B29, Chemical Copper Grade Lead
Neutron Shield	2.75 thick	NS-4-FR, Solid Synthetic Polymer
Transfer Adapter		
Base Plate	2.0 thick plate	ASTM A36 Carbon Steel
Locating Ring	2.75 wide × 73.75	ASTM A36 Carbon Steel

Table 1.2-1 Design Characteristics of the UMS® Universal Storage System (Continued)

Design Characteristic	Value (in.)	Material
Vertical Concrete Cask		
Weldment Structure		
Shell	2.5 thick × 79.50 dia	ASTM A36 Carbon Steel
Top Flange	2.0 thick × 101.40 dia.	ASTM A36 Carbon Steel
Support Ring	2.5 thick × 74.50 dia.	ASTM A36 Carbon Steel
Base Plate	2.0 thick × 67.50 dia.	ASTM A36 Carbon Steel
Concrete Cask		
Concrete Shell	28.3 thick × 136 dia.	Type II Portland Cement
Shield Plug (NS-4-FR)	5.13 × 74.0 dia.	ASTM A36 Carbon Steel and NS-4-FR
Shield Plug (NS-3)	5.63 × 74.0 dia.	ASTM A36 Carbon Steel and NS-3
Cask Lid	1.50 thick × 85.6 dia.	ASTM A36 Carbon Steel
Rebar	Various Lengths	ASTM A615, GR 60, ASTM A615, GR75, and A-706 Carbon Steel

Table 1.2-2 Major Physical Design Parameters of the Transportable Storage Canister

Canister Parameter	Value
Canister Shell	
Outside Diameter (in.)	67.1
Thickness (in.)	0.625
Overall Length (in.)	
Class 1 (PWR)	175.1
Class 2 (PWR)	184.2
Class 3 (PWR)	191.8
Class 4 (BWR)	185.6
Class 5 (BWR and BWR DF)	190.4 and 190.7
Capacity (No. of fuel assemblies)	
Classes 1 – 3 (PWR)	24
Classes 4 – 5 (BWR)	56
Maximum Heat Load (kW)	
PWR	23.0
BWR	23.0
Maximum Long-Term Fuel Cladding Temperature – (°F [°C])	
Classes 1 – 3 (PWR)	752 (400)
Classes 4 – 5 (BWR)	752 (400)
Internal Atmosphere	Helium

Table 1.2-3 Transportable Storage Canister Fabrication Specification Summary

Materials

- All material shall be in accordance with the referenced drawings and meet the applicable ASME code sections.

Welding
- All welds shall be in accordance with the referenced drawings.
- All filler metals shall be appropriate ASME materials.
- All welders and welding operators shall be qualified in accordance with ASME Section IX [14].
- All welding procedures shall be written and qualified in accordance with ASME Section IX.
- All welds specified to be visually examined shall be examined as specified in ASME Section V, Article 9 with acceptance per ASME Code Section VIII [15], UW-35 and UW-36.
- All welds specified to be dye penetrant examined shall be examined in accordance with the requirements of ASME Section V, Article 6, with acceptance in accordance with ASME Section III, NB-5350.
- All personnel performing examinations shall be qualified in accordance with the NAC International Quality Assurance program and SNT-TC-1A [16].
- All welds specified to be radiographed shall be examined in accordance with the requirements of ASME Code Section V, Article 2, with acceptance per ASME Code Section III, NB 5320.
- All welds specified to be ultrasonically examined shall be examined per ASME Code Section V, Article 5, with acceptance per ASME Code Section III, NB-5330.

Fabrication
- All cutting, welding, and forming shall be in accordance with ASME Code Section III, NB-4000 unless otherwise specified. Code stamping is not required.
- All surfaces shall be cleaned to a surface cleanness classification C or better as defined in ANSI N45.2.1 [17], Section 2.
- All fabrication tolerances shall meet the requirements of the referenced drawings after fabrication.
- Fit-up testing of a “dummy” fuel assembly into each fuel tube and insertion of the completed basket into the canister shell is required. Verification of the basket overall length and diameter is required.

Packaging
- Packaging and shipping shall be in accordance with ANSI N45.2.2 [18].

Quality Assurance
- The canister shall be fabricated under a quality assurance program that meets 10 CFR 72 Subpart G and 10 CFR 71 Subpart H.
- The supplier’s quality assurance program must be accepted by the licensee prior to initiation of work.
- A Certificate of Conformance shall be issued by the fabricator stating that the canister meets the specifications and drawings.

Table 1.2-4 Major Physical Design Parameters of the Fuel Basket

Basket Parameter	Value
Basket Assembly Length, in.	
Class 1 (PWR)	162.6
Class 2 (PWR)	171.7
Class 3 (PWR)	179.3
Class 4 (BWR)	173.1
Class 5 (BWR)	177.9
Basket Assembly Diameter, in.	65.5
Number of Support Disks	
Class 1 (PWR)	30
Class 2 (PWR)	32
Class 3 (PWR)	34
Class 4 (BWR)	40
Class 5 (BWR)	41
Number of Heat Transfer Disks	
Class 1 (PWR)	29
Class 2 (PWR)	31
Class 3 (PWR)	33
Class 4 (BWR)	17
Class 5 (BWR)	17
Number of Fuel Tubes	
Classes 1 – 3 (PWR)	24 (with neutron absorber on all four sides)
Classes 4 – 5 (BWR)	BWR Basket 56 (42 with neutron absorber on two sides; 11 with neutron absorber on one side; and 3 with no neutron absorber) BWR DF Basket 52 (38 with neutron absorber on two sides; 11 with neutron absorber on one side; and 3 with no neutron absorber). 4 BWR DFCs with 2 neutron absorbers are located in corner locations.
Number of Tie Rods	
Classes 1 – 3 (PWR)	8
Classes 4 – 5 (BWR)	6

1.3 Universal Storage System Contents

The Universal Storage System is designed to store up to 24 PWR fuel assemblies or up to 56 BWR fuel assemblies. The design basis fuel contents are subject to the limits presented in Section 1.3.1. Site specific contents are described in Section 1.3.2. The site specific contents are either shown to be bounded by the evaluation of the design basis fuel, or are separately evaluated to establish limits which are maintained by administrative controls.

1.3.1 Design Basis Spent Fuel

The Universal Storage System is evaluated based on a set of fuel assembly parameters that establish bounding conditions for the system. The bounding fuel parameters are provided in Table 2.1.1-1 for PWR fuel and in Table 2.1.2-1 for BWR fuel. Fuel assembly designs having parameters bounded by those in Tables 2.1.1-1 and 2.1.2-1 are acceptable for loading. Four different assembly array sizes: 14 × 14, 15 × 15, 16 × 16 and 17 × 17, produced by several different fuel vendors, were evaluated in the development of the PWR design basis spent fuel description. Four different arrays: 7 × 7, 8 × 8, 9 × 9 and 10 × 10 produced by several different fuel vendors were evaluated in the development of the BWR design basis spent fuel description.

The Universal Storage System fuel limits are:

1. The characteristics of the PWR and BWR fuel to be stored shall be in accordance with Tables 2.1.1-1 and 2.1.2-1, respectively.

2. The total decay heat of the PWR fuel shall not exceed 23.0 kW.

3. The total decay heat of the BWR fuel shall not exceed 23.0 kW.

4. The maximum initial enrichment shall not exceed 5.0 wt % ^{235}U for PWR and 5.0 wt % ^{235}U for BWR fuel assemblies.

5. The maximum initial enrichment of the PWR fuel is based on a pool/canister water boron content of at least 1,000 parts per million for some fuel parameter combinations. The maximum initial enrichment of the BWR fuel is defined as the maximum initial peak planar-average enrichment. The initial peak planar-average enrichment is the maximum initial peak planar-average enrichment at any height along the axis of the fuel assembly. The initial peak planar-average may be higher than the bundle average enrichment value that appears in fuel design or plant documents. Unenriched fuel assemblies are not evaluated and are not included as a proposed content.

6. The maximum PWR fuel assembly burnup (MWD/MTU) and minimum cooling time (years) shall be as defined by Table 2.1.1-2.

7. The maximum BWR fuel assembly burnup (MWD/MTU) and minimum cooling time (years) shall be as defined by Table 2.1.2-2.

8. Radiation levels shall not exceed the requirements of 10 CFR 72.104 and 10 CFR 72.106.

9. An inert atmosphere shall be maintained within the canister where spent fuel is stored.

10. Stainless steel spacers may be used to axially position PWR fuel assemblies that are shorter than the canister cavity length to facilitate handling.

11. Flow mixers (thimble plugs), in-core instrument thimbles, burnable poison rods or solid stainless steel rods may be placed in PWR guide tubes as long as the maximum fuel assembly weights listed in Table 2.1.1-1 are not exceeded and no credit for soluble boron is taken.

1.3.2 Site Specific Spent Fuel

This section describes fuel assembly characteristics and configurations, which are unique to specific reactor sites. These site specific content configurations result from conditions that occurred during reactor operations, participation in research and development programs (testing programs intended to improve reactor operations), and from the placement of control components or other items within the fuel assembly.

Site specific fuel assembly configurations are either shown to be bounded by the analysis of the standard design basis fuel assembly configuration of the same type (PWR or BWR), or are shown to be acceptable contents by specific evaluation of the configuration.

Unless specifically excepted, site specific fuel must meet all of the conditions specified for the design basis fuel presented in Section 1.3.1 above. Site specific fuels are also described in Section 2.1.3.

1.8 License Drawings

This section presents the list of License Drawings for the Universal Storage System.

1.8.1 License Drawings for the UMS® Universal Storage System

Drawing Number	Title	Revision No.	No. of Sheets
790-501	Canister/Basket Assembly Table, NAC-UMS®	3	1
790-559	Assembly, Transfer Adapter, NAC-UMS®	7	4
790-560	Assembly, Standard Transfer Cask (TFR), NAC-UMS®	17	7
790-561	Weldment, Structure, Vertical Concrete Cask (VCC), NAC-UMS®	16	4
790-562	Reinforcing Bar and Concrete Placement, Vertical Concrete Cask (VCC), NAC-UMS®	20	8
790-563	Lid, Vertical Concrete Cask (VCC), NAC-UMS®	6	1
790-564	Shield Plug, Vertical Concrete Cask (VCC), NAC-UMS®	8	3
790-565	Nameplate, Vertical Concrete Cask (VCC), NAC-UMS®	5	1
790-570	Fuel Basket Assembly, 56 Element BWR, NAC-UMS®	6	3
790-571	Bottom Weldment, Fuel Basket, 56 Element BWR, NAC-UMS®	3	1
790-572	Top Weldment, Fuel Basket, 56 Element BWR, NAC-UMS®	4	1
790-573	Support Disk and Misc. Basket Details, 56 Element BWR, NAC-UMS®	8	1
790-574	Heat Transfer Disk, Fuel Basket, 56 Element BWR, NAC-UMS®	3	1
790-575	BWR Fuel Tube, NAC-UMS®	11	2
790-581	PWR Fuel Tube, NAC-UMS®	9	2
790-582	Shell Weldment, Canister, NAC-UMS®	13	2
790-583	Assembly, Drain Tube, Canister, NAC-UMS®	9	1
790-584	Details, Canister, NAC-UMS®	20	3
790-585	Transportable Storage Canister (TSC), NAC-UMS®	25	3
790-587	Spacer Shim, Canister, NAC-UMS®	1	1
790-590	Loaded Vertical Concrete Cask (VCC), NAC-UMS®	9	2
790-591	Bottom Weldment, Fuel Basket, 24 Element PWR, NAC-UMS®	6	2

License Drawings (continued)

Drawing Number	Title	Revision No.	No. of Sheets
790-592	Top Weldment, Fuel Basket, 24 Element PWR, NAC-UMS®	8	1
790-593	Support Disk and Misc. Basket Details, 24 Element PWR, NAC-UMS®	7	2
790-594	Heat Transfer Disk, Fuel Basket, 24 Element PWR, NAC-UMS®	2	1
790-595	Fuel Basket Assembly, 24 Element PWR, NAC-UMS®	10	2
790-601	Damaged Fuel Can (DFC), BWR, NAC-UMS®	0NP*	1
790-605	BWR Fuel Tube, Over-Sized Fuel, NAC-UMS®	12	2
790-613	Supplemental Shielding, VCC Inlets, NAC-UMS®	2	1
790-617	Door Stop, NAC-UMS®	4	2
790-671	Bottom Weldment, Fuel Basket, 56 Element BWR DF, NAC-UMS®	1	1
70-672	Top Weldment, Fuel Basket, 56 Element BWR DF, NAC-UMS®	1	1

*Proprietary Drawing Removed

1.8.3 Site Specific Spent Fuel License Drawings

Drawing Number	Title	Revision No.	No. of Sheets
412-501	Spent Fuel Can Assembly, Maine Yankee (MY), NAC-UMS®	4	2
412-502	Fuel Can Details, Maine Yankee (MY), NAC-UMS®	6	6

The following drawings have been withheld as Sensitive Unclassified Non-Safeguards Information-Security-Related Information under Title 10 of the Code of Federal Regulation, 2.390:

Drawing No. 790-561, Revision No. 16, Sheets 1–4, Weldment, Structure, Vertical Concrete Cask (VCC) NAC-UMS®

Drawing No. 790-562, Revision No. 20, Sheets 1–8, Reinforcing Bar and Concrete Placement, Vertical Concrete Cask (VCC) NAC-UMS®

Drawing No. 790-570, Revision No. 6, Sheets 1–3, Fuel Basket Assembly, 56 Element BWR & BWR DF NAC-UMS®

Drawing No. 790-575, Revision No. 11, Sheets 1–2, BWR Fuel Tube, NAC-UMS®

Drawing No. 790-582, Revision No. 13, Sheets 1–2, Shell Weldment Canister NAC-UMS®

Drawing No. 790-583, Revision No. 9, Assembly Drain Tube, Canister, NAC-UMS®

Drawing No. 790-585, Revision No. 25, Sheets 1–3, Transportable Storage Canister (TSC) NAC-UMS®

Drawing No. 790-590, Revision No. 9, Sheets 1–2, Loaded Vertical Concrete Cask (VCC) NAC-UMS®

Drawing No. 790-601, Revision No. 0NP, Damaged Fuel Can (DFC) NAC-UMS®

Drawing No. 790-605, Revision No. 12, Sheets 1–2, BWR Fuel Tube, Over-Sized Fuel, NAC-UMS®

Drawing No. 790-671, Revision No. 1, Bottom Weldment, Fuel Basket, 56 Element BWR DF, NAC-UMS®

Drawing No. 790-672, Revision No. 1, Top Weldment, Fuel Basket, 56 Element BWR DF, NAC-UMS®

2.0 PRINCIPAL DESIGN CRITERIA

The Universal Storage System is a canister-based spent fuel dry storage cask system that is designed to be compatible with the Universal Transportation System. It is designed to store a variety of PWR and BWR fuel assemblies. This chapter presents the design bases, including the principal design criteria, limiting load conditions, and operational parameters of the Universal Storage System. The principal design criteria are summarized in Table 2-1.

Table 2-1 Summary of Universal Storage System Design Criteria

Parameter	Criteria
Design Life	50 years
Design Code - Confinement	ASME Code, Section III, Subsection NB [1] for confinement boundary
Design Code - Nonconfinement	
Basket	ASME Code, Section III, Subsection NG [2] and NUREG/CR-6322 [3]
Vertical Concrete Cask	ACI-349 [4], ACI-318 [5]
Transfer Cask	ANSI N14.6 [6] and NUREG-0612 [7]
Maximum Weight:	
Canister with Design Basis PWR Fuel Assembly (dry, including inserts) (Class 2)	72,900 lbs.
Canister with Design Basis BWR Fuel (dry, including damaged fuel) (Class 5)	75,800 lbs.
Vertical Concrete Cask (loaded) (Class 5)	323,900 lbs.
Transfer Cask (Class 3)	121,500 lbs.
Thermal:	
Maximum Fuel Cladding Temperature:	
PWR Fuel	752°F (400°C) for Normal and Transfer [25] 1058°F (570°C) Off-Normal and Accident [21]
BWR Fuel	752°F (400°C) for Normal and Transfer [25] 1058°F (570°C) Off-Normal and Accident [21]
Ambient Temperature:	
Normal (average annual ambient)	76°F
Off-Normal (extreme cold; extreme hot)	-40°F; 106°F
Accident	133°F
Concrete Temperature:	
Normal Conditions	≤ 150°F (bulk); ≤ 200°F (local) [24]
Off-Normal/Accident Conditions	≤ 350°F local/ surface [4]
Cavity Atmosphere	Helium

2.1 Spent Fuel To Be Stored

The Universal Storage System is designed to safely store up to 24 PWR spent fuel assemblies, or up to 56 BWR spent fuel assemblies, contained within a Transportable Storage Canister. On the basis of fuel assembly length and cross-section, the fuel assemblies are grouped into three classes of PWR fuel assemblies and two classes of BWR fuel assemblies. The class of the fuel assemblies is shown in Tables 6.2-1 and 6.2-2 for PWR and BWR fuel, respectively, and is based primarily on overall length. Additional BWR Class 5 fuel is presented in Table 6.7.2-1.

The PWR and BWR fuel having the parameters shown in Tables 2.1.1-1 and 2.1.2-1, respectively, may be stored in the Universal Storage System. As shown in Table 2.1.1-1, the evaluation of PWR fuel includes fuel having thimble plugs and burnable poison rods in guide tube positions. In addition, solid stainless steel rods may be inserted into guide tube positions as long as the fuel assembly weight limits in Table 2.1.1-1 are not exceeded and no soluble boron credit is taken. As shown in Table 2.1.2-1, the BWR fuel evaluation includes fuel with a zirconium alloy channel. Any empty fuel rod position must be filled with a solid filler rod fabricated from either zirconium alloy or Type 304 stainless steel, or may be solid neutron absorber rods inserted for in-core reactivity control prior to reactor operation.

In addition to the design basis fuel, fuel that is unique to a reactor site, referred to as site specific fuel, is also evaluated. Site specific fuel consists of fuel assemblies that are configured differently, or have different parameters (such as enrichment or burnup), than the design basis fuel assemblies.

Site specific fuel is described in Section 2.1.3.

Site specific fuel is shown to be bounded by the fuel parameters shown in Tables 2.1.1-1 or 2.1.2-1, or it is separately evaluated.

The minimum initial enrichment limits are shown in Tables 2.1.1-2 and 2.1.2-2 for PWR and BWR fuel, respectively. With the exception of select BWR UMS Class 5 fuel assemblies that were evaluated to low enrichment/low burnup combinations (down to 0.7 wt% ^{235}U with a maximum burnup of 5 GWd/MTU) the minimum enrichment limits exclude the loading of fuel assemblies enriched to less than 1.9 wt.% ^{235}U, including unenriched fuel assemblies, into the Transportable Storage Canister. Fuel assemblies with unenriched axial end-blankets may be loaded into the canister.

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2.1.2 BWR Fuel Evaluation

The parameters of the BWR fuel assemblies that may be loaded in the transportable storage canister (canister) are shown in Table 2.1.2-1. Each canister may contain up to 56 undamaged BWR fuel assemblies.

The design of the Universal Storage System is based on certain reference fuel assemblies that maximize the source terms used for the shielding and criticality evaluation, and that maximize the weight used in the structural evaluation. These reference fuel assemblies are described in the chapters appropriate to the condition being evaluated. The principal characteristics and parameters of a reference fuel, such as fuel volume, initial enrichment, cool time and burnup, do not represent limiting or bounding values. Bounding values for a fuel class are established based primarily on how principal parameters are combined and on the loading conditions or restrictions established for a class of fuel based on its parameters.

The maximum canister decay heat load for the storage of all types of BWR fuel assemblies is 23.0 kW (0.411 kW/assembly).

The minimum cooling time determination is based on the maximum decay heat load (23.0 kW) and the dose rate limits for the concrete and transfer casks and is presented in Section 5.5. BWR fuel must be loaded in accordance with Table 2.1.2-2 for BWR 7×7, 8×8, and 9×9 fuel assembly up to 45 GWd/MTU. The 8×8, 9×9 and 10×10 load tables for burnup above to 45 GWd/MTU and up to 60 GWd/MTU are listed in Section 5.8.2. BWR 10×10 assembly up to 45 GWd/MTU load tables are shown in Section 5.8.1.

Table 2.1.2-1 BWR Fuel Assembly Characteristics

Fuel Class[1]	7 × 7	7 × 7	8 × 8	8 × 8	8 × 8	9 × 9	9 × 9	10x10
Fissile Isotopes	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2
Max Initial Enrichment (wt % ^{235}U)[1]	4.5	4.7	Note 6	Note 6	Note 6	Note 6	Note 6	Note 6
Number of Fuel Rods	48	49	60	62	63	72/74	79	91/92
Number of Water Holes	1[4]	0	1/4[5]	2	4	1(2/7[5])	2	1/2
Max Assembly Average Burnup (MWd/MTU)	45,000	45,000	60,000	60,000	60,000	60,000	60,000	60,000
Cladding Material	Zirconium Alloy	Zirconium Alloy	Zirconium Alloy	Zirconium Alloy	Zirconium Alloy	Zirconium Alloy	Zirconium Alloy	Zirconium Alloy
Nonfuel Hardware[2]	Channel	Channel	Channel	Channel	Channel	Channel	Channel	Channel
Max Channel Thickness (mil)	120	120	120	120	120	120	120	120
Max Weight (lb) per Storage Location[3]	702	702	702	702	702	702	702	702
Max Decay Heat (Watts) per Storage Location	410.7	410.7	410.7	410.7	410.7	410.7	410.7	410.7
Fuel Condition	Undamaged	Undamaged	Undamaged /Damaged	Undamaged /Damaged	Undamaged /Damaged	Undamaged /Damaged	Undamaged /Damaged	Undamaged /Damaged

General Notes:

- Minimum cool time and minimum enrichment set minimum cool time when combined with maximum fuel assembly burnup.

Notes:

1. Fuel must be loaded in accordance with Chapter 5 minimum cool time tables.
2. Each BWR fuel assembly may have a zirconium alloy channel or be unchanneled, but cannot have a stainless steel channel.
3. Weight includes the weight of the channel.
4. Solid fill or water rod.
5. Water rods may occupy more than one fuel lattice location.
6. See Section 6.7 for uniform (damaged and undamaged) and undamaged preferential load allowable enrichments.

Any evidence of permanent deformation, cracking, galling of bearing surfaces, or unacceptable liquid penetrant examination results is cause for rejection. Any identified defects must be repaired and the load test repeated prior to final acceptance.

2.3.3.2 Protection by Instrumentation

No instrumentation is required for the safe storage operations of the UMS®. A remote temperature-monitoring system may be used to measure the outlet air temperature of the concrete casks in long-term storage. The outlet and ISFSI ambient air temperatures can be monitored daily as a check of the continuing thermal performance of the concrete cask. Alternately, a daily visual inspection for blockage and integrity of the air inlet and air outlet screens of all concrete casks may be performed. Following any natural phenomena event, such as an earthquake or tornado, the concrete casks shall be inspected for damage and air inlet and air outlet blockage.

2.3.4 Nuclear Criticality Safety

The Universal Storage System design includes features to ensure that nuclear criticality safety is maintained (i.e., the cask remains subcritical) under normal, off-normal, and accident conditions. The design of the canister and fuel basket is such that, under all conditions, the highest neutron multiplication factor (k_{eff}) is less than 0.95. The criticality evaluation for the design basis fuel is presented in Section 6.4 and Section 6.7.

2.3.4.1 Control Methods for Prevention of Criticality

Criticality control in the PWR basket is achieved using a neutron flux trap configuration. Individual fuel assemblies are surrounded by four neutron absorber sheets, one on each side of the assembly, that provide absorption of moderated neutrons. The assemblies are separated by a gap that is filled with water during hypothetical accident conditions when the canister is flooded. Fast neutrons escaping one fuel assembly are moderated in the gap between the assemblies and absorbed by the neutron absorber material surrounding the assemblies. The minimum loading of the neutron absorber sheets is 0.025 g $^{10}B/cm^2$. The sheets are mechanically supported by the fuel tube structure to ensure that the neutron absorber sheets remain in place during the design basis normal, off-normal, and accident events.

Individual fuel assemblies in the BWR basket are separated from adjacent assemblies by a single neutron absorber sheet between fuel assemblies. Of the total 56 fuel tubes, 42 tubes contain neutron absorber sheets on two sides of the tubes, 11 tubes contain neutron absorber sheets on one side, and the remaining 3 tubes contain no neutron absorber sheets. The arrangement of the fuel tubes ensures that there is at least one neutron absorber sheet between adjacent fuel assemblies. Although this configuration of water gaps and neutron absorber sheets does not form a classic neutron flux trap, the design ensures that there is sufficient absorption of moderated neutrons by the neutron absorber to maintain criticality control in the basket (k_{eff} < 0.95). The minimum loading of the neutron absorber sheets in the BWR fuel tubes is 0.011 g $^{10}B/cm^2$. The neutron absorber sheets are mechanically supported by the fuel tube structure to ensure that the sheets remain in place during the design basis normal, off-normal, and accident events. In the case of the BWR DF basket the DFCs replace the four corner fuel tubes with BWR DFCs that each of two neutron absorbers with the same absorber content as the tubes (0.011 g $^{10}B/cm^2$).

The efficiency of the neutron absorber sheets in preserving nuclear criticality safety is demonstrated by the criticality results presented in Chapter 6.

The principal criticality design criterion is that k_{eff} remain below 0.95 under all conditions. Assumptions made in the analyses used to demonstrate conformance to this criterion include:

1. Fuel assembly with maximum ^{235}U loading (95% theoretical density);
2. 75 percent of the nominal ^{10}B loading in the neutron absorber sheet;
3. Infinite array of casks in the X-Y (horizontal) plane;
4. Infinite fuel length with no inclusion of end leakage effects (for CSAS models, MONK and MCNP models contain a finite axial extent);
5. No credit taken for structural material present in the assembly; and,
6. No credit taken for fuel burnup or for the buildup of fission product neutron poisons.

Use of administrative controls of fuel burnup levels, neutron absorption properties of the burned fuel, and the presence of steel shell of the canister provide further criticality controls in the Universal Storage System.

2.3.4.2 Error Contingency Criteria

For CAS the calculated values of k_{eff} include error contingencies and calculation and modeling biases. The standards and regulations of criticality safety require that k_{eff}, including uncertainties, k_s, be less than 0.95. The bias and 95/95 uncertainty are applied to the calculation of k_s by using:

$$k_s = k_{nom} + 0.0052 + [(0.0087)^2 + (2\sigma_{MC})^2]^{1/2} \leq 0.95$$

where:

k_{nom} = the nominal k_{eff} for the cask, and
σ_{MC} = the Monte Carlo uncertainty.

The calculation of error contingencies and uncertainties is presented in Section 6.4 for CSAS and MONK. MONK and MCNP code bias and bias uncertainty, in terms of USL, is discussed in Section 6.5.

2.3.4.3 Verification Analyses

The CSAS25 criticality analysis sequence is benchmarked through a series of calculations based on 63 critical experiments. These experiments span a range of fuel enrichments, fuel rod pitches, poison sheet characteristics, shielding materials, and geometries that are typical of light water reactor fuel in a cask. To achieve accurate results, three-dimensional models, as close to the actual experiment as possible, are used to evaluate the experiments. The results of the benchmark calculations are provided in Section 6.5.

Evaluations of the Upper Subcritical Limit (USL) for use in MONK and MCNP analysis is provided in Section 6.5.

2.3.5 Radiological Protection

The Universal Storage System, in keeping with the As Low As Is Reasonably Achievable (ALARA) philosophy, is designed to minimize, to the extent practicable, operator radiological exposure.

2.3.5.1 Access Control

Access to a Universal Storage System ISFSI site is controlled by a peripheral fence to meet the requirements of 10 CFR 72 and 10 CFR 20 [19]. Access to the storage area, and its designation as to the level of radiation protection required, are established by site procedure. The storage area is surrounded by a fence, having lockable truck and personnel access gates. The fence has intrusion-detection features as determined by the site procedure.

2.3.5.2 Shielding

The Universal Storage System is designed to limit the dose rates as follows:

- external surface dose (gamma and neutron) to less than 50 mrem/hr (average) on the Vertical Concrete Cask sides.
- external surface dose to less than 50 mrem/hr (average) on the Vertical Concrete Cask top.
- a maximum of 100 mrem/hr (average) at the Vertical Concrete Cask air inlets and outlets.
- the supplemental shielding at the top of the canister shield lid reduces personnel exposure during canister closure operations.

Sections 72.104 and 72.106 of 10 CFR 72 set whole body dose limits for an individual located beyond the controlled area at 25 millirems per year (whole body) during normal operations and 5 rems (5,000 millirems) from any design basis accident. The analyses showing the actual Universal Storage System doses, and dose rates, are included in Chapters 5.0, 10.0 and 11.0.

2.3.5.3 Ventilation Off-Gas

The Universal Storage System is passively cooled by radiation and natural convection heat transfer at the outer surface of the concrete cask and in the canister-concrete cask annulus. The bottom of the cask is conservatively assumed to be an adiabatic surface. In the canister-concrete cask annulus, air enters the air inlets, flows up between the canister and concrete cask liner in the annulus, and exits the air outlets. The air flow in the annulus is due to the buoyancy effect created by the heating of the air by the canister and concrete cask liner walls. The details of the passive ventilation system design are provided in Chapter 4.0.

Table 2.3-1 Quality Category Classification of Universal Storage System Components (continued)

Drawing No.	Description	Item No.	Component	Function	Quality Category
790-562 (Continued)	Reinforcing Bar And Concrete Placement	28, 36, 39	Concrete Anchor	Operations	NQ
		16-19, 40-41, 49	Screen/Strip/Screw/Washer	Operations	NQ
		15	Concrete Shell	Shielding/ Structural	B
		1-11, 33, 46			
790-563	Lid, Vertical Concrete Cask	1	Lid	Structural/Operations	B
790-564	Shield Plug, Vertical Concrete Cask	13			
		12			
		11			
		10			
		9			
		4, 8	Neutron Shield Cover	Shielding/Operations	B
		3, 5	Neutron Shield	Shielding	B
		2, 6, 7	NS Retaining Ring	Structural	B
		1	Shield Plug	Shielding	B
790-565	Nameplate, Vertical Concrete Cask	1	Nameplate	Operations	NQ
790-570	BWR Fuel Basket	23	Flat Washer	Structural	C
		4	Drain Tube Sleeve	Operations	C
790-571	Bottom Weldment, BWR Fuel Basket	3	Support	Structural	A
		2	Pad	Structural	A
		1	Plate	Structural	A

Table 2.3-1 Quality Category Classification of Universal Storage System Components (Continued)

Drawing No.	Description	Item No.	Component	Function	Quality Category
790-572	Top Weldment, BWR Fuel Basket	6	Baffle	Structural	A
		3-5	Support		
		2	Ring		
		1	Plate		
790-573	Support Disk and BWR Basket Details	8	Split Spacer	Structural	A
		7	Top Spacer	Structural	A
		5, 6	Tie Rod	Structural	A
		4	Top Nut	Structural	A
		3	Spacer	Structural	A
		1	Support Disk	Structural	A
790-574	Heat Transfer Disk, BWR	1	Heat Transfer Disk	Thermal	A
790-575	BWR Fuel Tube	10	Flange	Structural	A
		7-9	Cladding	Criticality Control	A
		4-6	Neutron Absorber	Criticality Control	A
		1-3	Tubing	Structural	A
790-581	PWR Fuel Tube	10	Flange	Structural	A
		7-9	Cladding	Criticality Control	A
		4-6	Neutron Absorber	Criticality Control	A
		1-3	Tubing	Structural	A
790-582	Canister, Shell	7	Location Lug	Operations	C
		6	Bottom	Structural/Confinement	A
		1-5, 8	Shell	Structural/Confinement	A

Table 2.3-1 Quality Category Classification of Universal Storage System Components (Continued)

Drawing No.	Description	Item No.	Component	Function	Quality Category
790-583	Drain Tube Assembly	7	Metal Boss Seal	Operations	C
		2-6, 8	Tube	Operations	C
		1	Nipple	Operations	C
790-584	Canister Details	8	Key	Operations	C
		7	Spacer Ring	Structural	C
		6	Lid Support Ring	Structural	B
		5	Cover	Confinement/Operations	B
		4	Structural Lid	Structural	A
		3	Metal Boss Seal	Operations	C
		2	Nipple	Operations	C
		1	Shield Lid	Shielding/Confinement	B
790-585	Transportable Storage Canister	24	Dowel Pin	Operations	NQ
		23	Structural Lid Plug	Operations	NQ
		22	Shield Lid Plug	Operations	NQ
790-587	Spacer Shim, Canister	1-6	Spacer Shims #1 - #6	Operations	C
790-590	Loaded Vertical Concrete Cask	19	Tab	Operations	NQ
		18	Seal Wire	Operations	C
		17	Security Seal	Operations	C
		16	Seal Tape (Optional)	Operations	NQ
		15	Cover	Operations	C
		14	Washer (Lid Bolt)	Operations	NQ
		13	Lid Bolt	Operations	NQ

Table 2.3-1 Quality Category Classification of Universal Storage System Components (Continued)

Drawing No.	Description	Item No.	Component	Function	Quality Category
790-591	Bottom Weldment, PWR Basket	3, 5-7	Support	Structural	A
		4	Pad	Structural	A
		2	Support	Structural	A
		1	Bottom Disk	Structural	A
790-592	Top Weldment, PWR Basket	7	Baffle	Structural	A
		3, 5-6	Support	Structural	A
		4	Center Support	Structural	A
		2	Ring	Structural	A
		1	Top Disk	Structural	A
790-593	Support Disk and Details, PWR	8	Top Spacer	Structural	A
		5-7	Tie Rod	Structural	A
		4, 9, 10	Top Nut	Structural	A
		3	Spacer	Structural	A
		2	Split Spacer	Structural	A
		1	Support Disk	Structural	A
790-594	Heat Transfer Disk, PWR	1	Heat Transfer Disk	Thermal	A
790-595	PWR Fuel Basket	8	Flat Washer	Structural	C
		4	Drain Tube Sleeve/Tube	Operations	C
790-605	BWR Fuel Tube, Over-Sized	7	Flange	Structural	A
		5-6	Cladding	Criticality Control	A
		3-4	Neutron Absorber	Criticality Control	A
		1-2	Tubing	Structural	A

Table 2.3-1 Quality Category Classification of Universal Storage System Components (Continued)

Drawing No.	Description	Item No.	Component	Function	Quality Category
790-613	Supplemental Shielding, VCC Inlets	4	Shims	Operations	NQ
		3	Paint	Operations	NQ
		2	Pipe	Shielding	B
		1	Side Plate	Shielding	B
790-617	Door Stop	6	Attachment Screw	Operations	NQ
		5	Lock Pin	Operations	NQ
		4	Handle	Operations	NQ
		3	Back Plate	Operations	NQ
		2	Top Plate	Operations	NQ
		1	Bottom Plate	Operations	NQ
412-502	Maine Yankee (MY) Fuel Can Details, NAC-UMS®	16	Dowel Pin	Operations	C
		13	Support Ring	Structural/Operations	B
		12	Lift Tee	Structural/Operations	B
		10, 19	Tube Body	Structural/Criticality	A
		9, 18	Side Plate	Structural/Criticality	A
		8	Bottom Plate	Structural/Criticality	A
		7, 15	Backing Screen	Operations	C
		6, 14	Filter Screen	Confinement	B
		5	Lid Bottom	Structural/Criticality	A
		4	Wiper	Operations	C
		3	Lid Guide	Operations	C
		2	Lid Plate	Structural/Criticality	A
		1	Lid Collar	Confinement	A

Table 2.3-1 Quality Category Classification of Universal Storage System Components (Continued)

Drawing No.	Description	Item No.	Component	Function	Quality Category
790-601	Damaged Fuel Can (DFC) BWR, NAC-UMS®	15	Cladding	Criticality Control	A
		14	Neutron Absorber	Criticality Control	A
		13	Bottom Lid	Structural/Criticality	A
		12	Interior Lid Wall	Structural/Criticality	A
		11	Lid Wall	Structural/Criticality	A
		10	Lid Plate	Structural/Criticality	A
		8	Filter Screen	Confinement	C
		7	Backing Screen	Operations	C
		6	Collar	Operations	C
		5	Bottom Plate	Structural/Criticality	A
		3	Top Flange	Structural/Criticality	A
		2	Tube Body	Structural/Criticality	A
790-671	Bottom Weldment, Fuel Basket, 56 Element BWR, NAC-UMS®	3	Support	Structural	A
		2	Pad	Structural	A
		1	Plate	Structural	A
790-672	Top Weldment, Fuel Basket, 56 Element BWR DF, NAC-UMS®	6, 7	Baffle	Structural	NQ
		3, 4, 5	Support	Structural	A
		2	Ring	Structural	A
		1	Plate	Structural	A

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Transportable Storage Canister

The transportable storage canister consists of a cylindrical shell assembly closed at its top end by an inner shield lid and an outer structural lid. The canister forms the confinement boundary for the basket assembly that contains the PWR or BWR spent fuel. Three canister classes accommodate the PWR fuel assemblies (Tables 2.1.1-1) and two canister classes accommodate the BWR fuel assemblies (Table 2.1.2-1). As discussed in Chapter 1, Class 5 BWR DF canister is used to load up to four damaged fuel cans. The canister is fabricated from Type 304L stainless steel. The canister shield lid is 7-in. thick, SA-240 Type 304 stainless steel, and the structural lid is 3.0-in. thick SA-240, Type 304L stainless steel. SA-182 Type 304 stainless steel may be substituted for the SA-240 Type 304 stainless steel used in the shield lid, provided that the SA-182 material has yield and ultimate strengths equal to or greater than those of the SA-240 material. Similarly, SA-182 Type 304L stainless steel may be substituted for the SA-240 Type 304L stainless steel used in the structural lid, provided that the SA-182 material has yield and ultimate strengths equal to or greater than those of the SA-240 material. Both lids are welded to the canister shell to close the canister. The minimum weld sizes for the PWR canister are 0.75 inch for the structural lid and 0.375 inch for the shield lid. For analysis purposes, bounding PWR canister results are reported except for the BWR canister tip-over evaluation (Section 11.2.12.3.2). The minimum weld sizes for the BWR canister are 0.875 inch for the structural lid and 0.5 inch for the shield lid. The shield lid is supported by a support ring. The structural lid is supported, prior to welding, by the shield lid. A groove is machined into the structural lid circumference to accept a spacer ring. The spacer ring facilitates welding of the structural lid to the canister shell. The bottom of the canister is a 1.75-in. thick SA-240, Type 304L stainless steel plate that is welded to the canister shell. The canister is also described in Section 1.2.1.1.

The fuel basket assembly is provided in two configurations — one for up to 24 PWR fuel assemblies and one for up to 56 BWR fuel assemblies. Note that the BWR DF basket may contain up to four BWR damaged fuel cans. The PWR basket is comprised of Type 17-4 PH stainless steel support disks, Type 6061-T651 aluminum alloy heat transfer disks, and Type 304 stainless steel fuel tubes equipped with a neutron absorber and stainless steel cover. The remaining structural components are Type 304 stainless steel. The BWR basket is comprised of SA-533 carbon steel support disks coated with electroless nickel, Type 6061-T651 aluminum alloy heat transfer disks, and fuel tubes constructed of the same materials as the PWR tubes. The remaining structural components of the BWR basket are Type 304 stainless steel. The basket assemblies are more fully described in Section 1.2.1.2.

The fuel basket support disks, heat transfer disks, and fuel tubes, together with the top and bottom weldments, are positioned by tie rods (with spacers and washers) that extend the length of the basket and hold the assembly together. The support disks provide structural support for the fuel tubes. They also help to remove heat from the fuel tubes. The heat transfer disks provide the primary heat removal capability and are not considered to be structural components. The heat transfer disks are sized so that differential thermal expansion does not result in disk contact with the canister shell. The number of heat transfer disks and support disks varies depending upon the length of the fuel to be confined in the basket. The fuel tubes house the spent fuel assemblies. The top and bottom weldments provide longitudinal support for the fuel tubes. The fuel tubes are fabricated from Type 304 stainless steel. No structural credit is taken for the presence of the fuel tubes in the basket assembly analysis. The walls of each PWR fuel tube support a sheet of neutron absorber material that is covered by stainless steel. No structural credit is taken in the basket assembly analysis for the neutron absorber sheet or its stainless steel cover. The PWR assembly fuel tubes have a nominal inside dimension of 8.8-inches square and a composite wall thickness of 0.14 inch. The BWR assembly fuel tubes have a nominal inside dimension of 5.9-inches square and a composite wall thickness of 0.20 inch. Depending upon its location in the basket assembly, an individual BWR fuel tube may support neutron absorber material on one or two sides. Certain fuel tubes located on the outer edge of the basket do not have neutron absorber material. The fuel tubes have been evaluated to ensure that the neutron absorber material remains in place under normal conditions and design basis off-normal and accident events.

Four over-sized fuel storage positions are located on the periphery of the BWR basket to provide additional space for BWR fuel assemblies with channels that have been reused, since reused channels are expected to have increased bowing or bulging. Normal BWR fuel assemblies may also be stored in these locations.

As mentioned above, five classes of transportable storage canisters are provided for the storage of PWR and BWR spent fuel. The analysis is based on the identification of bounding conditions and the application of those conditions to determine the maximum stresses.

The canister is designed to be transported in the Universal Transport Cask. Transport conditions establish the design basis loading, except for lifting, because the hypothetical accident transport conditions produce higher stresses in the canister and basket than do the design basis storage conditions. Consequently, the canister and basket design is conservative with respect to storage conditions. The evaluation of the canister and basket assembly for transport conditions is documented in the Safety Analysis Report for the Universal Transport Cask [2].

Table 3.2-2 Universal Storage System Weights and CGs – BWR Configuration

Item Description	Class 4		Class 5		Class 5 - DF	
	Calculated Weight (lb)	Center of Gravity[1]	Calculated Weight (lb)	Center of Gravity[1]	Calculated Weight (lb)	Center of Gravity[1]
Fuel Content (Including channels)	39,400	—	39,400	—	39,400	—
Concrete Cask Lid	2,500	—	2,500	—	2,500	—
Concrete Cask Shield Plug	4,900	—	4,900	—	4,900	—
Canister (empty, w/o lids)	8,800	—	9,000	—	9,000	—
Canister Structural Lid	3,000	—	3,000	—	3,000	—
Canister Shield Lid	7,000	—	7,000	—	7,000	—
Transfer Adapter Plate	11,200	—	11,200	—	11,200	—
Transfer Cask Lifting Yoke[4]	6,000	—	6,000	—	6,000	—
Water in Canister	15,100	—	15,200	—	15,200	—
Basket	17,200	—	17,600	—	17,700	—
Canister (with basket, without fuel or lids)	25,900	—	26,500	—	26,500	—
Canister (with fuel, and shield and structural lids)	75,000	97.1	75,600	98.1	75,800	98.2
Concrete Cask (empty, with shield plug and lid, includes optional lift lugs) – 140 pcf concrete	233,700	—	238,400	—	—	—
Concrete Cask (with loaded Canister and lids, includes optional lift lug)[2] – 140 pcf concrete	308,700	113.7	313,900	115.8	—	—
Concrete Cask (empty, with shield plug and lid, includes optional lift lugs) – 148 pcf concrete	243,200	111.8	248,000	114.2	248,000	114.2
Concrete Cask (with loaded Canister and lids, includes optional lift lug)[2] – 148 pcf concrete	319,000	113.6	323,900	115.7	324,000	115.7
Transfer Cask (empty)[3]	118,000	—	120,700	—	120,700	—
Transfer Cask and Canister (empty, without lids) [3]	143,900	—	147,200	—	147,200	—
Transfer Cask and Canister (with fuel, water and shield lid) [3]	205,100	—	208,400	—	208,400	—
Transfer Cask and Canister (with fuel, dry with lids) [3]	193,000	—	196,200	—	196,200	—

General Note: All weights are rounded up. Therefore, assembly weights cannot be computed using rounded values of component weights.

1. Weights and CGs are calculated from nominal design dimensions.
2. Center of gravity is measured from the bottom of the concrete cask.
3. Standard or Advanced Transfer Cask
4. Transfer cask lifting yoke weight for specific sites may vary from listed weight. The site-specific yoke weight should be used for site-specific applications.

Table 3.2-3 Calculated Under-Hook Weights for the Standard Transfer Cask

Configuration	PWR Class 1	PWR Class 2	PWR Class 3	BWR Class 4	BWR Class 5	BWR Class 5 - DF
Transfer cask (empty)	112,300	117,300	121,500	118,000	120,700	120,700
Transfer cask, basket and canister (empty, without lids) and yoke[1]	141,400	147,800	152,700	149,800	153,000	153,200
Transfer cask; loaded canister wet (fuel, water and shield lid); and yoke[1]	199,800	207,800	210,900	211,000	214,300	214,500
Transfer cask, loaded canister dry (fuel and lids) and yoke[1]	188,700	196,000	198,000	198,900	202,100	202,300

General Note: All weights are rounded to the next 100 lb.

1. Transfer cask lifting yoke weight for specific sites may vary from listed weight. The site-specific yoke weight should be used for site-specific applications.

3.9 Structural Evaluation of Class 5 BWR DF Configuration

This section presents the structural evaluation for the Class 5 BWR damaged fuel (BWR5 DF) configuration of the UMS storage system. This configuration includes the BWR5 DF canister and the BWR5 DF basket assembly that may contain up to four BWR damaged fuel cans (DFCs). The BWR5 DF canister is identical to the BWR5 canister with a slight increase (0.3 inches) of the nominal length. The BWR5 DF basket is identical to the BWR5 basket, but with the four corner slot openings of the top and bottom weldments increased to allow the placement of the DFCs. Thus, the fuel tubes at the four corner slots of the BWR5 basket are replaced by the DFCs. For the BWR5 DF basket, the bottoms of the DFCs are supported by the canister bottom plate (for the BWR5 basket, all fuel tubes are supported by the bottom weldment). The BWR5 DF canister is placed in the same vertical concrete cask (VCC) for storage condition and in the same transfer cask for transfer operation as the BWR5 canister. Note that there are negligible differences in the weight and C.G. of the loaded concrete cask for the BWR5 and BWR5 DF configurations (as shown in Table 3.2-2). Section 3.9.1 presents a structural evaluation of the lifting and storage conditions for the BWR5 DF configuration of the UMS system. Section 3.9.2 provides a structural evaluation of the BWR damaged fuel can (DFC).

3.9.1 Structural Evaluation of BWR5 DF Configuration of UMS System

3.9.1.1 Lift Evaluation

The lift evaluation of the vertical concrete cask (VCC) loaded with BWR5 damaged fuel (DF) analyzes two lifting situations for the VCC: the bottom lift and the top lift conditions. In addition to these VCC lifts, the loaded BWR5 DF canister and transfer cask are evaluated for lift conditions.

Concrete Cask Bottom Lift Evaluation

The concrete cask bottom lift evaluation that is documented in Section 3.4.3.1 uses a loaded VCC maximum weight of 330,000 lb and a loaded canister maximum weight of 95,000 lb, which are both greater than those of the loaded VCC and canister for BWR5 DF configuration. A height of 130 inches is used for the CG to calculate a CG-horizontal-shift for a hypothetical tip-over evaluation that assumes that one of the hydraulic jacks fails, which is higher than the CG of the VCC loaded with BWR5 DF. Since the weights and the height of the CG used in Section 3.4.3.1 are all bounding, no further evaluation is required.

Concrete Cask Top Lift Evaluation

The concrete cask top lift evaluation that is documented in Section 3.4.3.1.3 uses a loaded VCC maximum weight of 325,000 lb, which is greater than that of the loaded VCC for BWR5 DF configuration. Since the weight used in Section 3.4.3.1.3 is bounding, no further evaluation is required.

Canister Lift Evaluation

The canister lift evaluation that is documented in Section 3.4.3.2 uses a loaded canister maximum weight of 76,000 lb, which is greater than that of the loaded BWR5 DF canister. Since the weight used in Section 3.4.3.2 is bounding, no further evaluation is required.

Transfer Cask Lift

The transfer cask lift evaluation that is documented in Section 3.4.3.3.1 uses a loaded transfer cask maximum weight of 210,000 lb to evaluate the shell and trunnions, which is greater than that of the transfer cask loaded with BWR5 DF canister. Since the weight used in Section 3.4.3.3.1 is bounding, no further evaluation of the transfer cask shell and trunnions is required.

Sections 3.4.3.3.3 and 3.4.3.3.4 use a maximum weight of 131,800 lb (equivalent to a 145,000 lb load including a 10% DLF) to evaluate the transfer cask bottom plate weld, shield doors, door rails and door rail welds during lift conditions. This load considers that the weight of the largest wet loaded canister in the transfer cask, which is greater than that of a wet loaded BWR5 DF canister. Since the weight used in Sections 3.4.3.3.3 and 3.4.3.3.4 is bounding, no further evaluation of the transfer cask bottom plate weld, shield doors, door rails or door rail welds is required.

3.9.1.2 Canister Structural Evaluation

The canister structural evaluations that are documented in Sections 3.4.4.1 and 11.1.3 use an upper-bounding canister weight, which is greater than the weight of the loaded BWR5 DF canister. Additionally, the maximum internal pressures of the BWR5 DF canister are bounded by the maximum internal pressures that are used in Sections 3.4.4.1 and 11.1.3 for all normal, off-normal and accident conditions. Since the canister weight and internal pressures used in Sections 3.4.4.1 and 11.1.3 are bounding, no further evaluation is required.

3.9.1.3 Basket Structural Evaluation

The BWR fuel basket support disks and weldments are evaluated for normal, off-normal and the 24-inch drop accident conditions in Sections 3.4.4.1, 11.1.3 and 11.2.4, respectively. The BWR fuel basket support disks are also evaluated for the tip-over condition as shown in Section 11.2.12. Thermal stresses are evaluated for normal and off-normal conditions. As discussed in Section 4.7, the maximum basket temperature for the BWR5 DF configuration is bounded by the maximum temperature for the BWR5 configuration (all fuel assemblies are undamaged). Therefore, the thermal stress evaluation for the basket in Sections 3.4.4.1 and 11.1.3 remain bounding.

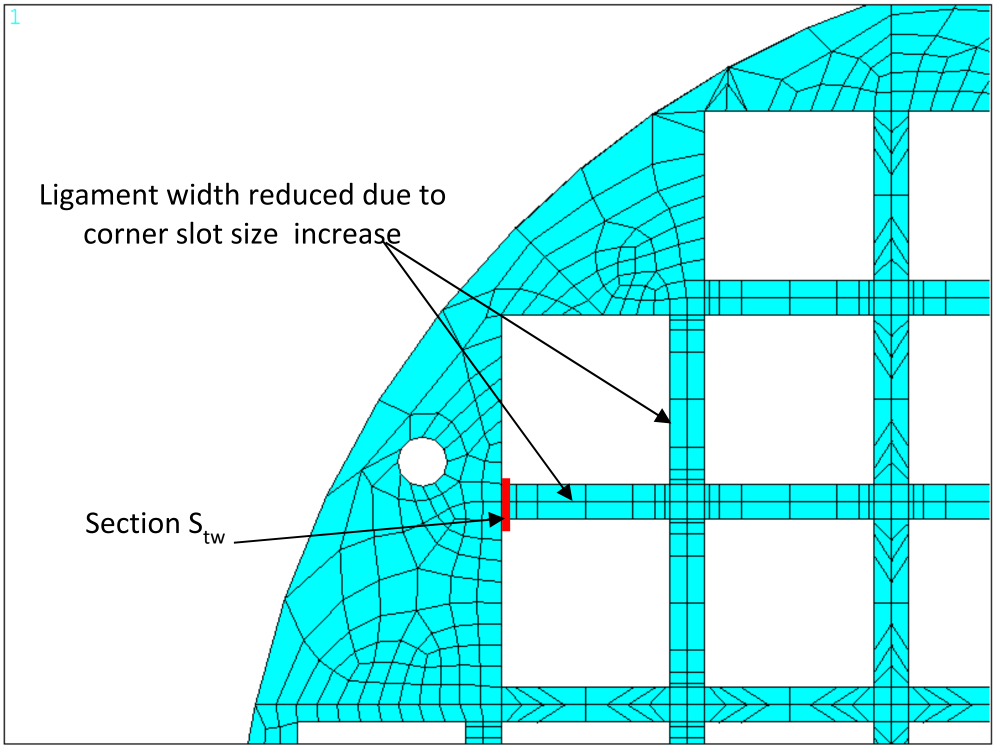
Support Disk Evaluation

The support disks have the identical design for both the BWR5 and BWR5 DF configurations. The governing load condition for the support disks is the side impact (in the in-plane direction of the disk). For the off-normal conditions, the analysis in Section 11.1.3 uses a maximum weight (per disk) of 1,095 lb, which is greater than that for the support disk for BWR5 DF basket (1,076 lb). For the accident condition of tip-over event, the analysis for BWR support disks in Section 11.2.12 uses a load of 32.6 kips per disk (30g), which is greater than the load of 32.4 kips per disk (30g) for the support disk for BWR5 DF basket. Therefore, the evaluation of support disks for normal, off-normal and accident conditions in Sections 3.4.4.1, 11.1.3, 11.2.4 and 11.2.12 are bounding and no further evaluation is required.

Basket Weldments Evaluation

Top Weldment

The top weldment for the BWR DF configuration is based on the top weldment for BWR configuration with the opening of the four corner slots increased from 5.90 inches × 5.90 inches to 6.428 inches × 6.428 inches. The governing load condition for the top weldment is the 60-g end impact for 24-inch cask drop accident. With the increased corner slot size, the width of ligaments adjacent to the slot is reduced and the stresses in the ligaments need to be evaluated. Based on the stress results from the analysis in Section 11.2.4, the maximum sectional stress intensity for the ligaments of corner slots for the BWR basket top weldment is 12.1 ksi (see Section S_{tw} in the following figure for location).



The sectional stress intensity at section S_{tw} of the ligament for the top weldment of BWR DF configuration is determined to be 17.0 ksi (=12.1×1.178/0.839), using the ratio of the ligament widths of both configurations. Since the maximum stress intensity of the ligaments for the corner slots of the top weldment for the BWR DF basket (17.0 ksi) is well below the maximum stress intensity (34.1 ksi) of the top weldment for the BWR basket for undamaged fuel as presented in Table 11.2.4-3, no further analysis is required.

Bottom Weldment

The bottom weldment for the BWR DF configuration is based on the bottom weldment for BWR configuration with the opening of the four corner slots increased from 5.630 inches × 5.630 inches to 6.428 inches × 6.428 inches. The governing load condition for the bottom weldment is the 60-g end impact for 24-inch cask drop accident. With the increased corner slot size, the width of ligaments adjacent to the slot is reduced and the stresses in the ligaments need to be evaluated. Based on the stress results from the analysis in Section 11.2.4, the maximum sectional stress intensity for the ligaments of corner slots is 27.6 ksi. Using the same method as the top weldment evaluation, the sectional stress intensity for the affected sections of corner slot ligaments is determined to be 39.8 ksi. Since the maximum stress intensity of the ligaments for the corner slots of the bottom weldment for the BWR DF basket (39.8 ksi) is well below the maximum stress

intensity (51.9 ksi) of the bottom weldment for the BWR basket for undamaged fuel as presented in Table 11.2.4-3, no further analysis is required.

Note that the bottom weldment for BWR5 DF configuration is subjected to a total weight (1g) of 4,359 lb, which is less than the weight (1g) applied to the bottom weldment for BWR5 configuration (4,651 lb), since the DFCs at corner slots are not supported by the bottom weldment for the BWR DF basket. Therefore, the calculated sectional stress at Section S_{bw} above for 60g end impact is conservative.

3.9.1.4 Concrete Cask

Thermal

The thermal load imposed on the VCC is not changed for BWR5 DF. The VCC thermal stress analyses for normal and accident conditions (Section 3.4.4.2 and Section 11.2.7) remain bounding. Therefore, no further thermal evaluation is required.

Dead Loads

The dead weight used in the analysis in Section 3.4.4.2.1 is 250,000 lb, which is greater than the dead weight of the loaded VCC for BWR5 DF configuration. Therefore, the analysis in Section 3.4.4.2.1 is bounding for the VCC dead load evaluation.

Live Loads

Transfer Cask Load on VCC (Live Load)

The transfer cask weight (fully loaded and including the weight of the yoke) that is used in the evaluation in Section 3.4.4.2.2 is 215,000 lb, which is greater than that containing BWR5 DF canister. Therefore, the analysis in Section 3.4.4.2.2 is bounding for the transfer cask live load on the VCC.

Snow/Ice Loading on VCC (Live Load)

The external pressure applied to the top of the VCC remains the same for BWR5 DF configuration. Therefore, the evaluation in Section 3.4.4.2.2 remains bounding for the snow/ice live load on the VCC.

Tornado and Missile Impact Load

The UMS storage system is evaluated for tornado wind loading and missile impact loading as documented in Section 11.2.11. The evaluation confirms that the cask is stable with regard to tornado wind loading in conjunction with impact form high energy missile. The maximum concrete shell stresses under maximum tornado wind loading are well below the allowables. The maximum weight of a loaded cask for the BWR5 DF configuration (324 kip) is similar to that of the BWR5 configuration already analyzed (323.9 kip), and the C.G. is the same for both configurations (115.7 inches). Therefore, the evaluation for tornado wind loading and tornado missile impact as documented in Section 11.2.11 is applicable to the cask loaded with BWR5 DF. No further evaluation is required.

Flood Accident Analysis

The weight of the loaded cask for BWR5 DF configuration is slightly larger than that of the loaded cask for BWR5 configuration. The flood analysis in Section 11.2.9 uses conservative (lighter) weight of 314,000 lb for the evaluation. Since heavier weight would increase the cask's resistance to overturning and sliding, the stability of the concrete cask against overturning and sliding during a design basis flood accident and the resulting stresses for the cask for BWR DF configuration are bounded by the analysis documented in Section 11.2.9. No further analysis is required.

Earthquake Analysis

The C.G. of the cask loaded with BWR5 DF is less than the C.G. the loaded cask evaluated in Section 11.2.8 for earthquake accident conditions, which shows that the cask will not tip-over nor slide during an earthquake with 0.26g ground acceleration. Therefore, the earthquake analysis in Section 11.2.8 is bounding and no further analysis is required.

Concrete Cask Bottom Weldment Pedestal 24-inch Drop Evaluation

The concrete cask bottom weldment pedestal that is already analyzed for a 24-inch drop accident condition in Section 11.2.4 used a loaded TSC weight of 76,000 lb, which is greater than the weight of the loaded BWR5 DF TSC. Therefore, the 24-inch drop analysis in Section 11.2.4 is bounding and no further evaluation is required.

Concrete Cask Tip-Over Analysis

Tip-over of the concrete cask is a nonmechanistic, hypothetical accident condition that presents a bounding case for evaluation. Existing postulated design basis accidents do not result in the tip-

over of the concrete cask. Functionally, the concrete cask does not suffer significant adverse consequences due to this event. The concrete cask, TSC, and basket maintain design basis shielding, geometry control of contents, and contents confinement performance requirements. A detailed evaluation for the hypothetical tip-over event for the UMS casks is presented Section 11.2.12. The maximum weight of a loaded cask for the BWR5 DF configuration (324 kip) is similar to that of the BWR5 configuration already analyzed (323.9 kip), and the C.G. is the same for both configurations (115.7 inches). Therefore, the evaluation in Section 11.2.12 is applicable to the BWR5 DF configuration and no additional analysis is required.

3.9.2 Structural Evaluation for BWR Damaged Fuel Can

The BWR damaged fuel can (DFC, shown in Drawing 790-601) is provided to accommodate BWR damaged fuel (DF). The DFC fits within the corner slots of the BWR5 DF basket. The primary function of the BWR DFC is to confine the fuel material within the can to minimize the potential for dispersal of the fuel material into the canister cavity volume.

The DFC walls consist of 0.05-inch thick Type 304 stainless steel sheet (18 gauge) with a total length of 177.57 inches. The DFC weldment has a bottom plate that is 0.63 inches thick. Four holes in the bottom plate, filter-screened with Type 304 stainless steel wire screens (with 250 openings/inch × 250 openings/inch mesh, each supported by backing screens with wire mesh having 16 openings/inch × 16 openings/inch), permit water to be drained from the can during loading operations. Since the bottom surface of the DFC rests on the canister bottom plate, additional slots are machined in the DFC (extending from the holes to the side of the bottom assembly) to allow the water to be drained from the can. At the top of the DFC, the top flange extends beyond each of the four walls to allow the use of a handling tool to lift the can and contents.

The structural evaluation of the BWR DFC determines that it is structurally adequate for all conditions of handling and storage, including accident conditions. In normal operation, the can is in a vertical position. The weight of the DFC contents is transferred through the bottom plate of the can to the canister bottom plate, which is the identical load path for undamaged fuel. The only normal operation loading in the vertical direction is the combined weights of the DFC tube body, top flange, and lid assembly. The lifting of the can with its contents is also in the vertical direction.

Classical hand calculations are used to qualify the stresses in the BWR DFC. Calculated stresses are compared to allowable stresses in accordance with ASME Section III, Subsection NG. Bounding accelerations of 60g (end impact) and 30g (side impact). The DFC is also evaluated for

normal handling loads including a 10% dynamic load factor. The DFC lifting structure is designed with a load factor of 6 on the basis of material yield stress and 10 on the basis of ultimate stress.

A conservative bounding temperature of 600°F is used in the evaluation of the DFC for storage conditions and for the lifting analysis. The ASME Code, Section III, Subsection NG allowable stresses used for stress analysis are as follows:

Property	600°F
S_u	63.3 ksi
S_y	18.6 ksi
S_m	16.7 ksi
E	25.2×10^3 ksi

The DFC is evaluated for dead weight and handling loads for normal conditions of storage. Since the can is not restrained, it is free to expand. Therefore, the thermal stress is considered to be negligible.

3.9.2.1 DFC Dead Weight Evaluation

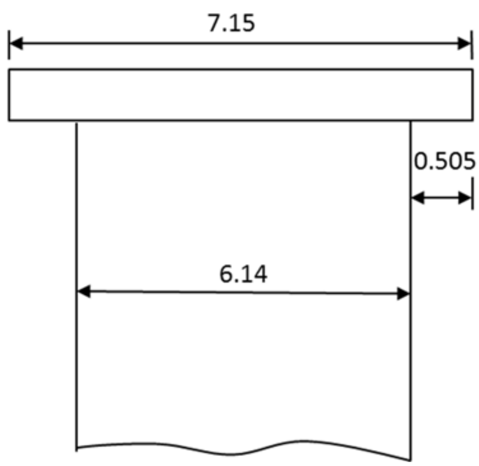
The total weight of the BWR damaged fuel can (DFC) is 113 pounds. The maximum compressive stress acting in the tube of the DFC is due to its own weight in addition to that of the top flange and lid assembly. However, the total weight of the DFC is conservatively used for the evaluation. A 10% dynamic load factor is applied to the DFC weight for an applied load of 124.3 pounds to account for inertial loads during handling. Based on the minimum cross-sectional area of $(6.14)^2 - (6.05)^2 = 1.097$ in^2, the margin of safety at 600°F is:

$$\begin{aligned} \text{M.S.} &= 16{,}700/(124.3/1.097) - 1 \\ &= +\text{ Large} \end{aligned}$$

3.9.2.2 DFC Lifting/Handling Evaluation

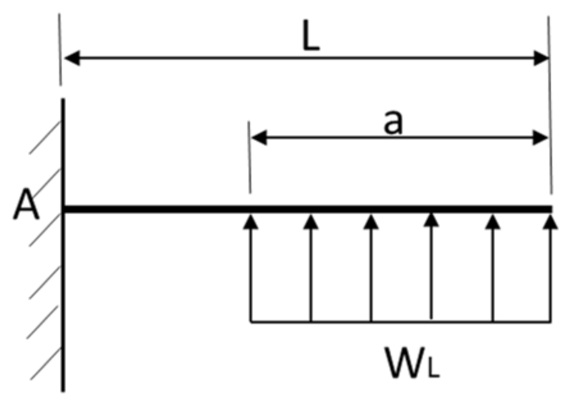
The top flange is subjected to bending and shear stresses due to its interaction with the lifting tool during handling operations. The lifting tool supports the four sides of the top flange while lifting the DFC. For the lift evaluation, a total handling load of 815 lb (the weight of the fuel assembly, 702 lb, plus the DFC self-weight, 113 lb) is used with a 10% dynamic load factor (DLF). The following sketch shows the outer dimensions (inches) of the top flange relative to that of the tube.

The flange lip extends past the outer dimensions of the tube (on all four sides of the flange) by 0.505 inch.



(Unit: inch)

The lifting tool has four fingers that contact the bottom of the DFC flange during lift. The bearing area dimensions of each of the four lifting tool fingers on the bottom surface of the DFC flange is 1.25 inches wide × 0.3 inch deep. The top flange stress is determined by analyzing the flange as a cantilevered beam with cross-sectional dimensions of 0.5 inch tall × 1.25 inches wide × 0.505 inch deep. The depth of the finger bearing area is 0.3 inch from the free end of the cantilevered beam. The following sketch represents the cantilevered flange loading configuration.



where:

L = 0.505 in

a = 0.3 in

W_L = (815/4)(1.1)/0.3 = 747 lb/in

The reaction and moment at the fixed end of the beam (at Point A) are calculated as follows.

The reaction at the left end of the beam (R_A) is:

$$R_A = W_L \times a = 224 \text{ lb}$$

The moment at the left end of the beam (M_A) is:

$$M_A = W_L \times \left[aL - \frac{a^2}{2} \right] = 747 \times \left[0.3 \times 0.505 - \frac{0.3^2}{2} \right] = 80 \text{ in-lb}$$

The maximum bending stress (σ_b) in the side plate is:

$$\sigma_b = \frac{M_A c}{I} = \frac{80 \times 0.25}{0.013} = 1538 \text{ psi}$$

where:

I = $(1.25)(0.5)^3 / 12 = 0.013 \text{ in}^4$

c = $0.5 / 2 = 0.25$ in

The maximum shear stress (τ) occurs at the right end of the slot:

$$\tau = \frac{R_A}{A} = \frac{224}{1.25(0.5)} = 359 \text{ psi}$$

The von Mises stress (σ_{max}) is

$$\sigma_{max} = \sqrt{\sigma_b^2 + 3\tau^2} = \sqrt{1538^2 + 3(359)^2} = 1659 \text{ psi}$$

The factors of safety on material yield strength (FS_y) and ultimate strength (FS_u) of Type 304 Stainless Steel at 600°F are:

$$FS_y = \frac{S_y}{\sigma_{max}} = \frac{18,600}{1659} = 11.2 > 6$$

$$FS_u = \frac{S_u}{\sigma_{\max}} = \frac{63,300}{1659} = 38.2 > 10$$

DFC tube body welds evaluation

The welds joining the tube body to the flange and bottom assembly are full penetration welds (ASME, Section III, Subsection NG, Type III, paragraph NG-3352.3). Per Subsection NG, Table NG-3352-1, the weld quality factor (n) for a Type III weld with visual surface inspection is 0.5.

The weld stress (σ_w) is:

$$\sigma_w = \frac{1.1(P)}{A} = \frac{1.1(809)}{1.097} = 811 \text{ psi}$$

where:

P = the combined weight of the tube body, the neutron absorber weight, bottom assembly, the cladding weight, and can contents;
62 + 26 +7 + 12 + 702 = 809 lb.

A = cross sectional area of thinner member joined = 1.097 in^2

The factors of safety on material yield strength (FS_y) and ultimate strength (FS_u) of Type 304 Stainless Steel at 600°F are:

$$FS = \frac{n \cdot S_y}{\sigma_w} = \frac{0.5(18,600)}{811} = 11.5 > 6$$

$$FS = \frac{n \cdot S_u}{\sigma_w} = \frac{0.5(63,300)}{811} = 39.0 > 10$$

Therefore, the criteria of NUREG-0612 and ANSI N14.6 for the lifting of non-redundant systems are satisfied.

DFC tube body tensile stress evaluation

The tube body will be subjected to tensile loads during lifting operations. The load (P) includes the can contents (702 lb design weight), the tube body weight (62 lb) , the neutron absorber weight

(26 lb), the cladding weight (12 lb) and the bottom assembly weight (7 lb) for a total of 809 lb. A load of 809 lb with a 10% dynamic load factor is used for the analysis.

The tensile stress (σ_t) is then:

$$\sigma_t = \frac{1.1P}{A} = \frac{1.1(809\ lb)}{1.097\ in.^2} = 811 \text{ psi}$$

where:

$A = 6.14^2 - 6.05^2 = 1.097 \text{ in}^2$

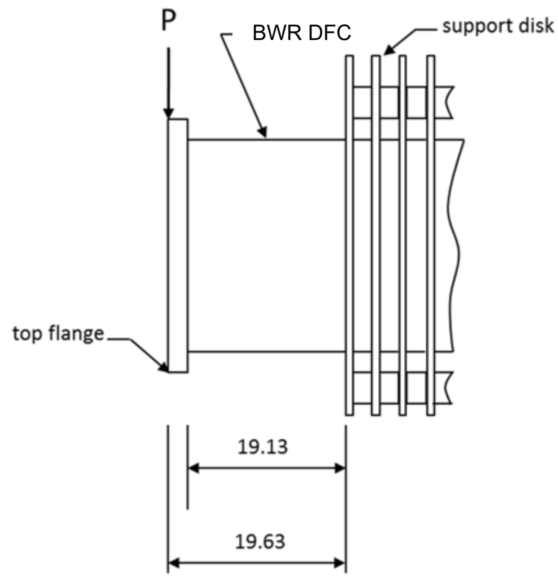
The factor of safety (FS) based on allowable for primary membrane (tensile) stress for Type 304 Stainless Steel at 600°F is:

$FS = 1.0\ Sm / \sigma_t = 16{,}700 / 811 = 20.1 > 1$

3.9.2.3 BWR Damaged Fuel Can Tube Body−Side Impact

The governing side impact condition corresponding to the hypothetical cask tip-over accident is evaluated in this section. The majority of the BWR damaged fuel can (DFC) tube body is contained in the basket assembly. Because both the tube body and the support disks of the basket have square cross sections, they will be in full contact (for 158.83 inches longitudinally) during the side impact and no significant bending stress will be introduced into the support disk. The last 19.63 inches (tube body and top flange) will be unsupported past the support disk in the side impact configuration.

The tube body will be evaluated as a cantilevered beam with the combined weight (P) of the overhanging tube body, top flange, and lid assembly multiplied by the appropriate acceleration factor and, conservatively, concentrated at the top end of the top flange.



(Unit: inch)

The maximum bending stress (f_b) is determined as follows.

$$f_b = \frac{M_{max} c}{I} = \frac{11{,}778(3.07)}{6.793} = 5{,}322 \ \ psi$$

where:

M_{max}	=	P × a × L = 20(30)(19.63) = 11,778 lb·in
a	=	30g
P	=	20 lb; (lid plate, 2 lb + lid wall, 2 lb + top flange, 2 lb + tube body (62 lb × 19.13/177.57 in/in = 6.68 lb) + cladding (12 lb × 19.13/177.1 in/in = 1.3 lb) + neutron absorber (26 lb × 19.13/176.3 in/in = 2.82 lb), which is equal to 16.8 lb; use 20 lb bounding)
L	=	19.63 in (total overhang length of the tube body and top flange)
c	=	6.14/2 = 3.07 in
I	=	$\frac{bh^3 - b_i h_i^3}{12} = \frac{6.14^4 - 6.05^4}{12} = 6.793 \ in^4$

The shear stress (τ) is:

$$\tau = \frac{Pg}{A} = \frac{20(30)}{1.097} = 547 \ \ psi$$

where:

$$A = 6.14^2 - 6.05^2 = 1.097 \text{ in}^2$$

$$\sigma_1, \sigma_2 = \frac{1}{2}\left(f_b \pm \sqrt{f_b^2 + 4\tau^2}\right) = \frac{1}{2}\left(5{,}322 \pm \sqrt{5{,}322^2 + 4(547)^2}\right) = 5{,}378.\ psi\ and\ -56\ psi$$

The stress intensity (σ_{max}) = $|\sigma_1 - \sigma_2|$ = 5,434 psi

The margin of safety (MS) is:

$$MS = \frac{1.0\ S_u}{\sigma_{\max}} - 1 = \frac{1.0(63{,}300)}{5{,}434} - 1 = +10.6$$

3.9.2.4 BWR Damaged Fuel Can Tube Body−End Impact

The DFC is evaluated for a bottom end impaction corresponding to the cask 24-inch drop accident in this section. For the bottom end drop, the top flange, the lid assembly (Lid plate + Lid wall), neutron absorber, cladding and the tube body act against the bottom assembly (Bottom plate weldment + Collar + Bottom lid). The total weight is conservatively used for tube body compression.

DFC tube body compressive stress evaluation

For the end impact accident conditions, the tube is evaluated for a 60g acceleration. The compressive load (P) on the tube is the combined weight of the lid assembly, top flange, and tube body times 60g:

The compressive load (P) is:

P = 113lb × 60g = 6,780 lb;

The compressive stress (S_c) in the tube body is:

$$S_c = \frac{P}{A} = \frac{6{,}780\ lb}{1.097\ in.^2} = 6{,}180\ \ psi$$

The margin of safety (MS) is then:

$$MS = \frac{0.7 S_u}{S_c} - 1 = \frac{0.7(63{,}300)\ psi}{6{,}180\ \ psi} - 1 = +6.2 \text{ for accident conditions at 600°F.}$$

DFC tube body buckling evaluation

The tube is evaluated, using the Euler formula, to determine the critical buckling load (P_{cr}):

$$P_{cr} = \frac{\pi^2 EI}{L_e^2} = \frac{\pi^2 \left(25.2 \times 10^6\right)(6.793)}{[2(177.57)]^2} = 13{,}396 \text{ lb}$$

where:

$E = 25.2 \times 10^6$ psi

$I = \dfrac{6.14^4 - 6.05^4}{12} = 6.793 in.^4$

L_e = 2L (worst case condition)

L = tube body length (177.57 in)

Because the maximum compressive load (6,780 lb under the accident condition) is much less than the worst-case critical buckling load (13,396 lb) and the support disks also provide lateral constrains to the body tube, the tube has adequate resistance to buckling.

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4.4 Thermal Evaluation for Normal Conditions of Storage

The finite element method is used to evaluate the thermal performance of the Universal Storage System for normal conditions of storage. The general-purpose finite element analysis program ANSYS is used to perform the finite element evaluations.

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4.4.1 Thermal Models

Finite element models are utilized for the thermal evaluation of the Universal Storage System, as shown below. These models are used separately to evaluate the system for the storage of PWR or BWR fuel.

1. Two-Dimensional Axisymmetric Air Flow and Concrete Cask Models
2. Three-Dimensional Canister Models
3. Three-Dimensional Transfer Cask and Canister Models
4. Three-Dimensional Periodic Canister Internal Models
5. Two-Dimensional Fuel Models
6. Two-Dimensional Fuel Tube Models
7. Two-Dimensional Forced Air Flow Model for Transfer Cask Cooling

The two-dimensional axisymmetric air flow and concrete cask model includes the concrete cask, air in the air inlets, annulus and the air outlets, the canister and the canister internals, which are modeled as homogeneous regions with effective thermal conductivities. The effective thermal conductivities for the canister internals in the radial direction are determined using the three-dimensional periodic canister internal models. The effective conductivities in the canister axial direction are calculated using classical methods. The two-dimensional axisymmetric air flow and concrete cask model is used to perform computational fluid dynamic analyses to determine the mass flow rate, velocity and temperature of the air flow, as well as the temperature distribution of the concrete, concrete cask steel liner and the canister. Two models are generated for the evaluations of the PWR and the BWR systems, respectively. These models are essentially identical, but have slight differences in dimensions and the effective properties of the canister internals.

The three-dimensional canister model comprises the fuel assemblies, fuel tubes, stainless steel or carbon steel support disks, aluminum heat transfer disks, top and bottom weldments, the canister shell, lids and bottom plate. The canister model is employed to evaluate the temperature distribution of the fuel cladding and basket components. The fuel assemblies and the fuel tubes in the three-dimensional canister model are modeled using effective conductivities. The effective conductivities for the fuel assemblies are determined using the two-dimensional fuel models. The effective conductivities for the fuel tubes are determined using the two-dimensional fuel tube

models. Two three-dimensional canister models are generated for the PWR and BWR canisters, respectively.

The three-dimensional transfer cask model includes the transfer cask and the canister with its internals. This model is used to perform transient and steady state analyses for the transfer condition, starting from removing the transfer cask/canister from the spent fuel pool, vacuum drying and finally back-filling the canister with helium. Separate transfer cask models are required for PWR and BWR systems.

The three-dimensional canister internal model consists of a periodic section of the canister internals. For the PWR canister, the model contains one support disk with two heat transfer disks (half thickness) on its top and bottom, fuel assemblies, fuel tubes and the media in the canister. For the BWR canister, two models are required. The first model, for the central region of the BWR canister, contains one heat transfer disk with two support disks (half thickness) on its top and bottom, fuel assemblies, fuel tubes and the media in the canister. The other model, for the region without heat transfer disks, contains two support disks (half thickness), fuel assemblies, fuel tubes and the media in the canister. The purpose of the three-dimensional periodic canister internal model is to determine the effective thermal conductivity of the canister internals in the canister radial direction. The effective conductivities are used in the two-dimensional axisymmetric air flow and concrete cask models. The media in the canister is considered to be helium. The fuel assemblies and fuel tubes in this model are modeled as homogeneous regions with effective thermal properties, which are determined by the two-dimensional fuel models and the two-dimensional fuel tube models.

The two-dimensional fuel model includes the fuel pellets, cladding and the media occupying the space between fuel rods. The media is considered to be helium for storage conditions and water, vacuum, helium or saturated steam for transfer conditions. The model is used to determine the effective thermal conductivities of the fuel assembly. In order to account for various types of fuel assemblies, a total of seven fuel models are generated: Four models for the 14×14, 15×15, 16×16 and 17×17 PWR fuel assemblies and four models for the 7×7, 8×8, 9×9 and 10×10 BWR fuel assemblies. The effective properties are used in the three-dimensional canister models, the three-dimensional periodic canister internal models and the three-dimensional transfer cask and canister model.

F = the gray body shape factor for the surfaces
T_i = temperature of the i th node
T_j = temperature of the j th node

The total heat transfer can be expressed as the sum of the radiation and the conduction processes:

$$Q_t = q_r + q_k$$

where q_r is specified above for the radiation heat transfer and q_k, which is the heat transfer by conduction is expressed as:

$$q_k = \frac{KA}{g}(T_i - T_j)$$

where:

T_i = temperature of the i th node
T_j = temperature of the j th node
g = gap distance (between the two surfaces defined by node i and node j)
K = conductivity of the gas in the gap
A = area of gap surface

By combining the two expressions (for q_k and q_r) and factoring out the term $A(T_i - T_j)/g$,

$$Q_t = [g\sigma\varepsilon F(T_i^2 + T_j^2)(T_i+T_j) + K][A(T_i - T_j)/g]$$

or

$$Q_t = K_{eff}A(T_i - T_j)/g$$

where:

$$K_{eff} = g\sigma\varepsilon F(T_i^2 + T_j^2)(T_i+T_j) + K$$

The material conductivity used in the analysis for the elements comprising the gap includes the heat transfer by both conduction and radiation.

Effective emissivities (ε) are used for all radiation calculations, based on the formula below [17]. The view factor is taken to be unity.

$\varepsilon = 1/ (1/\varepsilon_1 + 1/\varepsilon_2 - 1)$ where ε_1 & ε_2 are the emissivities of two parallel plates

Radiation between the exterior surfaces of the fuel tubes is conservatively ignored in the model.

Volumetric heat generation (Btu/hr-in^3) is applied to the active fuel region based on design heat load, active fuel length of 144 inches and an axial power distribution as shown in Figures 4.4.1.1-3 and 4.4.1.1-4 for PWR and BWR fuel, respectively.

Note that the three-dimensional BWR canister model is also used for the thermal evaluation of the BWR DF canister containing up to four damaged fuel cans (DFCs) at the corner slots of the BWR DF fuel basket. Since the BWR DF basket is essentially identical to the BWR basket with slightly larger opening at the four corner slots in the basket top and bottom weldments (support disk design for both baskets is identical), the three-dimensional BWR canister model is applicable for the evaluation for BWR DF configuration. The evaluation considers 100% failure of the fuel rods and claddings in the DFCs with two Cases of debris compaction levels: Case 1: 100% compaction of the fuel debris resulting in a 45-inch debris level in the bottom of each fuel can (see Figure 4.4.1.2-5), and Case 2: 50% compaction of the fuel debris resulting in a 90-inch debris level in the bottom of each fuel can. The decay heat for a single fuel assembly (0.411 kW) is concentrated in the debris region with the remainder of the active fuel region having no heat generation rate applied. To ensure the analysis is bounding, the debris region is located at the lower part of the active fuel region in lieu of the bottom of the damaged fuel can. This location is closer to the center of the basket where the maximum fuel cladding temperature occurs. The effective thermal conductivities for the design basis BWR fuel assembly (Section 4.4.1.5) are used for the debris region. This is conservative since the debris (100% failed rods) is expected to have higher density (better conduction) and more surface area (better radiation) than an undamaged fuel assembly. In addition, the thermal conductivity of helium is used for the remainder of the active fuel length.

Figure 4.4.1.2-5 Active Fuel Region in the Three-dimensional BWR Canister Model for DF Configuration

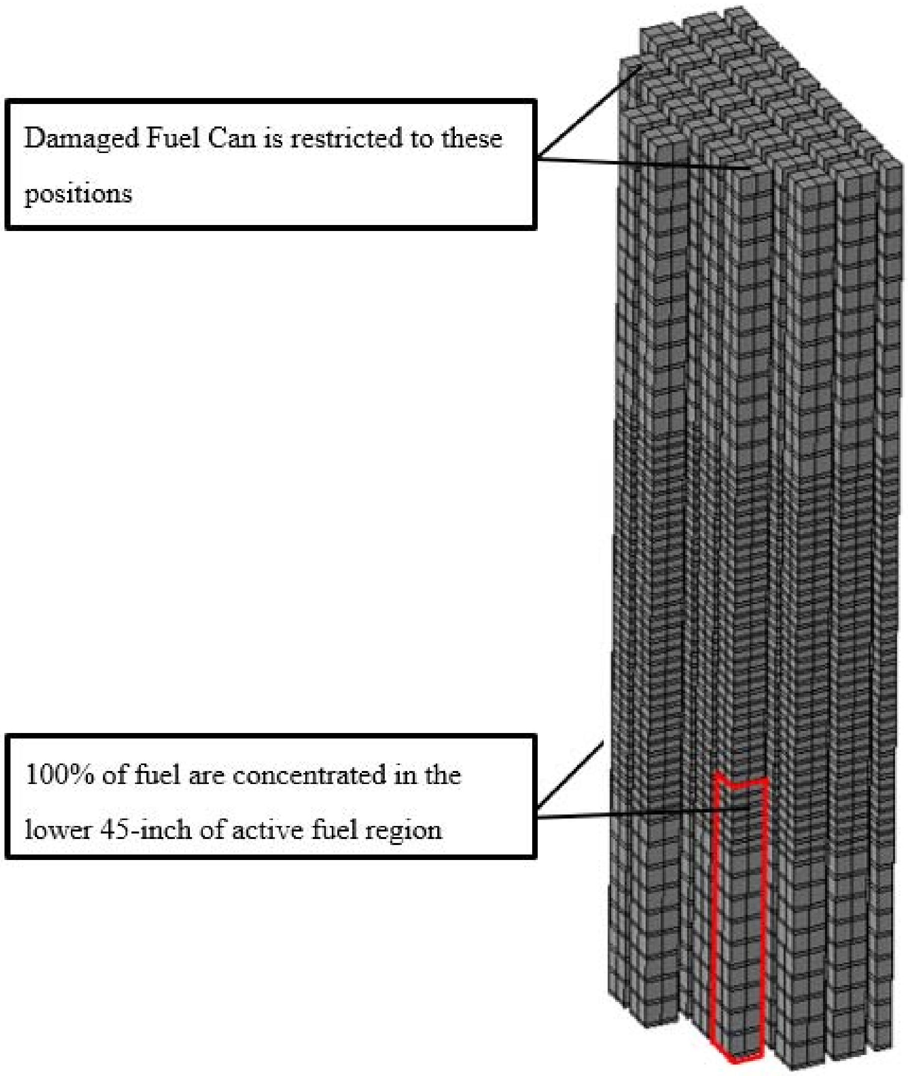


Table 4.4.1.2-1 Effective Thermal Conductivities for PWR Fuel Assemblies

Conductivity (Btu/hr-in-°F)	**Temperature (°F)**			
	220	**414**	**611**	**812**
Kxx	0.020	0.027	0.037	0.049
Kyy	0.020	0.027	0.037	0.049
Kzz	0.171	0.154	0.145	0.142

Note: x, y and z are in the coordinate system shown in Figure 4.4.1.2-1.

Table 4.4.1.2-2 Effective Thermal Conductivities for BWR Fuel Assemblies

Conductivity (Btu/hr-in-°F)	**Temperature (°F)**			
	186	**389**	**593**	**799**
Kxx	0.021	0.029	0.041	0.056
Kyy	0.021	0.029	0.041	0.056
Kzz	0.181	0.165	0.157	0.156

Note: x, y and z are in the coordinate system shown in Figure 4.4.1.2-3.

4.4.1.5 Two-Dimensional Fuel Models

The effective conductivity of the fuel is determined by the two-dimensional finite element model of the fuel assembly. The effective conductivity is used in the three-dimensional canister models (Section 4.4.1.2) and the three-dimensional periodic canister internal models (Section 4.4.1.4). A total of eight models are required: four models for the 14×14, 15×15, 16×16 and 17×17 PWR fuels and four models for the 7×7, 8×8, 9×9 and 10×10 BWR fuels. Because of similarity, only the figure for the PWR 17×17 model is shown in this section (Figure 4.4.1.5-1). All models contain a full cross-section of an assembly to accommodate the radiation elements.

The model includes the fuel pellets, cladding, media between fuel rods, media between the fuel rods and the inner surface of the fuel tube (PWR) or fuel channel (BWR), and helium at the gap between the fuel pellets and cladding. Four types of media are considered: helium, water, a vacuum and saturated steam. Modes of heat transfer modeled include conduction and radiation between individual fuel rods for the steady-state condition. ANSYS PLANE55 conduction elements and MATRIX50 radiation elements are used to model conduction and radiation. Radiation elements are defined between fuel rods and from rods to the wall. Radiation at the gap between the pellets and the cladding is conservatively ignored.

The effective conductivity for the fuel is determined by using an equation defined in a Sandia National Laboratory Report [30]. The equation is used to determine the maximum temperature of a square cross-section of an isotropic homogeneous fuel with a uniform volumetric heat generation. At the boundary of the square cross-section, the temperature is constrained to be uniform. The expression for the temperature at the center of the fuel is given by:

$$T_c = T_e + 0.29468\,(Qa^2 / K_{eff})$$

where: T_c = the temperature at the center of the fuel (°F)

T_e = the temperature applied to the exterior of the fuel (°F)

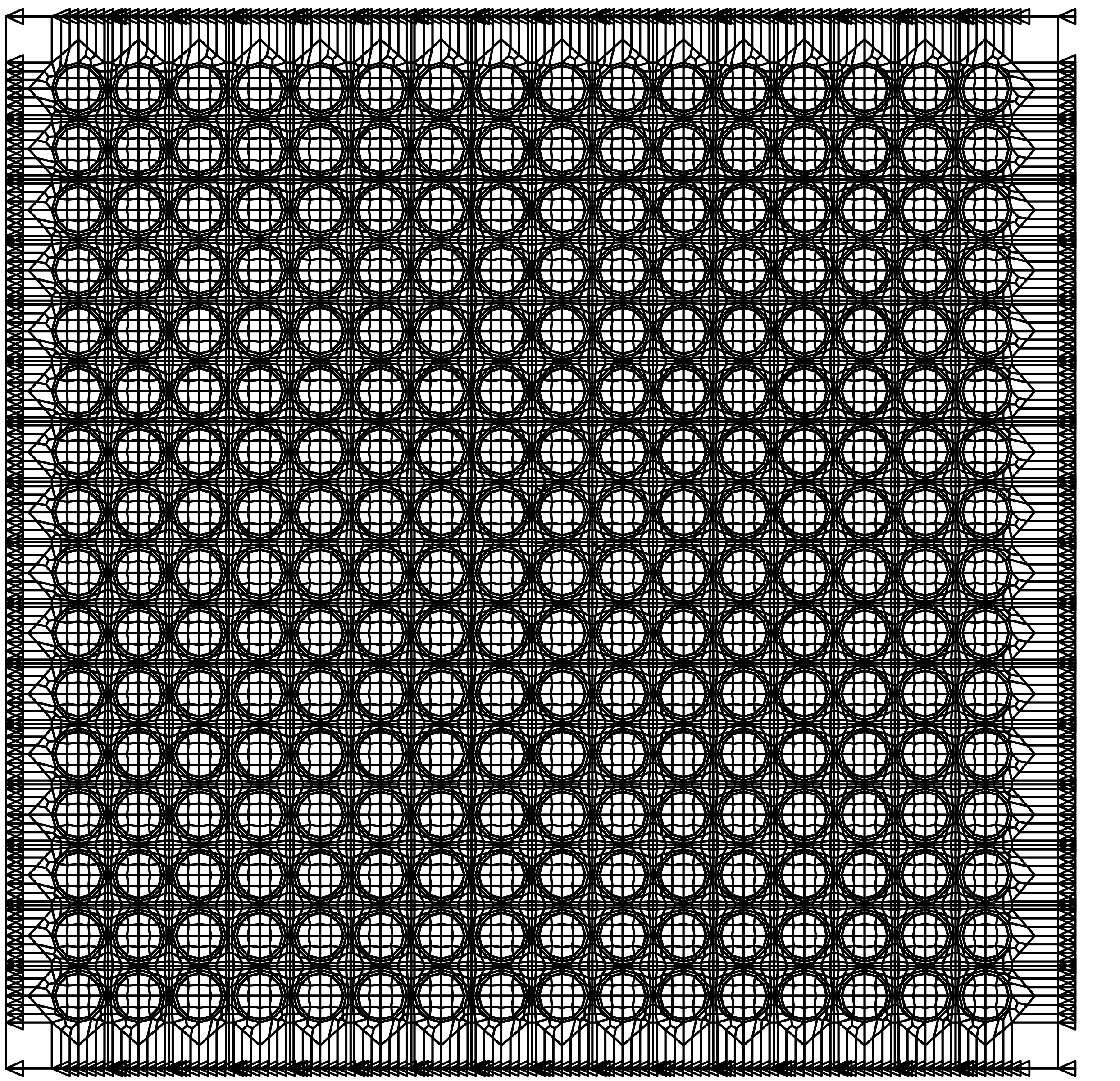
Q = volumetric heat generation rate (Btu/hr-in^3)

a = half length of the square cross-section of the fuel (inch)

K_{eff} = effective thermal conductivity for the isotropic homogeneous fuel material (Btu/hr-in-°F)

Volumetric heat generation (Btu/hr-in^3) based on the design heat load is applied to the pellets. The effective conductivity is determined based on the heat generated and the temperature difference from the center of the model to the edge of the model. Temperature-dependent effective properties are established by performing multiple analyses using different boundary temperatures. The effective conductivity in the axial direction of the fuel assembly is calculated on the basis of the material area ratio.

Figure 4.4.1.5-1 Two-Dimensional PWR (17×17) Fuel Model



4.4.1.6 Two-Dimensional Fuel Tube Models

The two-dimensional fuel tube model is used to calculate the effective conductivities of the fuel tube wall and BORAL plate. These effective conductivities are used in the three-dimensional canister models (Section 4.4.1.2), the three-dimensional transfer cask and canister models (Section 4.4.1.3) and the three-dimensional periodic canister internal models (Section 4.4.1.4). A total of three models is required: one PWR model and two BWR models (one with the neutron absorber plate, one without the neutron absorber plate), corresponding to the enveloping configurations of the 7×7, 8×8, 9×9 and 10×10 BWR fuels.

In the neutron absorber evaluation, the configuration shown in the fuel tube models in Figures 4.4.1.6-1 and 4.4.1.6-2 (for PWR and BWR fuel, respectively) incorporates the BORAL core matrix sandwiched between two layers of aluminum cladding. The thermal properties of BORAL are presented in Table 4.2-10.

As shown in Figure 4.4.1.6-1, the PWR model includes the fuel tube, the BORAL plate (including the core matrix sandwiched by aluminum cladding), the stainless steel cladding and the gap between the stainless steel cladding and the support disk or heat transfer disk. Four types of media are considered in the gaps: helium, water, a vacuum and saturated steam.

ANSYS PLANE55 conduction elements and LINK31 radiation elements are used to construct the model. The model consists of six layers of conduction elements and two radiation elements (radiation elements are not used for water condition) that are defined at the gaps (two for each gap). The thickness of the model (x-direction) is the distance measured from the outside face of the fuel assembly to the inside face of the slot in the support disk (assuming the fuel tube is centered in the hole in the disk). The gap size between the neutron absorber plate and the stainless steel cladding is 0.003 inch. The height of the model is defined as equal to the width of the model.

4.4.3 Maximum Temperatures for PWR and BWR Fuel

Temperature distribution and maximum component temperatures for the Universal Storage System under the normal conditions of storage and transfer, based on the use of the transfer cask, are provided in this section. Components of the Universal Storage System containing PWR and BWR fuels are addressed separately. Temperature distributions for the evaluated off-normal and accident conditions are presented in Sections 11.1 and 11.2.

Figure 4.4.3-1 shows the temperature distribution of the Vertical Concrete Cask and the canister containing the PWR design basis fuel for the normal, long-term storage condition. The air flow pattern and air temperatures in the annulus between the PWR canister and the concrete cask liner for the normal condition of storage are shown in Figures 4.4.3-2 and 4.4.3-3, respectively. The temperature distribution in the concrete portion of the concrete cask for the PWR assembly is shown in Figure 4.4.3-4. The temperature distribution for the BWR design basis fuel is similar to that of the PWR fuel and is, therefore, not presented. Table 4.4.3-1 shows the maximum component temperatures for the normal condition of storage for the PWR design basis fuel. The maximum component temperatures for the normal condition of storage for the BWR design basis fuel are shown in Table 4.4.3-2.

As shown in Figure 4.4.3-3, a high-temperature gradient exists near the wall of the canister and the liner of the concrete cask, while the air in the center of the annulus exhibits a much lower temperature gradient, indicating significant boundary layer features of the air flow. The temperatures at the concrete cask steel liner surface are higher than the air temperature, which indicates that salient radiation heat transfer occurs across the annulus. As shown in Figure 4.4.3-4, the local temperature in the concrete, directly affected by the radiation heat transfer across the annulus, can reach 186°F (less than the 200°F allowable temperature). The bulk temperature in the concrete, as determined using volume average of the temperatures in the concrete region, is 135°F, less than the allowable value of 150°F.

Under typical operations, the transient history of maximum component temperatures for the transfer conditions (canister, inside the transfer cask, containing water for 20 hours for PWR and 17 hours for BWR, vacuum for 27 hours for PWR and 25 hours for BWR, and in helium for 20 hours for PWR and 16 hours for BWR) is shown in Figures 4.4.3-5 and 4.4.3-6 for PWR and BWR fuels, respectively. The maximum component temperatures for the transfer conditions (vacuum and helium conditions) are shown in Tables 4.4.3-3 and 4.4.3-4, for PWR and BWR fuels, respectively. Note that the media inside the canister is considered to be saturated steam during the first four hours of the vacuum condition.

The maximum calculated water temperature is 203°F for both the PWR and BWR fuels at the end of 17 hours based on an initial water temperature of 100°F.

Note that a steady state analysis is performed for the normal condition of storage using the three-dimensional BWR canister model described in Section 4.4.1.2 to evaluate the maximum fuel and basket component temperatures for the BWR canister loaded with four DFCs at basket corner locations. 100% failure of the fuels in the DFCs is considered with two cases of compaction levels (100% and 50%). The analysis results are shown below:

Description	Maximum Temperature (°F)			
	Fuel Cladding	**Damaged Fuel**	**Support Disk**	**Heat Transfer Disk**
DF Case 1 (100% Compaction)	634	533	606	604
DF Case 2 (50% Compaction)	637	518	608	606
Design Basis BWR Fuel (Undamaged)	642	N/A	614	612
Allowable	752	N/A	700	650

The maximum temperatures for the fuel cladding, damaged fuel, support disks, and heat transfer disks for the two analyzed cases are bounded by those for the design basis BWR fuel (Table 4.4.3-2) and remain within the allowable temperatures. Additionally, the temperatures used in the structural analyses of the fuel basket envelop those calculated for both DF cases. Therefore, the BWR DF configuration is bounded by the design basis BWR configuration for all normal, off-normal and accident conditions of storage and transfer operations.

4.4.3.1 Maximum Temperatures at Reduced Total Heat Loads

This section provides the evaluation of component temperatures for fuel heat loads less than the design basis heat load of 23 kW. Transient thermal analyses are performed for PWR fuel heat loads of 20, 17.6, 14, 11 and 8 kW to establish the allowable time limits for the vacuum condition in the canister as described in the Technical Specifications for the Limiting Conditions of Operation (LCO), LCOs 3.1.1 and 3.1.4. The time limits ensure that the allowable temperatures of the limiting components — the heat transfer disks and the fuel cladding — are not exceeded. A steady-state evaluation is also performed for all the heat load cases in the vacuum condition and all the heat load cases in the helium condition. If the steady-state temperature calculated is less than the limiting component allowable temperature, then the

allowable time duration in the vacuum or helium conditions is defined to be 600 hours (25 days) based on the 30 day time test for abnormal regimes as described in PNL-4835 [34].

The three-dimensional transfer cask and canister model for the PWR fuel configuration, described in Section 4.4.1.3, is used for the transient and steady-state thermal analysis for the reduced heat load cases. To obtain the bounding temperatures for all possible loading configurations, thermal analyses are performed for a total of 14 cases as tabulated in the following table. The basket locations are shown in Figure 4.4.3-7. Since the maximum temperature for the limiting components (fuel cladding and heat transfer disk) always occurs at the central region of the basket, hotter fuels (maximum allowable heat load for 5-year cooled fuel: 0.958 kW = 23 kW/24) are specified at the central basket locations. The bounding cases for each heat load condition are noted with an asterisk (*) in the tabulation which follows. Six cases (cases 3 through 8) are evaluated for the 17.6 kW heat load condition. The first four cases (cases 3 through 6) represent standard UMS® system fuel loadings. The remaining two cases (cases 7 and 8) account for the preferential loading configuration for Maine Yankee site-specific fuel (Section 4.5.1.2), with case 8 being the bounding case for the Maine Yankee fuel.

Canister Heat Load (kW)	Heat Load Case	Heat Load (kW) Evaluated in Each Basket Location (See Figure 4.4.3-7)					
		1	2	3	4	5	6
20	1	0.958	0.958	0.709	0.958	0.709	0.709
20*	2	0.958	0.958	0.958	0.958	0.958	0.210
17.6	3	0.958	0.958	0.509	0.958	0.509	0.509
17.6*	4	0.958	0.958	0.568	0.958	0.958	0.000
17.6	5	0.958	0.958	0.958	0.958	0.568	0.000
17.6	6	0.958	0.958	0.284	0.958	0.958	0.284
17.6	7	0.958	0.146	1.050	0.146	1.050	1.050
17.6	8	0.958	0.958	1.050	0.384	1.050	0.000
14	9	0.958	0.958	0.209	0.958	0.209	0.209
14*	10	0.958	0.958	0.000	0.958	0.626	0.000
11	11	0.958	0.896	0.000	0.896	0.000	0.000
11*	12	0.958	0.958	0.000	0.834	0.000	0.000
8	13	0.958	0.521	0.000	0.521	0.000	0.000
8*	14	0.958	0.958	0.000	0.084	0.000	0.000

The heat load (23 kW/24 Assemblies = 0.958 kW) at the four (4) central basket locations corresponds to the maximum allowable canister heat load for 5-year cooled fuel (Table 4.4.7-8). The non-uniform heat loads evaluated in this section bound the equivalent uniform heat loads, since they result in higher maximum temperatures of the fuel cladding and heat transfer disk.

Volumetric heat generation (Btu/hr-in^3) is applied to the active fuel region in each fuel assembly location of the model using the axial power distribution for PWR fuel (Figure 4.4.1.1-3) in the axial direction.

The thermal analysis results for the closure and transfer of a loaded PWR fuel canister in the transfer cask for the reduced heat load cases are shown in Table 4.4.3-5, with a comparison to the results for the design basis heat load case. The temperatures shown are the maximum temperatures for the limiting components (fuel cladding and heat transfer disk). The maximum temperatures of the fuel cladding and the heat transfer disk are less than the allowable temperatures (Table 4.1-3) of these components for the short-term conditions of vacuum drying and helium backfill. As shown in Table 4.4.3-5, a time limit of 600 hours is specified for moving the canister out of the transfer cask after the canister is filled with helium. This time limit is for the heat load cases where the maximum fuel cladding/heat transfer disk temperatures for the steady-state condition are below the short-term allowable temperatures. Based on the differences in the PWR and BWR models for the transient analysis of the "water period" (see Section 4.4.1.3), a different method is used in post-processing the analysis results to determine the maximum water temperature at the end of the "water period." For the PWR configuration, the maximum water temperature is considered to be the maximum temperature of the fuel region in the model. For the BWR configuration, the maximum water temperature is considered to be the volumetric average temperature of the calculated cladding temperatures in the active fuel region of the hottest fuel assembly. The maximum water temperature is below 212°F for all PWR and BWR cases evaluated.

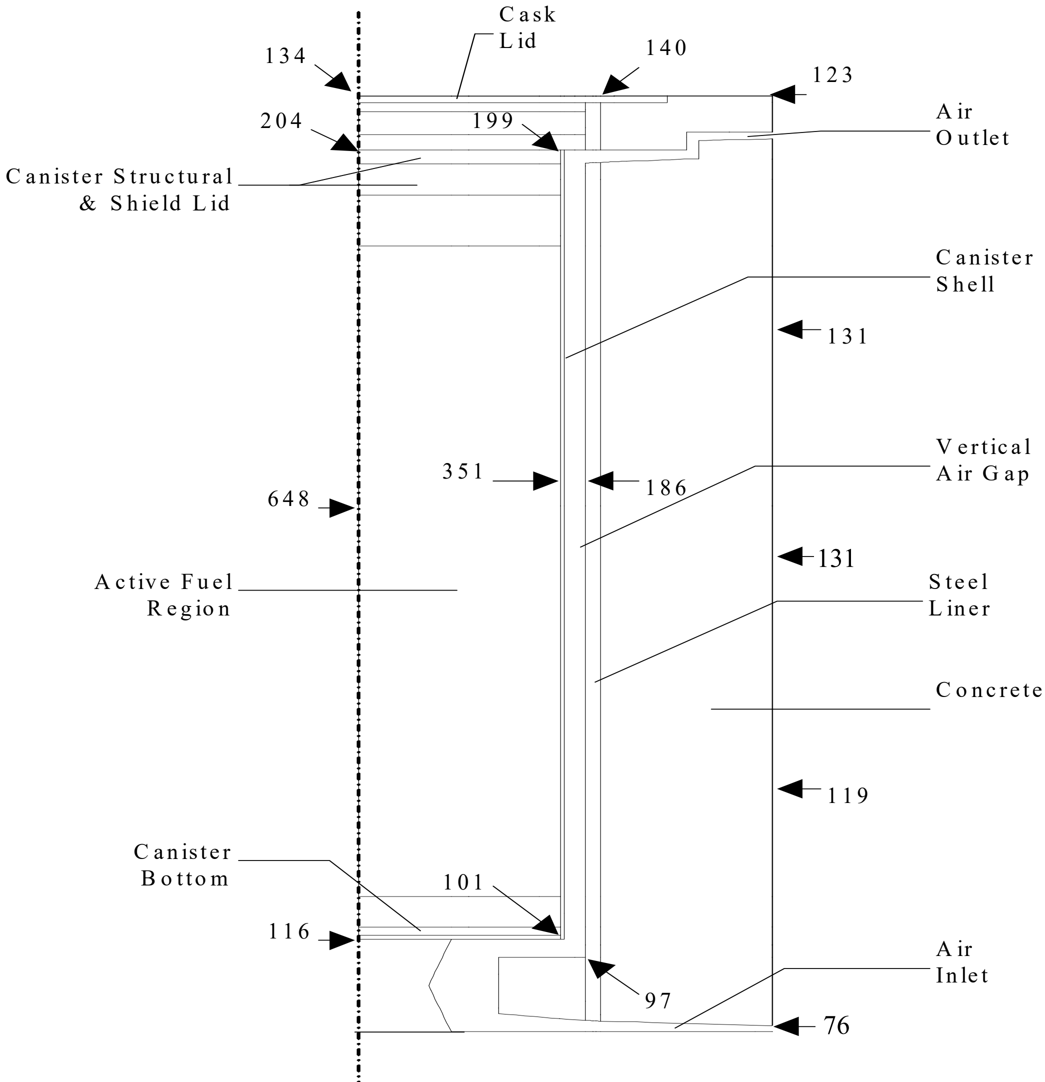
The Technical Specifications specify the remedial actions, either in-pool or forced air cooling, required to ensure that the fuel cladding and basket component temperatures do not exceed their short-term allowable temperatures, if the time limits are not met. LCOs 3.1.1 and 3.1.4 incorporate the operating times for heat loads that are less than the design basis heat loads as evaluated in this section.

Using the same three-dimensional transfer cask/canister models, analysis is performed for the conditions of in-pool cooling and forced air cooling followed by the vacuum drying and helium backfill operation (LCO 3.1.1). The conditions at the end of the vacuum drying as shown in Tables 4.4.3-5 (PWR) and 4.4.3-8 (BWR) are used as the initial conditions of the analyses. The LCO 3.1.1 "Action" analysis results are shown in Tables 4.4.3-6 and 4.4.3-7 for the PWR configuration and Tables 4.4.3-9 and 4.4.3-10 for the BWR configuration. Note that the duration of the second vacuum (after completion of the in-pool or forced air cooling) is limited (calculated based on the heat-up rate of the first vacuum), so the maximum temperatures at the

end of the second vacuum cycle will not exceed those at the end of the first vacuum cycle. The maximum temperatures at the end of the first vacuum (Table 4.4.3-5 for PWR and Table 4.4.3-8 for BWR) are conservatively presented as the maximum temperatures for the second vacuum condition. The maximum temperatures for the fuel cladding and the heat transfer disk are below the short-term allowable temperatures.

The in-pool cooling and the forced-air cooling operations (helium in canister) in LCO 3.1.4 are also evaluated for the PWR configuration for the 23 kW case and the BWR configuration for the 23 kW and 20 kW cases. The temperature profiles at the end of the helium condition, as shown in Table 4.4.3-5 for PWR and Table 4.4.3-8 for BWR, are used as the initial condition. The results for the BWR are shown in Tables 4.4.3-11 and 4.4.3-12 for the in-pool cooling and forced-air cooling, respectively. The results for the PWR are shown in Tables 4.4.3-13 and 4.4.3-14 for the in-pool cooling and forced-air cooling, respectively. Note that the time limit for the first helium backfill condition is used for the second helium backfill condition (after completion of the in-pool or forced-air cooling). Based on the heat-up rate of the first helium condition, the maximum component temperatures at the end of the second helium condition are well below the maximum temperatures at the end of the first helium condition. The maximum temperatures at the end of the first helium condition (Table 4.4.3-5 for PWR and Table 4.4.3-8 for BWR) are conservatively presented as the maximum temperatures for the second helium backfill condition, as shown in Tables 4.4.3-11 and 4.4.3-12 for the BWR configuration and Tables 4.4.3-13 and 4.4.3-14 for the PWR configuration.

Figure 4.4.3-1 Temperature Distribution (°F) for the Normal Storage Condition: PWR Fuel



normal storage condition. The 1°F temperature difference has an insignificant effect on the system pressure calculation. Each of the UMS® PWR fuel types is individually evaluated for normal condition pressure, and sets the maximum normal condition pressure at 4.21 psig. A summary of the maximum pressure in each PWR canister class is shown in Table 4.4.5-3. The table also includes the fuel type producing the listed maximum pressures.

4.4.5.2 Maximum Internal Pressure for BWR Fuel Canister

BWR canister maximum pressures are determined in the same manner as those documented for the PWR canister cases. Primary differences between PWR and BWR analysis include a maximum normal condition average gas temperature of 410°F, rod backfill gas pressures of 132 psig, and limits pressurizing gases to fission gases (including helium actinide decay gas), rod backfill gases, and canister backfill gas. The 132 psig employed in this analysis is significantly higher than the 6 atmosphere maximum pressure reported in open literature. BWR assemblies do not contain an equivalent to the PWR BPRAs and, therefore, do not require ^{10}B helium generated gases to be added. Fissile gas inventories for the maximum fissile material assemblies in each of the BWR lattices configurations (7×7, 8×8, 9×9 and 10×10) are shown in Table 4.4.5-4. Free volumes, without fuel components, in UMS® canister classes 4 and 5 (including DF class 5) are shown in Table 4.4.5-5. Maximum pressures for each canister class are listed in Table 4.4.5-6. The maximum normal condition pressure of 3.97 psig is based on a GE 7×7 assembly, designed for a BWR/2-3 reactor, with gas inventories conservatively taken from a 60,000 MWD/MTU source term. The normal condition pressure for a UMS® storage canister containing the GE 9×9 fuel assembly with 79 fuel rods is 3.96 psig. Similar fuel masses and displaced volume account for similar canister pressures.

DF materials are bounded by the evaluations as fuel assemblies containing clad failure would release both fission and fill gas prior to placement into the storage system. Vacuum drying would remove any gases in the failed clad.

Table 4.4.5-1 PWR Per Assembly Fuel Generated Gas Inventory (Fission Gas Basis – 60 GWd/MTU, 1.9 wt % ^{235}U)

Array	Assy Type	MTU	Moles
14×14	WE Standard	0.4144	35.52
15×15	B&W	0.4807	41.32
16×16	CE (System 80)	0.4417	38.10
17×17	WE Standard	0.4671	40.18

Table 4.4.5-2 PWR Canister Free Volume (No Fuel or Inserts)

Canister Class	1	2	3
Basket Volume (in^3)	69800	74490	77460
Canister Height (inch)	175.05	184.15	191.75
Canister Free Volume w/o Fuel (liter)	7970	8400	8770

Table 4.4.5-3 PWR Maximum Normal Condition Pressure Summary

Canister Class	Fuel Type	Pressure (psig)
Class 1	WE 17×17 Standard	4.20
Class 2	B&W 17×17 Mark C	4.21
Class 3	CE 16×16 System 80	4.11

Table 4.4.5-4 BWR Per Assembly Fuel Generated Gas Inventory

Array	Assy Type	MTU	Moles
7×7	GE 7×7 (49 Rods)	0.1985	16.78
8×8	GE 8×8 (63 Rods)	0.1880	16.07
9×9	GE 9×9 (79 Rods)	0.1979	16.86
10x10	GE 10x10 (92 Rods)	0.1979(1)	16.86(1)

Note 1: Conservatively applied the 9x9 fuel mass and inventory. 10x10 fuel mass, and therefore fission gas inventory at a fixed burnup, is less than that of the 9x9 fuel assembly evaluated.

Table 4.4.5-5 BWR Canister Free Volume (No Fuel or Inserts)

Canister Class	4	5	5DF
Basket Volume (in^3)	73110	74680	75532
Canister Height (inch)	185.55	190.35	190.65
Canister Free Volume w/o Fuel (liter)	8500	8740	8742

Table 4.4.5-6 BWR Maximum Normal Condition Pressure Summary

Canister Class	Fuel Type	Pressure (psig)
Class 4	GE 7×7	3.97
Class 5/5DF	GE 9×9	3.96

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5.8 BWR Inventory Expansion

This section evaluates expansion of the analyzed BWR fuel inventory to include the following:

- Addition of 10×10 BWR fuel type at low burnup (undamaged fuel)
- High burnup evaluation of 8×8, 9×9, and 10×10 undamaged fuel
- High burnup evaluation of 8×8, 9×9, and 10×10 damaged fuel

The evaluations are similar to those documented in previous sections with source terms generated using the TRITON and ARP modules of SCALE6.1 and dose rates determined using MCNP6.1. A three-dimensional response function methodology, similar to the one-dimensional methodology described in previous sections, is used to determine maximum system dose rates based on meeting the cask heat load of 23 kW. No dose rate limits are applied.

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5.8.1 Evaluation of Low Burnup 10x10 Undamaged Fuel

Industry data was surveyed to develop 10×10 fuel assembly parameters, shown in Table 5.8.1-1.

SCALE6.1 TRITON inputs were created to generate ARP cross section libraries and ARP inputs were executed to envelop a range of burnup, initial enrichment, and cool times required to populate minimum cool time tables. The 238-group ENDF-VII neutron library was used. Source terms were generated using the neutron and gamma group structures in Tables 5.2-28 and 5.2-29, respectively.

Based on a 23 kW cask heat load, minimum cool times were generated as shown in Table 5.8.1-2. Light element heat loads applied the flux factors in Table 5.2-30 and the cobalt impurity level of steel/inconel was assumed to be 0.8 g/kg (800 ppm) based on fuel designed for higher burnups.

Bounding dose rates for undamaged and damaged fuel are reported in Sections 5.8.2 and 5.8.3, respectively.

Table 5.8.1-1 Design Basis 10×10 Fuel Assembly Parameters

Description	10×10
Fuel Rod Height [in]	160.551
Top End-Cap Height [in]	0.346
Bottom End-Cap Height [in]	0.625
Max Active Length [in]	150.000
Max Rod Diameter [in]	0.404
Min Clad Thickness [in]	0.026
Max Pellet Diameter [in]	0.346
Array	10
Min Pitch [in]	0.510
Number of Water Rods	2
Water Rod OD [in]	0.808
Water Rod Thickness [in]	0.030
Channel Inner Dimension [in]	5.278
Min Channel Thickness [in]	0.080
Fuel Assembly Height [in]	176.200
Fuel Assembly Width [in]	5.518
Lower Nozzle Height [in]	6.760
Upper Nozzle Height [in]	7.500
Gap Fuel Rod to Top Nozzle [in]	1.389
Upper Plenum Region Height [in]	9.580
Number of Fuel Rods	92
Calculated MTU [MTU]	0.1946
Lower End Fitting SS Mass [kg]	4.740
Fuel Hw Mass [kg]	0.120
Upper Plenum Hw Mass [kg]	2.132
Upper End Fitting SS Mass [kg]	2.080

Table 5.8.1-2 Loading Table for Low Burnup 10×10 Fuel

Minimum Initial Assembly Avg. Enrichment, E (wt% ^{235}U)	Minimum Cooling Time (years)				
	30 < B ≤ 31	31 < B ≤ 32	32 < B ≤ 33	33 < B ≤ 34	34 < B ≤ 35
2.1 ≤ E < 2.3	5.0	5.0	5.0	5.0	-
2.3 ≤ E < 2.5	5.0	5.0	5.0	5.0	5.0
2.5 ≤ E < 2.7	5.0	5.0	5.0	5.0	5.0
2.7 ≤ E < 2.9	5.0	5.0	5.0	5.0	5.0
2.9 ≤ E < 3.1	5.0	5.0	5.0	5.0	5.0
3.1 ≤ E < 3.3	5.0	5.0	5.0	5.0	5.0
3.3 ≤ E < 3.5	5.0	5.0	5.0	5.0	5.0
3.5 ≤ E < 3.7	5.0	5.0	5.0	5.0	5.0
3.7 ≤ E < 3.9	5.0	5.0	5.0	5.0	5.0
3.9 ≤ E < 4.1	5.0	5.0	5.0	5.0	5.0
4.1 ≤ E < 4.3	5.0	5.0	5.0	5.0	5.0
4.3 ≤ E < 4.5	5.0	5.0	5.0	5.0	5.0
4.5 ≤ E < 4.7	5.0	5.0	5.0	5.0	5.0
4.7 ≤ E < 4.9	5.0	5.0	5.0	5.0	5.0
E ≥ 4.9	5.0	5.0	5.0	5.0	5.0
Minimum Initial Assembly Avg. Enrichment, E (wt% ^{235}U)	**Minimum Cooling Time (years)**				
	35 < B ≤ 36	**36 < B ≤ 37**	**37 < B ≤ 38**	**38 < B ≤ 39**	**39 < B ≤ 40**
2.3 ≤ E < 2.5	5.0	5.0	5.0	-	-
2.5 ≤ E < 2.7	5.0	5.0	5.0	5.0	5.3
2.7 ≤ E < 2.9	5.0	5.0	5.0	5.0	5.2
2.9 ≤ E < 3.1	5.0	5.0	5.0	5.0	5.1
3.1 ≤ E < 3.3	5.0	5.0	5.0	5.0	5.0
3.3 ≤ E < 3.5	5.0	5.0	5.0	5.0	5.0
3.5 ≤ E < 3.7	5.0	5.0	5.0	5.0	5.0
3.7 ≤ E < 3.9	5.0	5.0	5.0	5.0	5.0
3.9 ≤ E < 4.1	5.0	5.0	5.0	5.0	5.0
4.1 ≤ E < 4.3	5.0	5.0	5.0	5.0	5.0
4.3 ≤ E < 4.5	5.0	5.0	5.0	5.0	5.0
4.5 ≤ E < 4.7	5.0	5.0	5.0	5.0	5.0
4.7 ≤ E < 4.9	5.0	5.0	5.0	5.0	5.0
E ≥ 4.9	5.0	5.0	5.0	5.0	5.0

(B) Assembly average burnup (GWd/MTU)

Table 5.8.1-2 Loading Table for Low Burnup 10×10 Fuel (cont.)

Minimum Initial Assembly Avg. Enrichment, E (wt% ^{235}U)	Minimum Cooling Time (years)				
	40 < B ≤ 41	41 < B ≤ 42	42 < B ≤ 43	43 < B ≤ 44	44 < B ≤ 45
2.5 ≤ E < 2.7	5.5	5.7	5.9	6.2	-
2.7 ≤ E < 2.9	5.4	5.6	5.8	6.1	6.4
2.9 ≤ E < 3.1	5.3	5.5	5.7	6.0	6.2
3.1 ≤ E < 3.3	5.2	5.5	5.7	5.9	6.1
3.3 ≤ E < 3.5	5.2	5.4	5.6	5.8	6.0
3.5 ≤ E < 3.7	5.1	5.3	5.5	5.7	5.9
3.7 ≤ E < 3.9	5.0	5.2	5.5	5.7	5.9
3.9 ≤ E < 4.1	5.0	5.2	5.4	5.6	5.8
4.1 ≤ E < 4.3	5.0	5.1	5.3	5.5	5.7
4.3 ≤ E < 4.5	5.0	5.0	5.3	5.5	5.7
4.5 ≤ E < 4.7	5.0	5.0	5.2	5.4	5.6
4.7 ≤ E < 4.9	5.0	5.0	5.2	5.4	5.6
E ≥ 4.9	5.0	5.0	5.1	5.3	5.5

(B) Assembly average burnup (GWd/MTU)

5.8.2 Evaluation of High Burnup Undamaged BWR Fuel

Minimum cool times and dose rates for high burnup 8×8, 9×9, and 10×10 fuel are documented in this section. Source terms for high burnup fuel were determined using the SCALE6.1 TRITON/ARP methodology discussed in Section 5.8.1. Minimum cool times are based on the cask heat load of 23 kW, summarized in Table 5.8.2-1. Dose rates were computed using MCNP6.1 using a three-dimensional response function methodology similar to the one-dimensional response function methodology described in previous sections. Subcritical neutron multiplication was calculated within MCNP, with fuel modeled at 5.0 wt. % ^{235}U; this conservatively overestimates the neutron source.

Concrete in the VCC was evaluated at 145 lb/ft^3. The basket interior was modeled explicitly, and model homogenization was limited to the fuel region. The fuel assembly homogenization for the 9×9 fuel type is summarized in Table 5.8.2-2. Material compositions for basket and cask materials are shown in Table 5.8.2-3. The transfer cask was modeled with a dry cavity with both shield and structural lids installed.

Based on the cool times determined for low burnup 10×10 fuel (Section 5.8.1) and high burnup 8×8, 9×9, and 10×10 fuel, the 8×8 fuel assembly produces bounding system dose rates. Maximum dose rates are summarized in Table 5.8.2-4 through Table 5.8.2-7. Surface dose rates for the transfer cask are plotted in Figure 5.8.2-1 through Figure 5.8.2-3. Surface dose rates for the concrete cask are plotted in Figure 5.8.2-4 through Figure 5.8.2-7.

Table 5.8.2-1 Loading Table for High Burnup BWR Fuel

Minimum Initial Assembly Avg. Enrichment,E (wt% ^{235}U)	45 < Assembly Average Burnup ≤ 46 GWd/MTU		
	Minimum Cooling Time (years)		
	8×8	9×9	10×10
2.7 ≤ E < 2.9	6.1	6.7	6.7
2.9 ≤ E < 3.1	6.0	6.6	6.5
3.1 ≤ E < 3.3	5.9	6.5	6.4
3.3 ≤ E < 3.5	5.8	6.4	6.3
3.5 ≤ E < 3.7	5.7	6.2	6.2
3.7 ≤ E < 3.9	5.7	6.1	6.1
3.9 ≤ E < 4.1	5.6	6.0	6.0
4.1 ≤ E < 4.3	5.5	6.0	5.9
4.3 ≤ E < 4.5	5.5	5.9	5.9
4.5 ≤ E < 4.7	5.4	5.9	5.8
4.7 ≤ E < 4.9	5.4	5.8	5.8
E ≥ 4.9	5.3	5.8	5.7

Minimum Initial Assembly Avg. Enrichment,E (wt% ^{235}U)	46 < Assembly Average Burnup ≤ 47 GWd/MTU			47 < Assembly Average Burnup ≤ 48 GWd/MTU		
	Minimum Cooling Time (years)			Minimum Cooling Time (years)		
	8×8	9×9	10×10	8×8	9×9	10×10
2.7 ≤ E < 2.9	6.4	7.0	6.9	6.7	7.4	7.3
2.9 ≤ E < 3.1	6.3	6.9	6.8	6.6	7.2	7.2
3.1 ≤ E < 3.3	6.1	6.8	6.7	6.4	7.1	7.0
3.3 ≤ E < 3.5	6.0	6.6	6.6	6.3	6.9	6.9
3.5 ≤ E < 3.7	5.9	6.5	6.5	6.2	6.8	6.8
3.7 ≤ E < 3.9	5.9	6.4	6.4	6.1	6.7	6.7
3.9 ≤ E < 4.1	5.8	6.3	6.3	6.0	6.6	6.6
4.1 ≤ E < 4.3	5.7	6.3	6.2	5.9	6.5	6.5
4.3 ≤ E < 4.5	5.7	6.2	6.1	5.9	6.5	6.4
4.5 ≤ E < 4.7	5.6	6.1	6.0	5.8	6.4	6.3
4.7 ≤ E < 4.9	5.6	6.0	6.0	5.8	6.3	6.3
E ≥ 4.9	5.5	6.0	5.9	5.7	6.2	6.2

Table 5.8.2-1 Loading Table for High Burnup BWR Fuel (cont.)

Minimum Initial Assembly Avg. Enrichment,E (wt% ^{235}U)	48 < Assembly Average Burnup ≤ 49 GWd/MTU			49 < Assembly Average Burnup ≤ 50 GWd/MTU		
	Minimum Cooling Time (years)			Minimum Cooling Time (years)		
	8×8	9×9	10×10	8×8	9×9	10×10
2.7 ≤ E < 2.9	7.0	7.8	7.7	-	-	-
2.9 ≤ E < 3.1	6.8	7.6	7.5	7.1	8.0	7.9
3.1 ≤ E < 3.3	6.7	7.4	7.4	7.0	7.8	7.8
3.3 ≤ E < 3.5	6.6	7.3	7.2	6.9	7.7	7.6
3.5 ≤ E < 3.7	6.5	7.1	7.1	6.8	7.5	7.5
3.7 ≤ E < 3.9	6.4	7.0	7.0	6.6	7.4	7.3
3.9 ≤ E < 4.1	6.3	6.9	6.9	6.6	7.3	7.2
4.1 ≤ E < 4.3	6.2	6.8	6.8	6.5	7.1	7.1
4.3 ≤ E < 4.5	6.1	6.7	6.7	6.4	7.0	7.0
4.5 ≤ E < 4.7	6.0	6.7	6.6	6.3	6.9	6.9
4.7 ≤ E < 4.9	5.9	6.6	6.5	6.2	6.9	6.8
E ≥ 4.9	5.9	6.5	6.5	6.1	6.8	6.7

Minimum Initial Assembly Avg. Enrichment,E (wt% ^{235}U)	50 < Assembly Average Burnup ≤ 51 GWd/MTU			51 < Assembly Average Burnup ≤ 52 GWd/MTU		
	Minimum Cooling Time (years)			Minimum Cooling Time (years)		
	8×8	9×9	10×10	8×8	9×9	10×10
2.9 ≤ E < 3.1	7.5	8.5	8.4	7.9	8.9	8.8
3.1 ≤ E < 3.3	7.3	8.2	8.2	7.7	8.7	8.6
3.3 ≤ E < 3.5	7.2	8.0	8.0	7.6	8.5	8.4
3.5 ≤ E < 3.7	7.0	7.9	7.8	7.4	8.3	8.3
3.7 ≤ E < 3.9	6.9	7.8	7.7	7.3	8.2	8.1
3.9 ≤ E < 4.1	6.8	7.6	7.6	7.1	8.0	7.9
4.1 ≤ E < 4.3	6.7	7.5	7.5	7.0	7.9	7.8
4.3 ≤ E < 4.5	6.6	7.4	7.3	6.9	7.8	7.7
4.5 ≤ E < 4.7	6.6	7.3	7.2	6.8	7.7	7.6
4.7 ≤ E < 4.9	6.5	7.2	7.1	6.7	7.6	7.5
E ≥ 4.9	6.4	7.1	7.0	6.7	7.5	7.4

Table 5.8.2-1 Loading Table for High Burnup BWR Fuel (cont.)

Minimum Initial Assembly Avg. Enrichment,E (wt% ^{235}U)	52 < Assembly Average Burnup ≤ 53 GWd/MTU			53 < Assembly Average Burnup ≤ 54 GWd/MTU		
	Minimum Cooling Time (years)			Minimum Cooling Time (years)		
	8×8	9×9	10×10	8×8	9×9	10×10
2.9 ≤ E < 3.1	8.3	9.5	9.4	8.7	10.0	9.9
3.1 ≤ E < 3.3	8.1	9.2	9.1	8.5	9.8	9.7
3.3 ≤ E < 3.5	7.9	9.0	8.9	8.3	9.5	9.4
3.5 ≤ E < 3.7	7.8	8.8	8.7	8.1	9.3	9.2
3.7 ≤ E < 3.9	7.6	8.6	8.5	8.0	9.1	9.0
3.9 ≤ E < 4.1	7.5	8.5	8.4	7.8	8.9	8.8
4.1 ≤ E < 4.3	7.4	8.3	8.2	7.7	8.8	8.7
4.3 ≤ E < 4.5	7.2	8.2	8.1	7.6	8.6	8.5
4.5 ≤ E < 4.7	7.1	8.0	7.9	7.5	8.5	8.4
4.7 ≤ E < 4.9	7.0	7.9	7.8	7.4	8.3	8.3
E ≥ 4.9	6.9	7.8	7.8	7.2	8.2	8.1

Minimum Initial Assembly Avg. Enrichment,E (wt% ^{235}U)	54 < Assembly Average Burnup ≤ 55 GWd/MTU			55 < Assembly Average Burnup ≤ 56 GWd/MTU		
	Minimum Cooling Time (years)			Minimum Cooling Time (years)		
	8×8	9×9	10×10	8×8	9×9	10×10
3.1 ≤ E < 3.3	9.0	10.4	10.3	9.5	11.1	11.0
3.3 ≤ E < 3.5	8.8	10.1	10.0	9.2	10.8	10.7
3.5 ≤ E < 3.7	8.6	9.9	9.8	9.0	10.5	10.4
3.7 ≤ E < 3.9	8.4	9.6	9.5	8.8	10.2	10.1
3.9 ≤ E < 4.1	8.2	9.4	9.3	8.7	10.0	9.9
4.1 ≤ E < 4.3	8.0	9.2	9.1	8.5	9.8	9.7
4.3 ≤ E < 4.5	7.9	9.1	9.0	8.3	9.6	9.5
4.5 ≤ E < 4.7	7.8	8.9	8.8	8.2	9.4	9.3
4.7 ≤ E < 4.9	7.7	8.8	8.7	8.0	9.3	9.2
E ≥ 4.9	7.6	8.7	8.6	7.9	9.1	9.0

Table 5.8.2-1 Loading Table for High Burnup BWR Fuel (cont.)

Minimum Initial Assembly Avg. Enrichment,E (wt% ^{235}U)	56 < Assembly Average Burnup ≤ 57 GWd/MTU			57 < Assembly Average Burnup ≤ 58 GWd/MTU		
	Minimum Cooling Time (years)			Minimum Cooling Time (years)		
	8×8	9×9	10×10	8×8	9×9	10×10
3.1 ≤ E < 3.3	10.0	11.8	11.6	10.7	12.5	12.4
3.3 ≤ E < 3.5	9.8	11.5	11.3	10.4	12.1	12.0
3.5 ≤ E < 3.7	9.5	11.2	11.1	10.1	11.8	11.7
3.7 ≤ E < 3.9	9.3	10.9	10.8	9.8	11.6	11.4
3.9 ≤ E < 4.1	9.1	10.7	10.5	9.6	11.3	11.2
4.1 ≤ E < 4.3	8.9	10.4	10.3	9.4	11.1	10.9
4.3 ≤ E < 4.5	8.8	10.2	10.0	9.2	10.8	10.7
4.5 ≤ E < 4.7	8.6	10.0	9.9	9.0	10.6	10.5
4.7 ≤ E < 4.9	8.5	9.8	9.7	8.9	10.4	10.3
E ≥ 4.9	8.3	9.7	9.5	8.8	10.2	10.1

Minimum Initial Assembly Avg. Enrichment,E (wt% ^{235}U)	58 < Assembly Average Burnup ≤ 59 GWd/MTU			59 < Assembly Average Burnup ≤ 60 GWd/MTU		
	Minimum Cooling Time (years)			Minimum Cooling Time (years)		
	8×8	9×9	10×10	8×8	9×9	10×10
3.1 ≤ E < 3.3	11.3	13.3	13.1	-	-	-
3.3 ≤ E < 3.5	11.0	12.9	12.8	11.6	13.7	13.5
3.5 ≤ E < 3.7	10.7	12.6	12.4	11.3	13.4	13.2
3.7 ≤ E < 3.9	10.4	12.3	12.1	11.1	13.0	12.9
3.9 ≤ E < 4.1	10.2	11.9	11.8	10.8	12.7	12.6
4.1 ≤ E < 4.3	9.9	11.7	11.6	10.5	12.4	12.2
4.3 ≤ E < 4.5	9.7	11.5	11.3	10.3	12.1	12.0
4.5 ≤ E < 4.7	9.5	11.3	11.1	10.0	11.9	11.8
4.7 ≤ E < 4.9	9.4	11.1	10.9	9.9	11.7	11.5
E ≥ 4.9	9.2	10.9	10.7	9.7	11.5	11.4

Table 5.8.2-2 MCNP 9×9 Fuel Homogenization

Region	Density (g/cm^3)			
	UO_2	Zircalloy	SS304	Total
Active Fuel	2.9996	0.6319	--*	3.6315
Lower End Fitting	--	0.2200	1.2864	1.5064
Upper Plenum	--	0.0799	0.3031	0.3830
Upper End Fitting	--	--	0.5558	0.5558

* Stainless steel and inconel in the active fuel region were conservatively neglected in the fuel homogenization. However, the activated mass was considered when computing hardware dose rates.

Table 5.8.2-3 MCNP Material Compositions for Cask/Basket Regions

Material	Density (g/cm^3)	Element	ZAID[a]	Mass Fraction (wt. %)
Stainless Steel	7.94	Carbon	6012	0.08
		Silicon	14000	1.0
		Phosphorus	15031	0.045
		Chromium	24000	19.0
		Manganese	25055	2.0
		Iron	26000	68.375
		Nickel	28000	9.5
Carbon Steel	7.8212	Iron	26000	99.0
		Carbon	6012	1.0
Concrete	2.3227	Iron	26000	1.4
		Hydrogen	1001	1.0
		Aluminum	13027	3.4
		Calcium	20000	4.4
		Oxygen	8016	53.2
		Silicon	14000	33.7
		Sodium	11023	2.9
Lead	11.344	Lead	82000	100.0
Aluminum	2.702	Aluminum	13027	100.0
NS-4-FR	1.6316	Boron-10	5010	0.08
		Boron-11	5011	0.38
		Aluminum	13027	21.29
		Hydrogen	1001	6.00
		Oxygen	8016	42.42
		Carbon	6012	27.83
		Nitrogen	7014	2.00
Neutron absorber	2.6907	Boron-10	5010	1.19
		Boron-11	5011	5.43
		Carbon	6000	1.84
		Aluminum	13027	91.54

[a] ZAID is the MCNP identifier for an element or isotope.

Table 5.8.2-4 Transfer Cask Maximum Dose Rates – High Burnup BWR Fuel

Source	Cask Surface (mrem/hr with relative uncertainty)			1 Meter from Surface (mrem/hr with relative uncertainty)		
	Side	Top	Bottom	Side	Top	Bottom
Neutron	736 (0.4%)	348 (1.0%)	220 (0.6%)	241 (0.3%)	97.4 (0.9%)	53.3 (1.4%)
Gamma	69.4 (0.8%)	107 (4.9%)	375 (0.9%)	27.2 (0.5%)	62.8 (3.9%)	193 (1.1%)
Total	805 (0.3%)	455 (1.4%)	595 (0.6%)	268 (0.3%)	160 (1.6%)	247 (0.9%)

Table 5.8.2-5 Concrete Cask Maximum Dose Rates – High Burnup BWR Fuel

Source	Cask Surface (mrem/hr with relative uncertainty)		1 Meter from Surface (mrem/hr with relative uncertainty)	
	Side[a]	Top	Side	Top
Neutron	2.18 (1.2%)	88.0 (1.6%)	0.319 (0.3%)	21.3 (2.9%)
Gamma	18.8 (1.4%)	6.63 (2.0%)	8.80 (0.5%)	3.36 (1.5%)
Total	20.9 (1.2%)	94.6 (1.5%)	9.11 (0.5%)	24.6 (2.5%)

Table 5.8.2-6 Concrete Cask Air Inlet Maximum Dose Rates – High Burnup BWR Fuel

Source	Surface Dose Rate (mrem/hr with relative uncertainty)
Fuel Neutron	23.6 (1.0%)
Secondary Gamma	0.6 (2.2%)
Fuel Gamma	7.6 (19.8%)
Fuel Hardware	< 0.1 (11.0%)
Lower End Fitting	202.1 (0.2%)
Total	234.0 (0.7%)

Table 5.8.2-7 Concrete Cask Air Outlet Maximum Dose Rates – High Burnup BWR **Fuel**

Source	Surface Dose Rate (mrem/hr with relative uncertainty)
Fuel Neutron	1.4 (0.3%)
Secondary Gamma	0.4 (0.4%)
Fuel Gamma	0.5 (0.9%)
Fuel Hardware	< 0.1 (0.9%)
Upper End Fitting	23.3 (0.1%)
Upper Plenum	18.8 (0.1%)
Total	44.5 (0.1%)

[a] Side maximum dose rates are calculated at the air inlet elevation. This value presents the azimuthal average around the cask perimeter at the air inlet elevation. Fuel assembly midplane dose rate is 17.8 mrem/hr.

Figure 5.8.2-1 Transfer Cask Side Surface Dose Rate Profile – High Burnup BWR Fuel

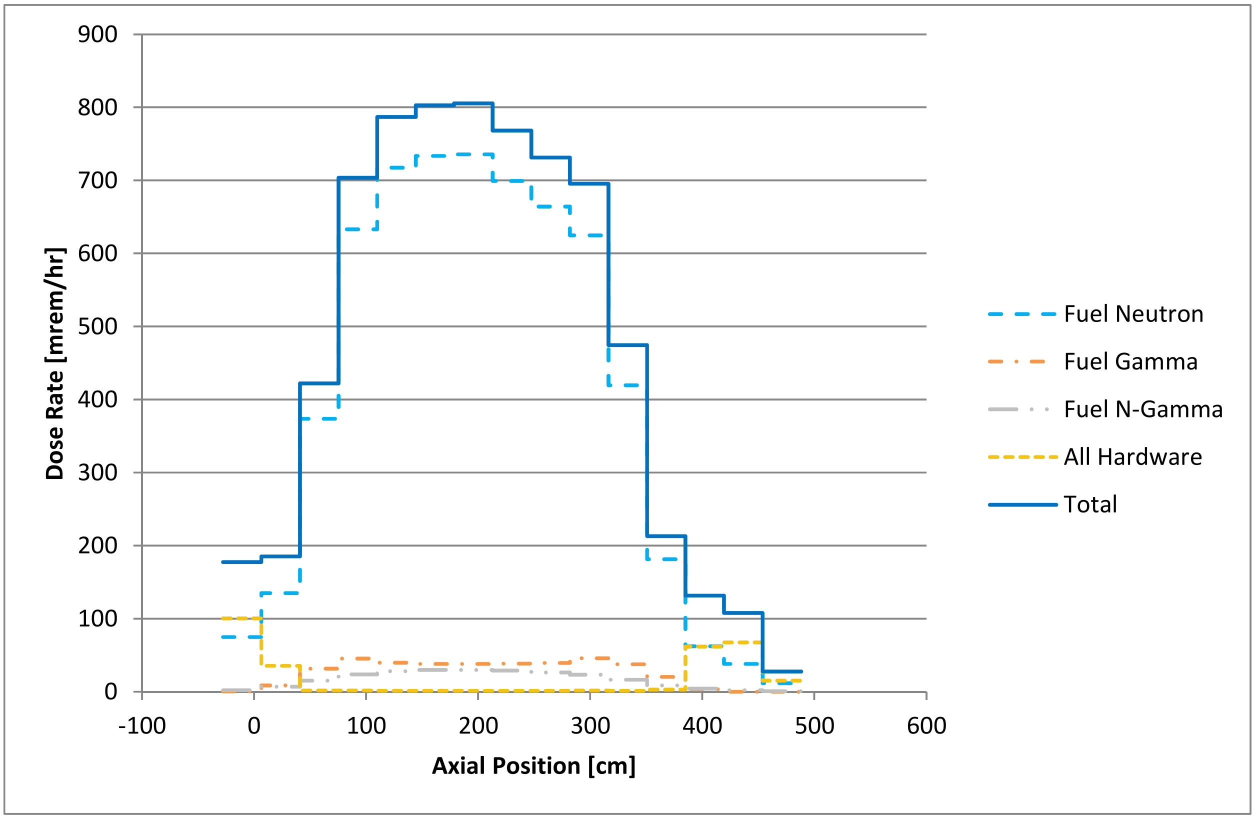


Figure 5.8.2-2 Transfer Cask Top Surface Dose Rate Profile – High Burnup BWR Fuel

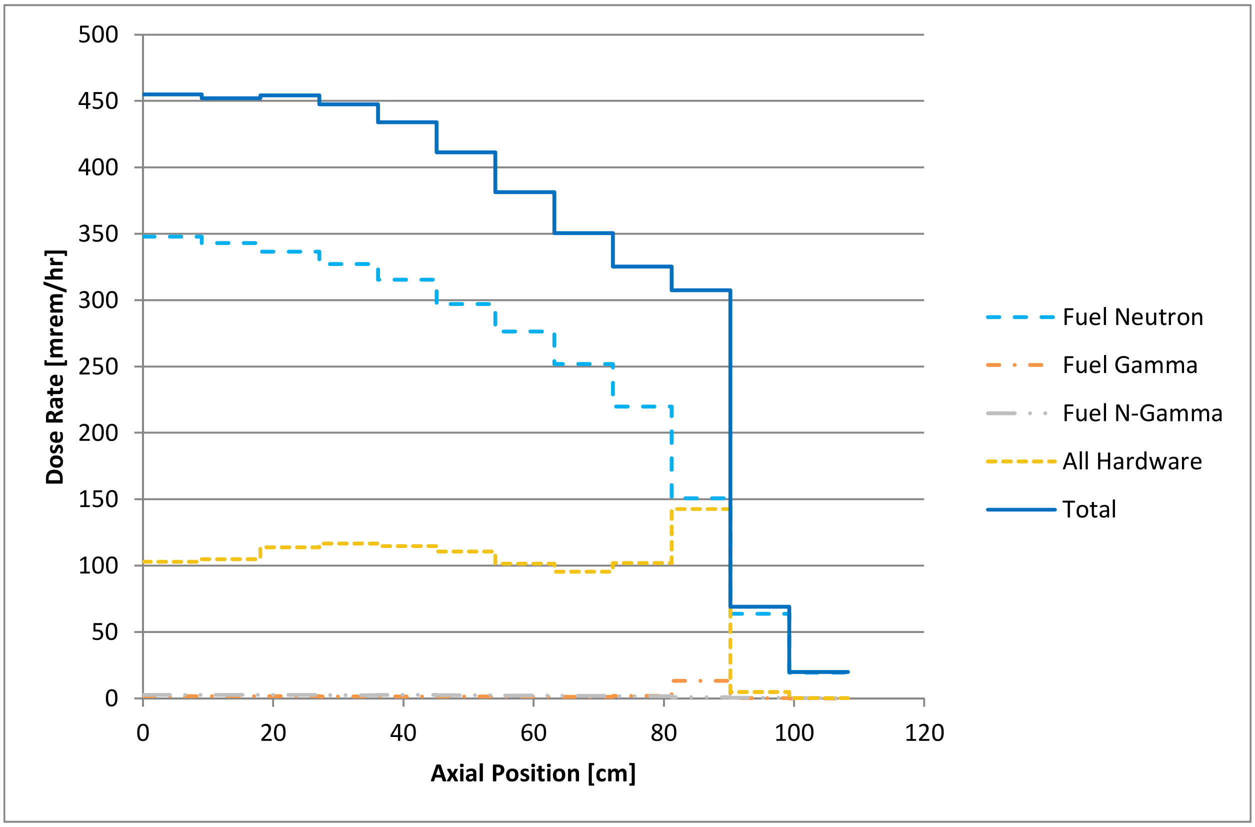


Figure 5.8.2-3 Transfer Cask Bottom Surface Dose Rate Profile – High Burnup BWR Fuel

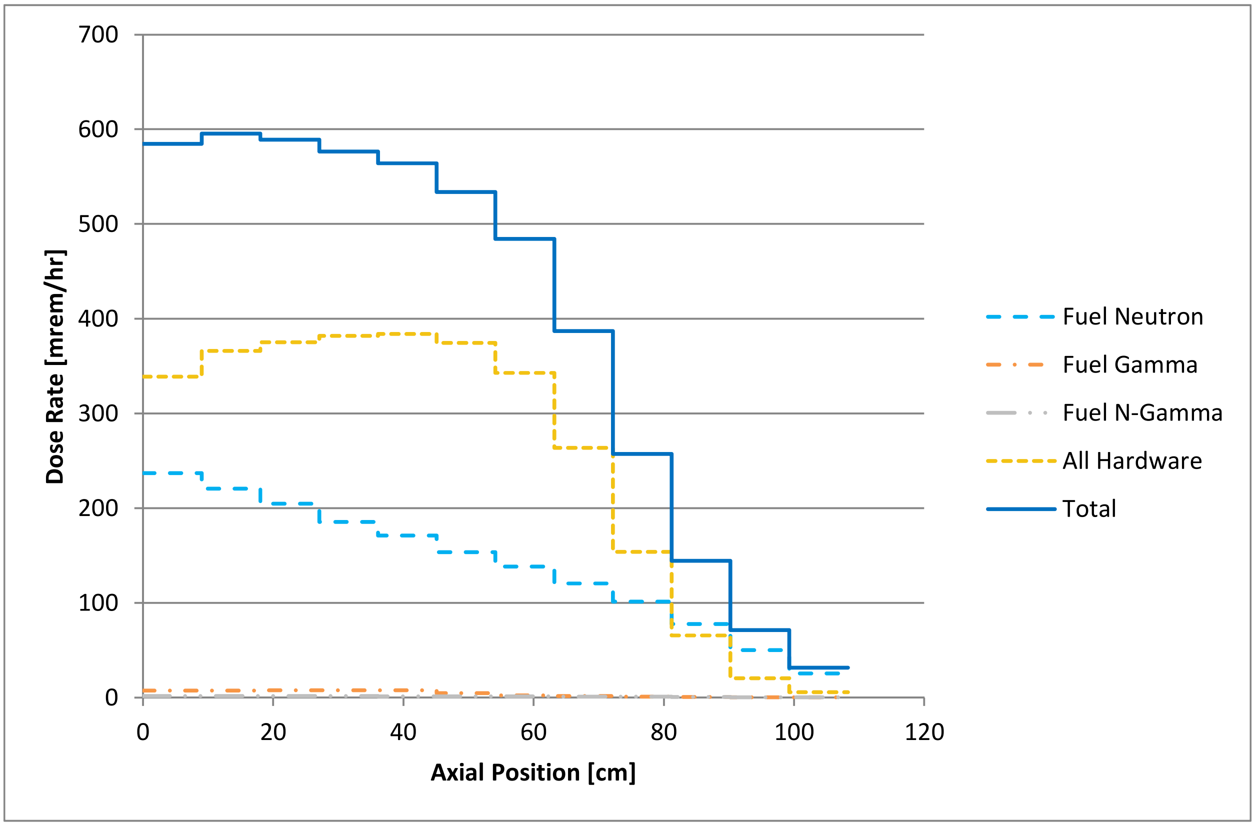


Figure 5.8.2-4 Concrete Cask Side Surface Dose Rate Profile – High Burnup BWR Fuel

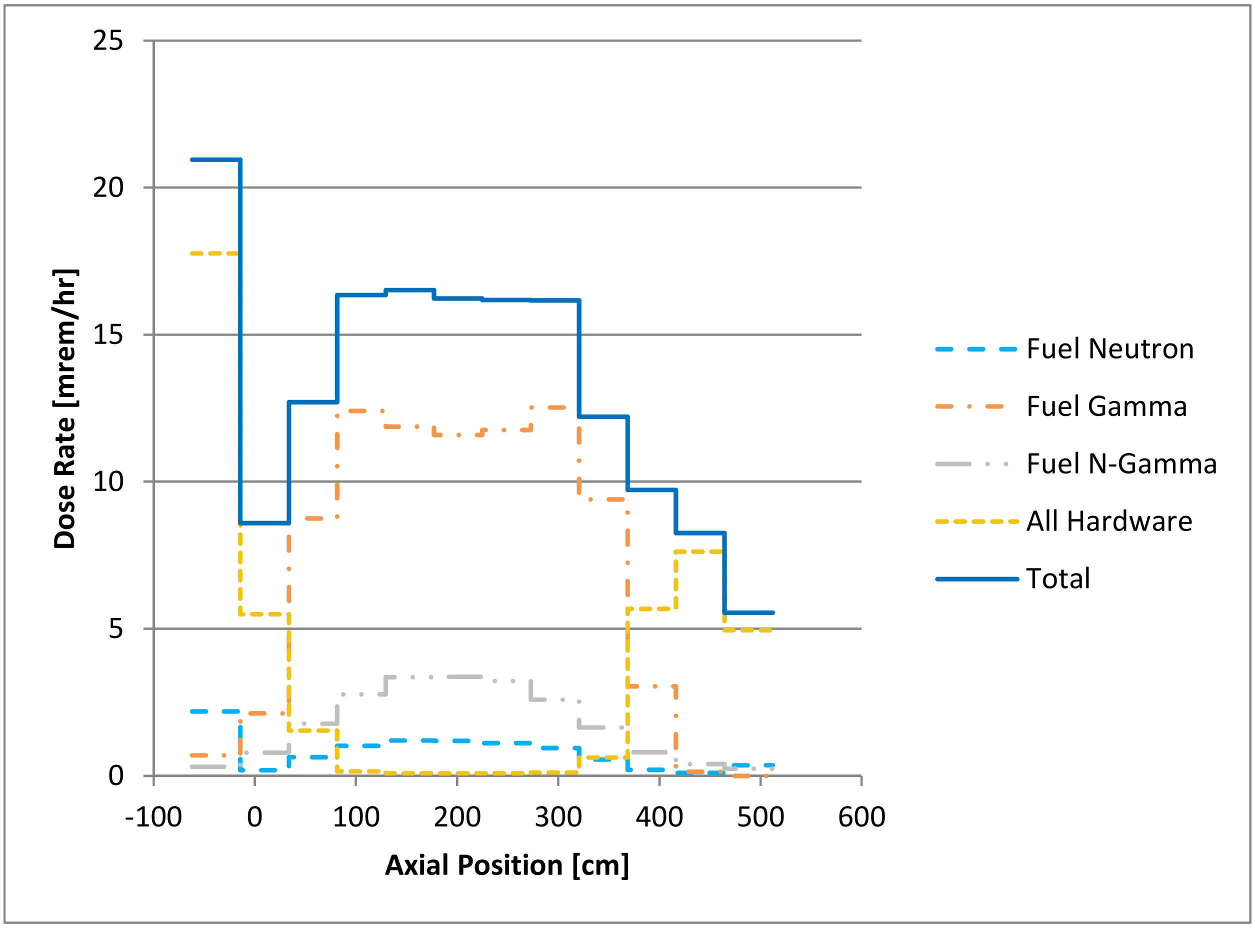


Figure 5.8.2-5 Concrete Cask Top Surface Dose Rate Profile – High Burnup BWR Fuel

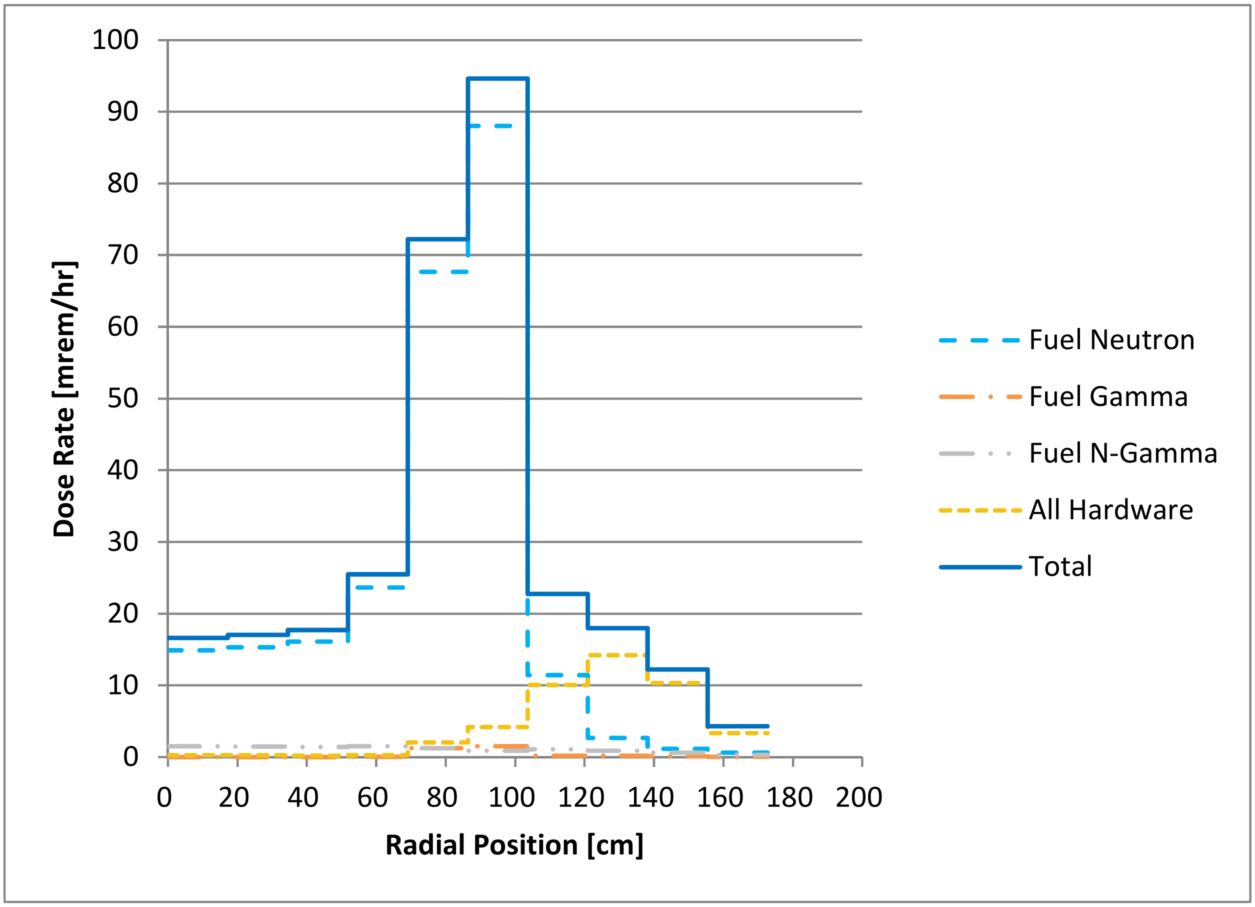


Figure 5.8.2-6 Concrete Cask Air Inlet Dose Rate Profile – High Burnup BWR Fuel

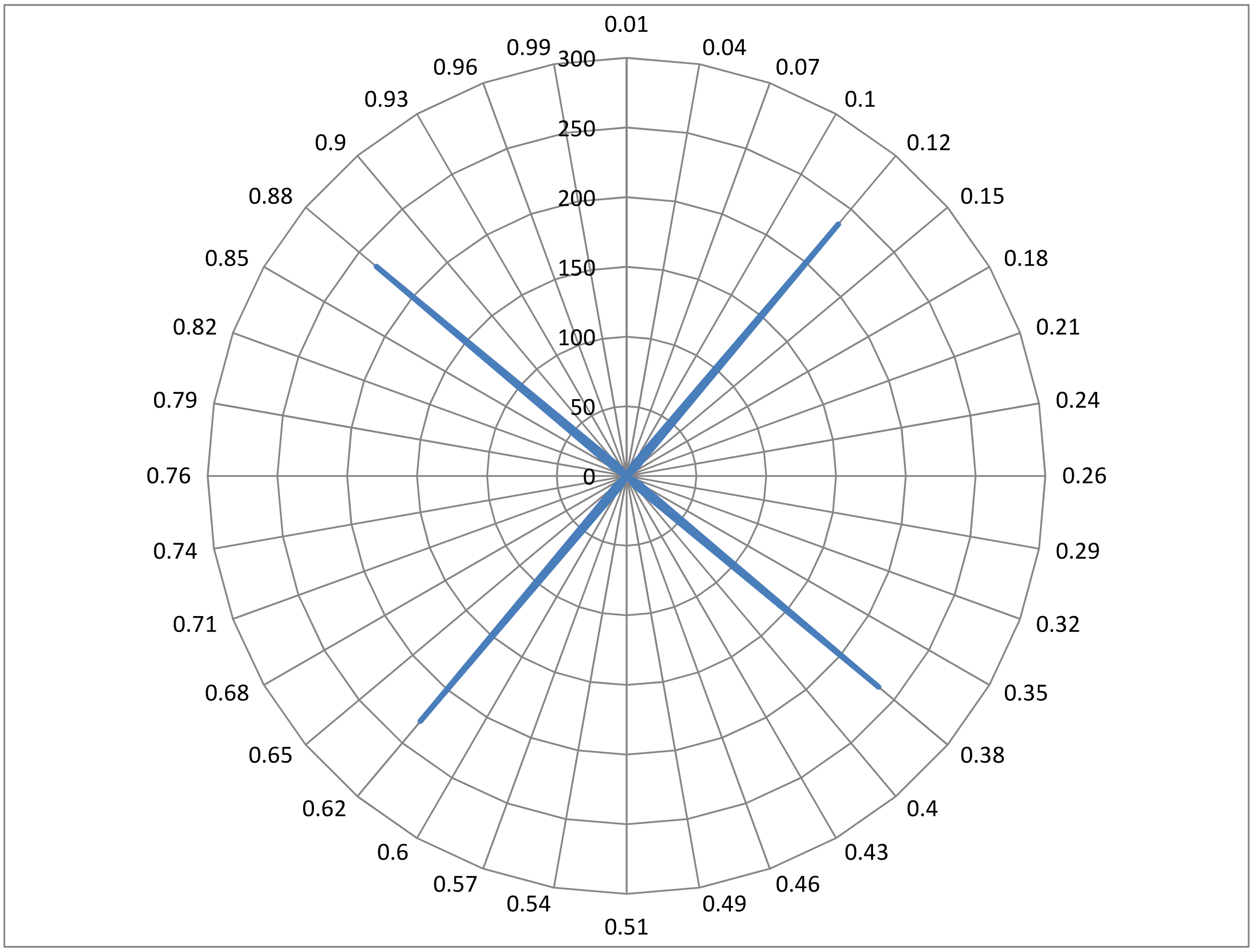
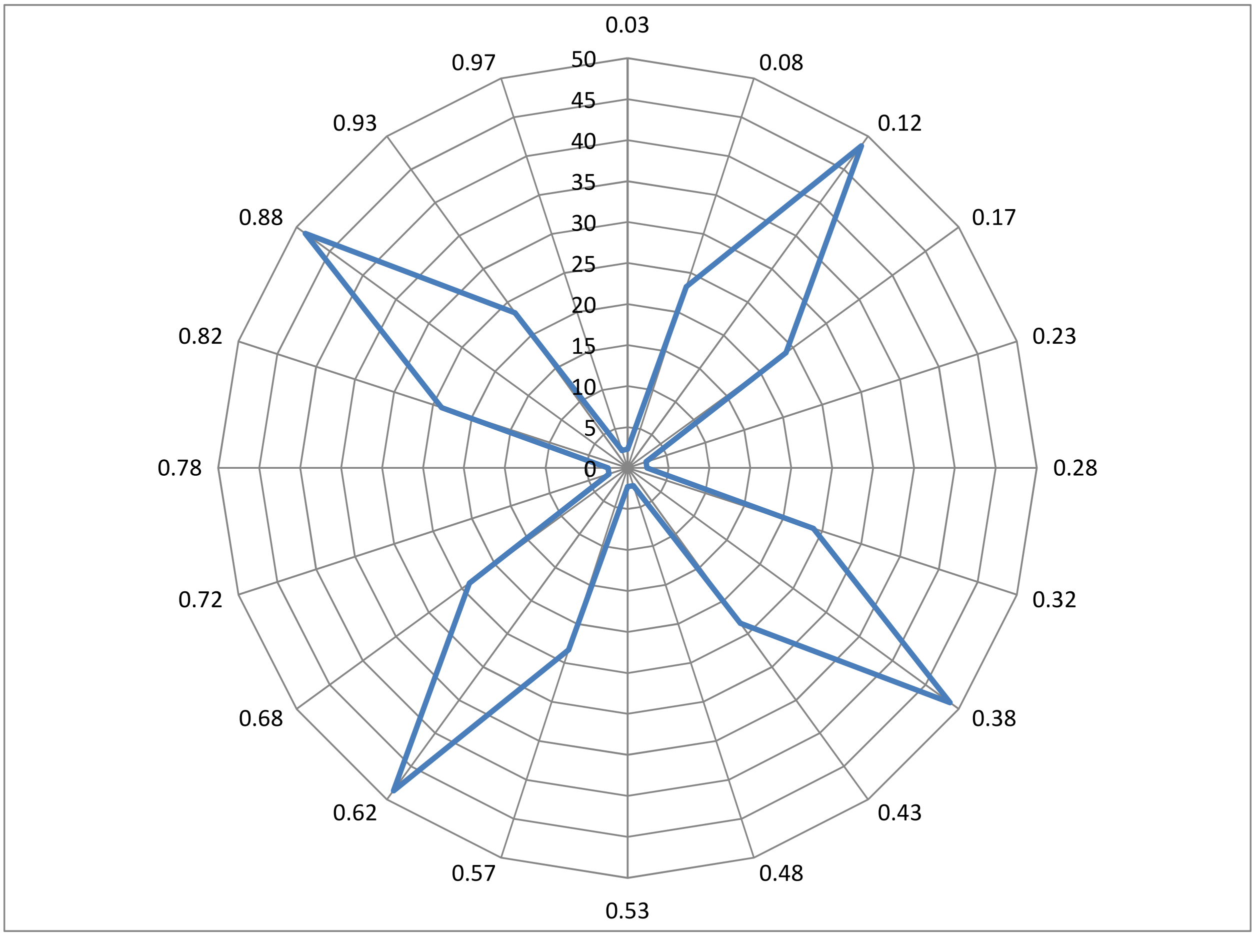


Figure 5.8.2-7 Concrete Cask Air Outlet Dose Rate Profile – High Burnup BWR Fuel



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5.8.3 Evaluation of High Burnup Damaged BWR Fuel

The 56-assembly BWR basket is designed to package up to four damaged fuel cans (DFCs) in the basket corners. Maximum dose rates are calculated for a payload with up to four DFCs loaded with damaged fuel assemblies.

Dose rates are based on a uniformly loaded UMS system with a maximum cask heat load of 23.0 kW, with minimum cool times from Section 5.8.2. The 8×8 assembly, which was bounding for undamaged fuel dose rates, is used to compute dose rates for damaged fuel.

Damaged fuel is evaluated by assuming the entire fuel assembly has collapsed. Packing fractions (PFs) up to a maximum of 0.75 are considered. The collapse is applied to the fuel rods only, assuming all tie rods remain intact and the fuel hardware will remain unchanged. The additional shielding of the collapsed fuel is retained.

Based on a range of matrix of packing fractions from 0.30 to 0.75, the mass and volume of damaged fuel is calculated. Once the total amount of damaged fuel is determined, it is distributed across the lower nozzle region based on the hardware volume and the packing fraction. After the damaged fuel mass available to the active fuel region is computed, its volume is computed first based on nominal density UO_2 (10.412 g/cm^3) and then adjusted for the packing fraction. Using the damaged fuel volumes and masses, and homogenized densities are computed. The active fuel region is divided into two axial zones, with the lower region containing only damaged fuel (UO_2) and the upper region containing homogenized clad and grid material. The cut plane for the two regions is based on the assumed packing fraction and is the regional volume divided by the DFC inner width. Based on the damaged fuel and hardware density values, the damaged fuel homogenizations are computed. MCNP material definitions are summarized in Table 5.8.3-1.

Maximum dose rates are summarized in Table 5.8.3-2 and Table 5.8.3-3 for the transfer and storage casks, respectively. Maximum outlet dose rates shown in Table 5.8.3-4. Results from the 56-fuel assembly undamaged basket are included for comparison. The basket with four damaged fuel assemblies increases maximum dose rates significantly for the transfer cask bottom and side due to fuel debris at the bottom of the DFC near the bottom forging and door where neutron shielding is minimal. Maximum dose rates are increased on the concrete cask side due to azimuthal peaking from the four DFC locations.

Surface dose rates for the transfer cask are plotted in Figure 5.8.3-1 and Figure 5.8.3-2. The side surface dose rates for the concrete cask are plotted in Figure 5.8.3-3.

Table 5.8.3-1 MCNP Damaged Fuel Material Definition at 0.75 Packing Fraction

Material	Density (g/cm^3)	Element/ Isotope	ZAID	Mass Fraction (wt. %)
Damaged Fuel in Lower End Fitting	7.7925	U-235	92235	3.7063E-02
		U-238	92238	7.0420E-01
		Oxygen	8016	9.9650E-02
		Chromium	24000	2.5894E-02
		Iron	26000	9.3132E-02
		Nickel	28000	1.2948E-02
		Zirconium	40000	2.2518E-02
		Tin	50000	3.3233E-04
		Hafnium	72000	2.2920E-06
		Carbon	6012	1.0893E-04
		Nitrogen	14000	1.3616E-03
		Phosphorus	15031	6.1273E-05
		Manganese	25055	2.7233E-03
Damaged Fuel in Active Fuel Region	7.8090	U-235	92235	4.4075E-02
		U-238	92238	8.3742E-01
		Oxygen	8016	1.1850E-01
Hardware Region Above Active Fuel	0.4485	Chromium	24000	1.0000E-03
		Iron	26000	1.3500E-03
		Nickel	28000	5.5000E-04
		Zirconium	40000	9.8250E-01
		Tin	50000	1.4500E-02
		Hafnium	72000	1.0000E-04

Table 5.8.3-2 Transfer Cask Maximum Dose Rates – High Burnup BWR Fuel

Fuel Description	Cask Surface (mrem/hr with relative uncertainty)			1 Meter from Surface (mrem/hr with relative uncertainty)		
	Side	Top	Bottom	Side	Top	Bottom
Undamaged	805 (0.3%)	455 (1.4%)	595 (0.6%)	268 (0.3%)	160 (1.6%)	247 (0.9%)
Damaged	853 (0.8%)	469 (0.6%)	688 (0.6%)	277 (0.7%)	161 (0.7%)	285 (0.5%)

Table 5.8.3-3 Concrete Cask Maximum Dose Rates – High Burnup BWR Fuel

Fuel Description	Cask Surface (mrem/hr with relative uncertainty)				1 Meter from Surface (mrem/hr with relative uncertainty)	
	Side[a]	Top	Inlet	Outlet	Side	Top
Undamaged	20.9 (1.2%)	94.6 (1.5%)	234 (0.7%)	44.5 (0.1%)	9.11 (0.5%)	24.6 (2.5%)
Damaged	23.8 (0.9%)	96.8 (1.7%)	262 (0.5%)	49.0 (0.3%)	9.81 (0.9%)	25.4 (3.2%)

Table 5.8.3-4 Concrete Cask Maximum Inlet Dose Rates – High Burnup BWR Fuel

Source	Inlet Dose Rate (mrem/hr with relative uncertainty)
Undamaged	234.0 (0.7%)
Damaged-PF30	253 (0.9%)
Damaged-PF50	254 (0.8%)
Damaged-PF63	260 (0.7%)
Damaged-PF75	262 (0.5%)

[a] Side maximum dose rates are calculated at the air inlet elevation. This value presents the azimuthal average around the cask perimeter at the air inlet elevation. The maximum fuel assembly midplane dose rate is 16.7 mrem/hr (0.30 packing fraction).

Figure 5.8.3-1 Transfer Cask Side Surface Dose Rate Profile – High Burnup Damaged BWR Fuel

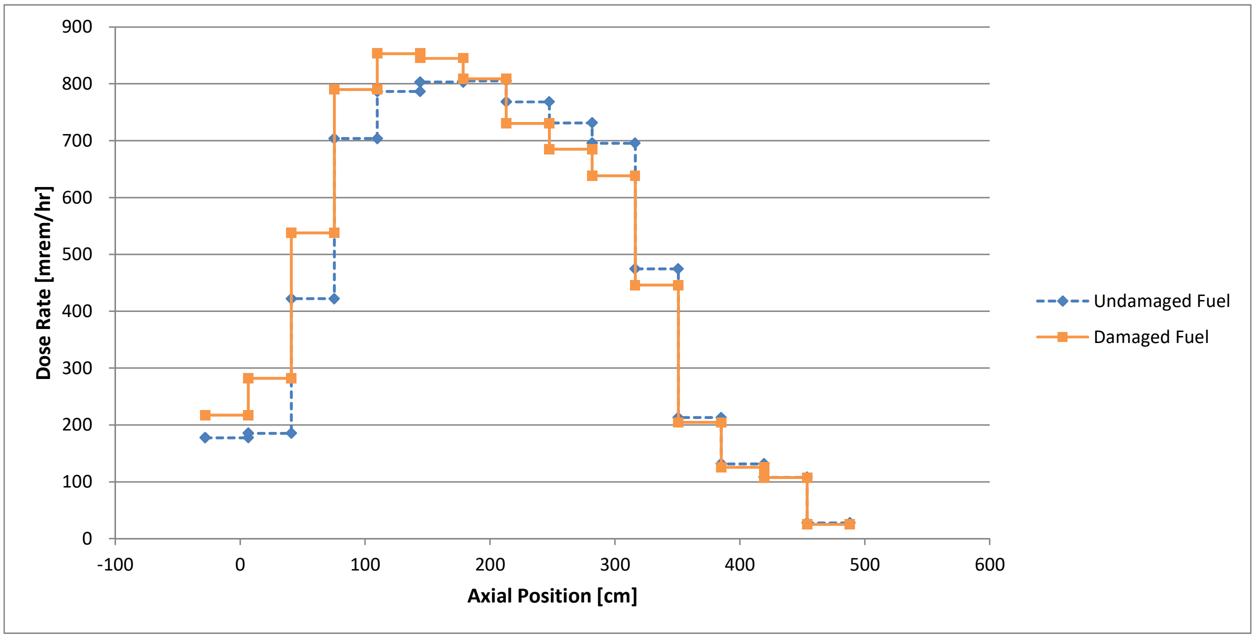


Figure 5.8.3-2 Transfer Cask Bottom Surface Dose Rate Profile – High Burnup Damaged BWR Fuel

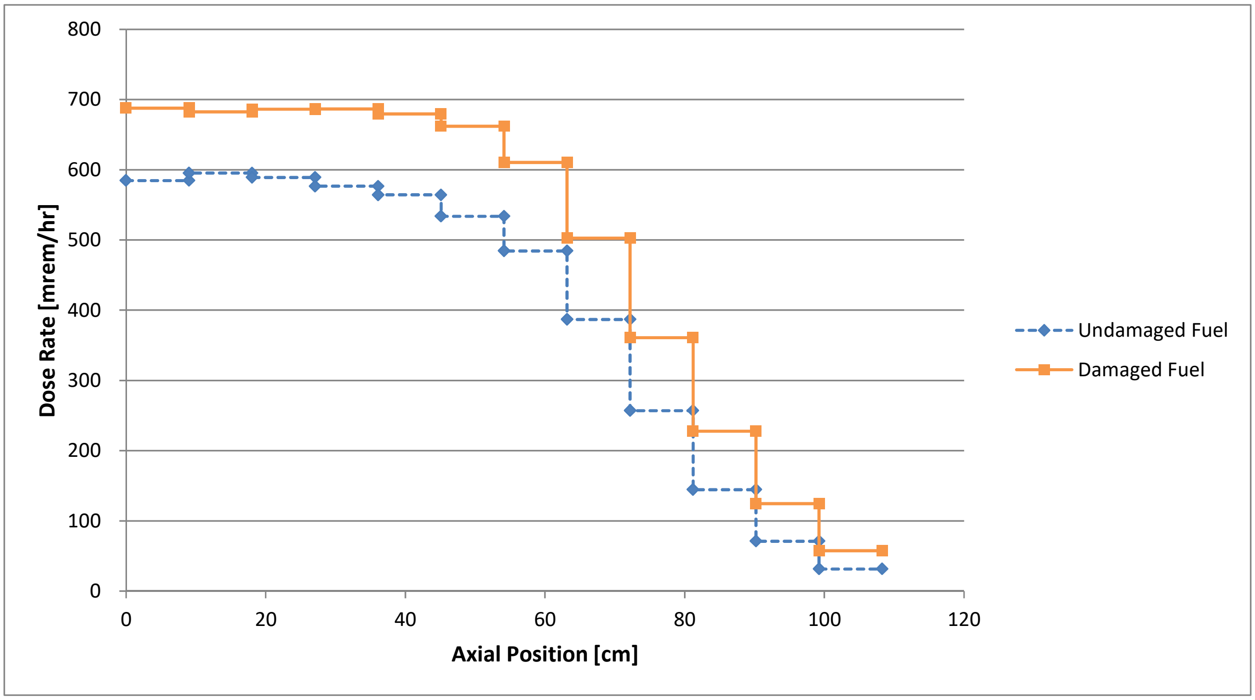
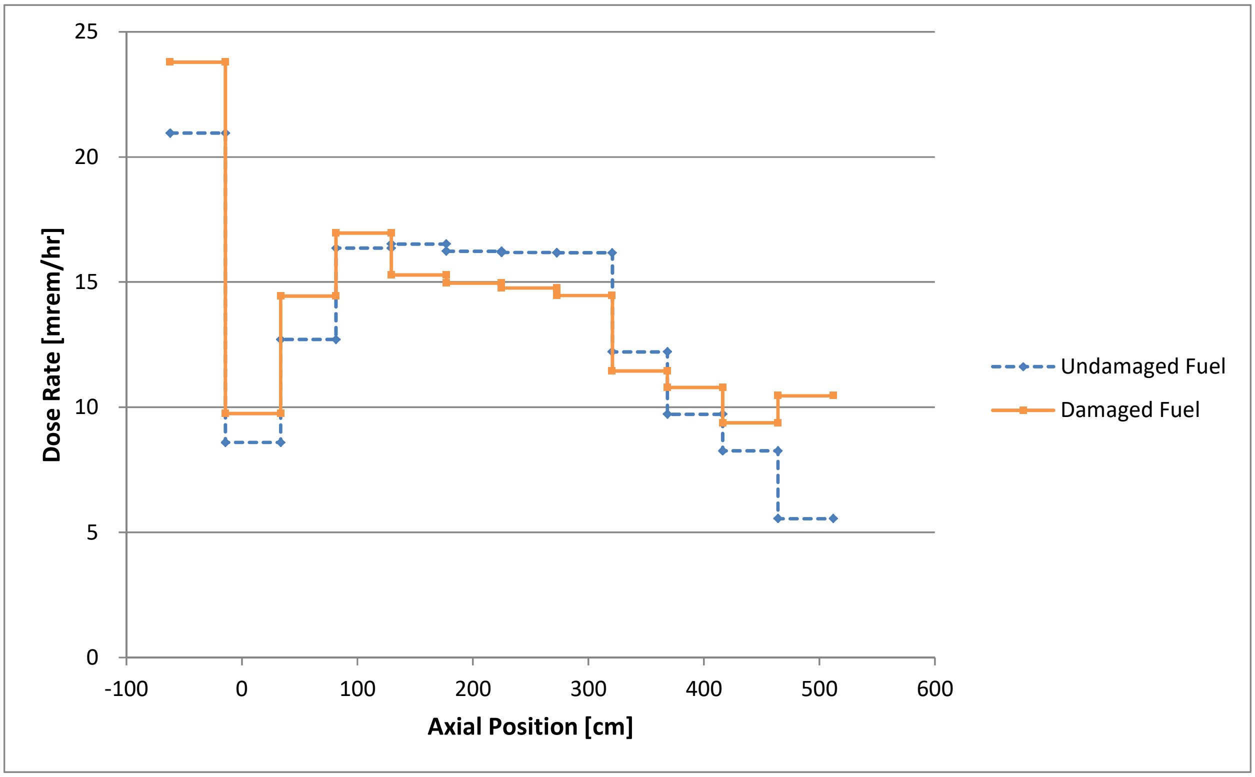


Figure 5.8.3-3 Concrete Cask Side Surface Dose Rate Profile – High Burnup Damaged BWR Fuel



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in the PWR fuel tubes is 0.025 g ^{10}B/cm^2. To reach higher initial enrichments than those allowed by using only the flux trap for criticality control, a separate evaluation, including soluble boron at 1000 ppm in the moderator, is performed. The soluble boron absorbs thermal neutrons inside the assembly, as well as in the flux traps. In combination with the flux traps and fixed neutron poison, the soluble boron allows loading of PWR fuel assemblies with an initial enrichment up to 5.0 wt. % ^{235}U.

Criticality control in the BWR basket is achieved by a single neutron absorber sheet between each fuel assembly. The neutron absorber modeled is a borated aluminum neutron absorber. Any similar material meeting the ^{10}B areal density and physical dimension requirement will produce similar reactivity results. Individual fuel assemblies in the BWR basket are held in place by fuel tubes or in the case of the BWR Damaged fuel basket a combination of fuel tubes and damaged fuel cans (DFCs). The fuel tubes are of three types: tubes with neutron absorber on two sides; tubes with neutron absorber on one side; and tubes with no neutron absorber. The fuel tube types are arranged such that there is at least one sheet of neutron absorber between adjacent assemblies. As in the PWR basket, a stainless steel cover holds the neutron absorber sheets in place, and the fuel tubes are separated by a gap that is filled with water when the canister is flooded. In the case of BWR fuel, this arrangement is sufficient to moderate and absorb thermal neutrons before they can cause a fission in the adjacent assembly. The use of flux traps between BWR assemblies is not necessary because of the smaller size and amount of fissile material in BWR assemblies compared with PWR assemblies. Of the total 56 fuel tubes in each BWR basket, 42 tubes contain neutron absorber sheets on two sides of the tubes; 11 tubes contain neutron absorber sheets on one side; and the remaining 3 tubes contain no neutron absorber sheets. The engineered placement of the neutron absorber sheets assures sufficient absorption of thermal neutrons to achieve a neutron multiplication factor (k_s) below 0.95. The minimum loading of the neutron absorber sheets in the BWR tubes is 0.011 g ^{10}B/cm^2. The BWR Class 4 and 5 basket designs include 40 and 41 carbon steel support disks, respectively. The BWR basket design also includes 17 aluminum heat transfer disks.

The SCALE 4.3 Criticality Safety Analysis Sequence (CSAS) [3, 4], ANSWERS MONK module [20] and MCNP [21] are used to perform the Universal Storage System criticality analysis. The CSAS sequence includes KENO-Va [5] Monte Carlo analysis to determine k_{eff} under normal and accident conditions. The 27-group ENDF/B-IV neutron cross-section library [6] is used in all calculations. CSAS with the 27-group library is benchmarked by comparison to 63 critical experiments relevant to light water reactor fuel in storage and transport casks. The MONK8A Monte Carlo Program for Nuclear Criticality Safety Analysis (SERCO Assurance [20]) employs the Monte Carlo technique in combination with JEF 2.2-based point energy neutron libraries to determine the effective neutron multiplication factor (k_{eff}). The specific libraries are dice96j2v5 for general neutron cross-section information and therm96j2v2 for thermal scatter data in the water moderator. MONK8a, with the JEF 2.2 neutron cross-section libraries, is benchmarked by

comparison to critical experiments relevant to light-water reactor fuel in storage and transport casks shown in Section 6.5. The MCNP6.2 particle transport code uses Monte Carlo techniques in combination with ENDF/B-VII cross sections. Code bias and uncertainty, establishing and upper subcritical limit, are included in Section 6.5.

The most reactive PWR assembly is the Westinghouse 17×17 OFA and the most reactive BWR fuel assembly is the Exxon/ANF/Siemens Power Corp. (Ex/ANF) 9×9 with 79 fuel rods (see Section 6.4.1.2 for detailed discussion). These assemblies, respectively, bound all PWR (Classes 1-3) and BWR (Classes 4-5) fuel assemblies to be stored (see Tables 6.2-1 and 6.2-2), as demonstrated in Section 6.4.1.2. The most reactive PWR and BWR fuel assemblies, evaluated as fresh fuel in their respective basket configuration, are used in the criticality calculations for the transfer cask and the concrete cask.

The maximum multiplication factors with uncertainties and code bias are calculated, using conservative assumptions, for the transfer cask and the Vertical Concrete Cask containing PWR (4.2 wt. % ^{235}U) or BWR (4.0 wt. % ^{235}U) fuel. The calculations for the transfer cask are performed for normal and accident conditions, and those for the concrete cask are performed for normal, accident, and off-normal conditions. The results of the analyses are presented in detail in Section 6.4.3 and are summarized as:

Condition	Maximum Multiplication Factors with Uncertainties (k_s)			
	PWR Fuel		BWR Fuel	
	Transfer Cask	Concrete Cask	Transfer Cask	Concrete Cask
Normal	0.93921	0.38329	0.91919	0.38168
Accident	0.94749	0.94704	0.92235	0.92332
Off-Normal	--	0.37420	--	0.38586

Note: BWR results shown are based on Section 6.4 evaluations. Updated BWR fuel assembly characteristics and BWR damaged fuel results are shown in Section 6.7.

Analysis of simultaneous moderator density variation inside and outside either the transfer or concrete casks shows a monotonic decrease in reactivity with decreasing moderator density. Thus, the full moderator density condition bounds any off-normal or accident condition. Analysis of moderator intrusion into the concrete cask heat transfer annulus with the dry canister shows a slight decrease in reactivity from the completely dry condition.

The fixed maximum enrichment evaluation is augmented by assembly-specific analyses. Fuel types identified in Section 6.2 are grouped based on key fuel lattice characteristics. Each of the groups is then evaluated to determine the maximum enrichment for which cask reactivity (k_{eff}) plus two sigma (2σ) remains below the upper safety limit (USL) of 0.9426. The maximum allowed

enrichment with the key lattice parameters is shown in Tables 6.1-1 and 6.1-2 for PWR and BWR fuel assemblies, respectively. Table 6.1-2 enrichments do not take credit for any soluble boron. At 1000 ppm soluble boron, the maximum allowed initial enrichment for all PWR fuel assembly types is 5.0 wt. % ^{235}U.

Table 6.1-1 PWR Fuel Assembly Maximum Allowed Enrichment

ID	No. of Fuel Rods	Max MTU	Max Pitch (in)	Min Rod Dia (in)	Min Clad Thick (in)	Max Pellet Dia (in)	Max Active Length (in)	No. Guide/ Instr. Tubes	Min Tube Thick (in)	Max Enrich. (wt.% ^{235}U)
ce14a	176	0.404	0.580	0.440	0.0280	0.3765	137.0	5	N/A	5.0
we14d	176	0.411	0.580	0.440	0.0260	0.3805	136.7	5	N/A	5.0
ce14my	176	0.411	0.590	0.4375	0.0240	0.3800	137.0	5	N/A	4.7
ex14a	179	0.369	0.556	0.424	0.0300	0.3505	142.0	17	0.034	5.0
we14a	179	0.414	0.556	0.422	0.0225	0.3674	145.2	17	0.034	5.0
we14b	179	0.361	0.556	0.400	0.0243	0.3444	144.0	17	0.034	5.0
ex15a	204	0.441	0.563	0.424	0.0300	0.3565	144.0	21	0.017	4.6
we15a	204	0.465	0.563	0.422	0.0242	0.3659	144.0	21	0.015	4.3
bw15a	208	0.481	0.568	0.430	0.0265	0.3686	144.0	17	0.016	4.4
ce16e	236	0.443	0.506	0.382	0.0230	0.3255	150.0	5	N/A	4.8
ex17a	264	0.412	0.496	0.360	0.0250	0.3030	144.0	25	0.016	4.4
we17a	264	0.467	0.496	0.374	0.0225	0.3225	144.0	25	0.015	4.5
we17b	264	0.428	0.496	0.360	0.0225	0.3088	144.0	25	0.015	4.3
bw17a	264	0.466	0.502	0.379	0.0240	0.3232	143.0	25	0.0175	4.4
Palisades[1]	216	0.432	0.550	0.418	0.0260	0.3580	132.0	N/A	N/A	4.2[1]
Palisades[1]	179	0.374	0.556	0.417	0.0300	0.3505	144.0	5	N/A	4.2[1]
Palisades[1]	216	0.431	0.550	0.417	0.0300	0.3580	131.8	N/A	N/A	4.2[1]

Note: Site specific.

1. Palisades 15×15 fuel assemblies and Prairie Island 14×14 assemblies are not re-evaluated and remain at the 4.2 wt% original design basis enrichment.

Table 6.1-2 BWR Fuel Assembly Maximum Allowed Enrichment

ID	No. of Fuel Rods	Max MTU	Max Pitch (in)	Min Rod Dia (in)	Min Clad Thick (in)	Max Pellet Dia (in)	Max Active Length (in)	No. Water Rods	Min Rod Thick (in)	Max Enrich. (wt.% ^{235}U)
ex07a	48	0.196	0.738	0.570	0.036	0.4900	144.0	0	N/A	4.5
ge07a	49	0.198	0.738	0.570	0.036	0.4880	144.0	0	N/A	4.5
ge07f	49	0.198	0.738	0.563	0.032	0.4870	144.0	0	N/A	4.5
ge07h	49	0.192	0.738	0.563	0.037	0.4770	146.0	0	N/A	4.7
ge08i	60	***0.1825***	0.640	***0.483***	0.032	0.4100	150.0	1	N/A	Section 6.7
ge08k	62	***0.1886***	0.640	0.483	0.032	0.4100	150.0	2	0.0300	Section 6.7
ex08b	62	***0.1845***	0.641	0.484	***0.035***	***0.4055***	150.0	2	***0.035***	Section 6.7
ge08n	63	***0.192***	0.640	0.493	0.034	0.4160	146.0	1	0.0340	Section 6.7
ex08a	63	0.177	0.641	0.484	0.036	0.4045	145.2	0	N/A	4.7
ex09b	74	0.167	0.572	0.424	0.030	0.3565	150.0	2	N/A	4.4
ge09a	74	0.185	0.566	0.441	0.028	0.3760	150.0	2	N/A	4.5
ex09c	79	0.1817	0.572	0.424	0.030	0.3565	150.0	2	***0.0305***	Section 6.7
ge09b	79	0.198	0.566	0.441	0.028	0.3760	150.0	2	0.0280	4.6
B9_72A	***72***	***0.1803***	***0.572***	***0.433***	***0.02.***	***0.374***	***150.0.***	***2***	***0.0285***	***Section 6.7***
B10_91A	***91/83***	***0.1906***	***0.51***	***0.3957***	***0.02385***	***0.342***	***150.0.***	***1***	***0.0285***	***Section 6.7***
B10_92A	***92/78***	***0.1966***	***0.51***	***0.404***	***0.026***	***0.3455***	***150.0***	***2***	***0.03***	***Section 6.7***

Note: Table includes updated characteristics that expands the Section 6.2 descriptions. Data that extends characteristics beyond those shown in Section 6.2 is obtained from Section 6.7.2 and is listed in bold italic font.

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Corresponding values for the cask containing BWR fuel assemblies are 0.38168 under normal storage conditions, 0.38586 under off-normal conditions and 0.92332 under accident conditions involving full moderator intrusion. These values reflect the following conditions:

- A method bias and uncertainty associated with KENO-Va and the 27 group ENDF/B-IV library
- An infinite cask array
- Normal condition is defined to be a dry basket, dry heat transfer annulus and dry exterior
- Accident condition is defined to be full interior, exterior and fuel clad gap moderator (water) intrusion
- Westinghouse 17×17 OFA fuel assemblies at 4.2 wt % ^{235}U (most reactive PWR fuel assembly type) or 56 Ex/ANF 9×9-79 rod fuel assemblies at 4.0 wt % ^{235}U (most reactive BWR fuel assembly type)
- No fuel burnup
- 75% of nominal ^{10}B loading in the neutron absorber
- Most reactive mechanical configuration for PWR (assemblies and fuel tubes moved toward the center of the basket; maximum fuel tube openings; minimum neutron absorber sheet widths and closely packed disk openings)
- Most reactive mechanical configuration for BWR (assemblies and fuel tubes moved toward the center of the basket)

Analysis of simultaneous moderator density variation inside and outside the concrete cask shows a monotonic decrease in reactivity with decreasing moderator density. Thus, the full moderator density situation bounds any off normal or accident condition. Analysis of moderator intrusion into the cask heat transfer annulus with a dry canister shows a slight decrease in reactivity from the completely dry situation. This is due to better neutron reflection from the concrete cask steel shell and concrete shielding with no moderator present.

Analysis of the BWR cask reactivity of the fuel assemblies in the axial region above the top of partial length rods shows this region to be less reactive than the region with all of the fuel rods present. Therefore, it is appropriate to represent partial length rods as full length rods in the BWR fuel models.

6.4.3.2 Criticality Results for PWR Fuel

Transfer Cask

Results of the calculations for the standard transfer cask containing PWR fuel are provided in Tables 6.4-11 through 6.4-13. The tables list k_s without the Δk penalty associated with neutron absorber plates. A Δk of 0.00246 is added in the k_s listed below. CSAS input for the normal conditions analysis for the standard transfer cask is provided in Figure 6.9-1. Figure 6.9-2 provides CSAS input for the standard transfer cask analysis under hypothetical accident conditions.

Under normal conditions involving loading, draining and drying, the maximum k_{eff} including bias and uncertainties (k_s) is 0.93921 for the standard transfer cask. In the accident situation involving fuel failure and moderator intrusion, the maximum k_{eff} including biases and uncertainties (k_s) is 0.94749. Thus, the multiplication factor for the standard transfer cask containing 24 design basis PWR fuel assemblies of the most reactive type in the most reactive configuration is below the NRC criticality safety limit of 0.95 including all biases and uncertainties under normal, and accident conditions.

Vertical Concrete Cask

Results of the calculations for the Vertical Concrete Cask containing PWR fuel are provided in Tables 6.4-14 through 6.4-16. Figure 6.9-3 provides CSAS input for the analysis of the cask under normal conditions. Figure 6.9-4 provides CSAS input for the concrete cask analysis for hypothetical accident conditions.

Under normal dry conditions, maximum k_{eff} including biases and uncertainty (k_s) is 0.38329 for the concrete cask. Under off-normal conditions involving flooding of the heat transfer annulus, the k_s of the cask is even less (0.37420). Under accident conditions involving full moderator intrusion into the canister and fuel clad gap, the maximum k_s of the concrete cask is 0.94704. Thus, the multiplication factor for the concrete cask containing 24 design basis PWR fuel assemblies of the most reactive type in the most reactive configuration is below the NRC criticality safety limit of 0.95 including all biases and uncertainties under normal, off-normal, and accident conditions.

6.4.3.3 Criticality Results for BWR Fuel

Transfer Cask

Results of the criticality calculations for the standard transfer cask containing BWR fuel are provided in Tables 6.4-17 through 6.4-19. CSAS input for the normal conditions analysis for the standard transfer cask are provided in Figure 6.9-5. Figure 6.9-6 provides CSAS input for the analysis for the standard transfer cask hypothetical accident conditions.

As the tables show, under normal conditions involving loading, draining and drying, the maximum k_{eff} including bias and uncertainties is 0.91919 for the standard transfer cask. In the accident condition involving fuel failure and moderator intrusion, the maximum k_{eff} including biases and uncertainties is 0.92235. Thus, the multiplication factor for the transfer cask containing 56 design basis BWR fuel assemblies of the most reactive type in the most reactive configuration is below the NRC criticality safety limit of 0.95 including all biases and uncertainties under normal, and accident conditions.

Vertical Concrete Cask

Tables 6.4-20 through 6.4-22 provide results of the criticality calculations for the Vertical Concrete Cask containing BWR fuel assemblies. CSAS input for the normal condition analysis for the concrete cask are provided in Figure 6.9-7. Figure 6.9-8 provides CSAS input under hypothetical accident conditions.

For the concrete cask containing BWR fuel, under normal dry conditions, maximum k_{eff} including biases and uncertainty is calculated to be 0.38168. Under off-normal conditions involving flooding of the heat transfer annulus, the k_{eff} of the cask is 0.38586. Under accident conditions involving full moderator intrusion into the canister and fuel clad gap, the maximum k_{eff} of the concrete cask is 0.92332. Thus, the multiplication factor for the concrete cask containing 56 design basis BWR fuel assemblies of the most reactive type in the most reactive configuration is below the NRC criticality safety limit of 0.95 including all biases and uncertainties under normal, off-normal, and accident conditions.

6.4.4 Fuel Assembly Lattice Dimension Variations

The nominal lattice dimensions for the most reactive PWR and BWR fuel under the most reactive accident conditions are varied to determine if dimensional perturbations significantly affect the reactivity of the system. Accident conditions are defined to be full interior, exterior and fuel-clad gap moderator (water) intrusion at a density of 1 g/cc and a temperature of 70 ^{o}F. Flooding the fuel-clad gap magnifies the effect on reactivity from lattice dimensional variations by adding or removing moderator from the undermoderated fuel lattice. The conclusions drawn are then used to establish fuel dimension limits for the PWR and BWR fuel assemblies previously evaluated as UMS® contents nominal fuel assembly dimensions.

The PWR analysis is performed modeling a Westinghouse 17×17 OFA fuel assembly in an infinite array of infinitely tall fuel tube cells. This prevents any leakage of neutrons from the system. The BWR analysis is performed modeling an infinite array of infinitely tall Vertical Concrete Casks filled with Exxon/ANF 9×9 fuel assemblies. The following fuel assembly nominal lattice dimensions are modified to determine if these perturbations significantly affect the reactivity of the system:

a) Pellet Radius
b) Clad Inner Radius
c) Clad Outer Radius
d) Water Rod Inner Radius
e) Water Rod Outer Radius

As shown in Tables 6.4-23 and 6.4-24, the following dimensional perturbations were determined to significantly decrease the reactivity of both the PWR and the BWR systems: decreasing the clad inner radius and increasing the clad outer radius. Decreasing the pellet radius of the BWR fuel assembly was also determined to significantly decrease the reactivity. The results are as expected as these perturbations decrease the H/U ratio in the undermoderated fuel lattice. Additionally, varying the BWR water rod dimensions was determined to have an insignificant effect on the reactivity of the system. Therefore, these nominal dimension variations are of no concern with regards to the criticality safety of the system.

6.5 Critical Benchmark Experiments

Criticality code validation is performed for the CSAS analysis sequence in the SCALE 4.3 package in Section 6.5.1, for the MONK8A code of the ANSWERS software package in Section 6.5.2, and for MCNP in Section 6.5.3.

6.5.1 SCALE 4.3 Benchmark Experiments and Applicability

This section provides the validation of the CSAS25 criticality analysis sequence contained in Version 4.3 of the SCALE package. CSAS includes the SCALE Material Information Processor, BONAMI-S, NITAWL-S, and KENO-Va. The Material Information Processor generates number densities for standard compositions, prepares geometry data for resonance self-shielding, and creates data input files for the cross-section processing codes. The BONAMI-S and NITAWL- S codes are used to prepare a resonance-corrected cross-section library in AMPX working format. The KENO-Va code uses Monte Carlo techniques to calculate the model k_{eff}. The 27-group ENDF/B-IV neutron cross-section library is used in this validation. The CSAS validation is required by the criticality safety standards ANSI/ANS-8.1 [11]. The section describes the method, computer program and cross-section libraries used, experimental data, areas of applicability, and bias and margins of safety.

ANSI/ANS-8.17 [12] prescribes the criterion to establish subcriticality safety margins. This criterion is as follows:

$$k_s \leq k_c - \Delta k_s - \Delta k_c - \Delta k_m \qquad (1)$$

where:

k_s = calculated allowable maximum multiplication factor, k_{eff}, of system being evaluated for all normal or credible abnormal conditions or events.

k_c = mean k_{eff} that results from calculation of benchmark criticality experiments using particular calculational method. If calculated k_{eff} values for criticality experiments exhibit trend with parameter, then k_c shall be determined by extrapolation based on best fit to calculated values. Criticality experiments used as benchmarks in computing k_c should have physical compositions, configurations, and nuclear characteristics (including reflectors) similar to those of system being evaluated.

Δk_s = allowance for

a. statistical or convergence uncertainties, or both, in computation of k_s,
b. material and fabrication tolerances, and
c. geometric or material representations used in computational method.

Δk_c = margin for uncertainty in k_c which includes allowance for

a. uncertainties in critical experiments,
b. statistical or convergence uncertainties, or both, in computation of k_c,
c. uncertainties resulting from extrapolation of k_c outside range of experimental data, and
d. uncertainties resulting from limitations in geometrical or material representations used in computational method.

Δk_m = arbitrary margin to ensure subcriticality of k_s.

The various uncertainties are combined statistically if they are independent. Correlated uncertainties are combined by addition.

Equation 1 can be rewritten as:

$$k_s \leq 1 - \Delta k_m - \Delta k_s - (1-k_c) - \Delta k_c \qquad (2)$$

Noting that the NRC requires a 5% subcriticality margin ($\Delta k_m = 0.05$) and the definition of the bias ($\beta = 1-k_c$), the equation 2 can then be written as:

$$k_s \leq 0.95 - \Delta k_s - \beta - \Delta\beta \qquad (3)$$

where $\Delta\beta = \Delta k_c$. Thus, the k_s (the maximum allowable value for k_{eff}) must be below 0.95 minus the bias, uncertainties in the bias, and uncertainties in the system being analyzed (i.e., Monte Carlo, mechanical, and modeling). This is an upper safety limit criteria often used in the DOE criticality safety community.

Table 6.5.2-3 MONK8A – JEF 2.2 Library Validation Statistics (continued)

Case	Configuration	wt % ^{235}U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G ^{10}B/cm^2	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k_{eff} (JEF2.2)	σ
50.01	triangular pitch	3.6	1.27	0.76	0.905	Zr	134.24	0	None	na	na	na	Water	2.40E-07	1.0005	0.0010
50.02	triangular pitch	3.6	1.27	0.76	0.905	Zr	134.23	193	None	na	na	na	Water	3.40E-07	1.0013	0.0010
50.03	triangular pitch	3.6	1.27	0.76	0.905	Zr	134.20	700	None	na	na	na	Water	3.50E-07	1.0054	0.0010
50.04	triangular pitch	3.6	1.27	0.76	0.905	Zr	134.18	1014	None	na	na	na	Water	3.71E-07	1.0042	0.0010
50.05	triangular pitch	3.6	1.27	0.76	0.905	Zr	134.16	1258	None	na	na	na	Water	3.82E-07	1.0044	0.0010
50.06	triangular pitch	3.6	1.1	0.76	0.905	Zr	72.08	0	None	na	na		Water	7.84E-07	1.0003	0.0010
50.07	triangular pitch	3.6	1.1	0.76	0.905	Zr	72.08	168	None	na	na		Water	8.38E-07	0.9990	0.0010
50.08	triangular pitch	3.6	1.5	0.76	0.905	Zr	232.53	0	None	na	na		Water	1.55E-07	1.0006	0.0010
50.09	triangular pitch	3.6	1.5	0.76	0.905	Zr	232.45	700	None	na	na		Water	1.81E-07	1.0054	0.0010
50.10	triangular pitch	4.4	1.5	0.76	0.905	Zr	189.50	0	None	na	na		Water	1.54E-07	1.0002	0.0010
50.11	triangular pitch	3.6	1.905	0.76	0.905	Zr	445.28	0	None	na	na		Water	7.67E-08	1.0033	0.0010
50.12	triangular pitch	3.6	1.27	0.76	0.905	Zr	185.93	0	None	na	na		Water	1.97E-07	0.9986	0.0010
50.13	triangular pitch	4.4	1.27	0.76	0.905	Zr	109.40	0	None	na	na		Water	2.76E-07	1.0001	0.0010
50.14	triangular pitch	4.4	1.27	0.76	0.905	Zr	109.39	112	None	na	na		Water	2.86E-07	1.0032	0.0010
50.15	triangular pitch	4.4	1.27	0.76	0.905	Zr	114.01	0	None	na	na		Water	1.37E-07	0.9986	0.0010
50.16	triangular pitch	4.4	1.27	0.76	0.905	Zr	118.14	1258	None	na	na		Water	3.62E-07	1.0042	0.0010
50.17	triangular pitch	3.6	1.5	0.76	0.905	Zr	350.93	0	None	na	na		Water	1.09E-07	0.9974	0.0010

6.5.3 MCNP Validation

6.5.3 MCNP 6 Critical Benchmark Experiments

Criticality code validation is performed for the MCNP Monte Carlo evaluation code and neutron cross-section libraries. Criticality validation is required by the criticality safety standards ANSI/ANS-8.1 [11].

6.5.3.1 Benchmark Experiments and Applicability

NUREG/CR-6361, "Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages" (NUREG), provides a guide to LWR criticality benchmark calculations and the determination of bias and subcritical limits in critical safety evaluations. In Section 2 of the NUREG, a series of LWR critical experiments are described in sufficient detail for independent modeling. In Section 3, the critical experiments are modeled, and the results (keff values) are presented. The method utilized in the NUREG is KENO-Va with the 44-group ENDF/B-V cross-section library embedded in SCALE 4.3. In Section 4, a guide for the determination of bias and subcritical safety limits is provided based on ANSI/ANS-8.17 [12] and statistical analysis of the trending in the bias. Finally, guidelines for experiment selection and applicability are presented in Section 5. The approach outlined in Section 4 of the NUREG is described in detail herein and is implemented for MCNP6.2 with ENDF/B-VII cross sections.

The NUREG/CR-6361 implements ANSI/ANS-8.17 criticality safety criterion as follows.

$$k_s \leq k_c - \Delta k_s - \Delta k_c - \Delta k_m \qquad \text{(Equation 1)}$$

where:

k_s = calculated allowable maximum multiplication factor, k_{eff}, of the system being evaluated for all normal or credible abnormal conditions or events.

k_c = mean k_{eff} that results from a calculation of benchmark criticality experiments using a particular calculation method. If the calculated k_{eff} values for the criticality experiments exhibit a trend with an independent parameter, then k_c shall be determined by extrapolation based on best fit to calculated values. Criticality experiments used as benchmarks in computing k_c should have physical compositions, configurations, and nuclear characteristics (including reflectors) similar to those of the system being evaluated.

Δk_s = allowance for the following.

- statistical or convergence uncertainties, or both, in computation of k_s
- material and fabrication tolerances
- geometric or material representations used in computational method

Δk_c = margin for uncertainty in k_c, which includes allowance for the following.

- uncertainties in critical experiments
- statistical or convergence uncertainties, or both, in computation of k_c
- uncertainties resulting from extrapolation of k_c outside range of experimental data
- uncertainties resulting from limitations in geometrical or material representations used in the computational method

Δk_m = arbitrary administrative margin to ensure subcriticality of k_s

The various uncertainties are combined statistically if they are independent. Correlated uncertainties are combined by addition.

Equation 1 can be rewritten as shown.

$$k_s \leq 1 - \Delta k_m - \Delta k_s - (1 - k_c) - \Delta k_c \qquad \text{(Equation 2)}$$

Noting that the definition of the bias is $\beta = 1 - k_c$, Equation 2 can be written as shown.

$$k_s + \Delta k_s \leq 1 - \Delta k_m - \beta - \Delta\beta \qquad \text{(Equation 3)}$$

where:

$$\Delta\beta = \Delta k_c$$

Thus, the maximum allowable value for keff plus uncertainties in the system being analyzed must be below 1 minus an administrative margin (typically 0.05), which includes the bias and the uncertainty in the bias. This can also be written as shown.

$$k_s + \Delta k_s \leq \text{Upper Subcritical Limit (USL)} \qquad \text{(Equation 4)}$$

where:

$$USL \equiv 1 - \Delta k_m - \beta - \Delta\beta \qquad \text{(Equation 5)}$$

This is the USL criterion as described in Section 4 of NUREG/CR-6361. Two methods are prescribed for the statistical determination of the USL. The “Confidence Band with Administrative Margin (USL-1)” approach is implemented here and is referred to generically as USL. A $\Delta km = 0.05$ and a lower confidence band are specified based on a linear regression of keff as a function of some system parameter. As recommended in NUREG/CR-6361, a simple linear regression is performed on each system parameter, and the line with the greatest correlation is used to functionalize β.

Section 6.5.3.3 contains the extensive list of LWR critical benchmarks employed in the validation of MCNP with its continuous energy neutron cross-section libraries. The range of parameters included in the benchmarks is shown in Table 6.5.3-1.

Included in Section 6.5.3.3 are linear fits of reactivity (keff) to each of the system parameters using MCNP6.2 with ENDF/B-VII. Experiments were chosen to reflect the fuel and basket geometry and materials, and the spent fuel cask criticality control mechanism. This includes the use of square pitched, low enriched uranium oxide fuel rods, a rectangular arrangement of assembles,

light water moderation, and criticality control by spacing, borated moderator, and/or borated absorber panels and tubes. Trending in keff was evaluated for the following independent variables: wt % 235U, rod pitch, H/U volume ratio, energy of the average neutron lethargy causing fission (EALCF), 10B loading of the absorber sheet, and soluble boron loading. No statistically significant trends were found for any of the system parameters. USLs are, therefore, generated for each of the independent variables. A minimum USL covering the range of applicability of the benchmark set is determined as detailed in Section 6.5.3.2.

6.5.3.2 Results of Benchmark Calculations

To evaluate the relative importance of the trend analysis to the upper subcritical limits, correlation coefficients are required for all independent parameters. The linear correlation coefficient, R, is calculated by taking the square root of the R2 value. In particular, the correlation coefficient, R, is a measure of the linear relationship between keff and a critical experiment parameter. If R is +1, a perfect linear relationship with a positive slope is indicated; and if R is -1, a perfect linear relationship with a negative slope is indicated. When R is 0, no linear relationship is indicated.

Table 6.5.3-2 contains the correlation coefficient, R, for each linear fit of keff versus experimental parameter. Linear fits and correlation constants are based on the 183 data-point evaluation sets plotted in Section 6.5.3. The cluster gap plot is limited to the 137 data points for experiments containing multiple fuel rod clusters. Single fuel rod cluster experiments documented in LEU-COMP-THERM sets 06, 14, 35 and 50, in addition to LEU-COMP-THERM experiments 01-01, 02-01 to -03, and 08-01 to -15, were therefore excluded from the cluster gap study. The 183 data points evaluated for the remaining parameters represent the complete set of experiments listed in Section 6.5.3 minus the three high energy lethargy experiments above 0.35 eV (Experiments LEU-COMP-THERM 14-05, -06 and -07). Addition of these points, while not resulting in a significant linear fit, produces a noticeable slope to the USL correlation not representative of the remaining data fits. As this increased slope results in a higher USL, it is acceptable to discard these data points. The three higher energy points are removed from all independent variables for consistency.

As there is no significant correlation to any of the independent variables, the USL for each independent variable is calculated and shown with its range of applicability in Table 6.5.3-2. Uncertainties included in the USLSTATS evaluation are the Monte Carlo uncertainty associated with the reactivity calculation and experimental uncertainty that was provided in the literature for each of the cases.

Based on all the independent variable correlations, a lower limit constant USL of 0.9427 may be applied. The range of applicability (area of applicability) of this limit may be extended to 5 wt % enriched fuel, as the correlation shows no significant trend with enrichment between 2.35 and 4.74 wt %, and that the limited trending observed increases the USL. Extending the range of

applicability for the average neutron lethargy is based on a minimal, but positive, trend of the USL versus EALCF. Studies, including additional data points up to 0.7722 eV, indicate that the trending continues to the higher energy levels.

Table 6.5.3-1 Range of Applicability for Complete Set of 186 Benchmark Experiments

Parameter	Minimum	Maximum
Enrichment (wt % ^{235}U)	2.350%	4.738%
Fuel rod pitch (cm)	1.30	2.54
Fuel pellet outer diameter (cm)	0.790	1.265
Fuel rod diameter (cm)	0.9400	1.4172
H/^{235}U atom ratio	72.7	403.9
Soluble boron (ppm by weight)	0	4986
Cluster Gap (cm)	1.206	13.750
Boron (^{10}B) plate loading (g/cm^2)	0.0000	0.0670
Energy of average neutron lethargy causing fission (eV)	0.09781	0.77219

Table 6.5.3-2 LEU Fresh Fuel Correlation Coefficients and USLs for Benchmark Experiments for MCNP6.2

Variable	R2	R	Range of Applicability	USLSTATS Correlation	USL Low	USL High
Enrichment (wt % 235U)	0.0375	0.1936	2.35<=X<=4.738	0.9449 - 4.39E-04X	0.9439	0.9429
Fuel rod pitch (cm)	0.0040	0.0632	1.3<=X<=2.54	0.9443 - 3.90E-04X	0.9433	0.9438
Fuel pellet outer diameter (cm)	0.0653	0.2555	0.79<=X<=1.265	0.9393 + 3.84E-03X	0.9423	0.9441
Fuel rod diameter (cm)	0.0774	0.2782	0.94<=X<=1.4170	0.9382 + 4.21E-03X	0.9421	0.9442
H/235U atom ratio	0.0576	0.2400	72.7<=X<=403.9	0.9452 - 5.83E-06X	0.9428	0.9445
Soluble boron (ppm by weight)	0.0348	0.1865	0<=X<=4986	0.9429 + 5.33E-07X	0.9429	0.9441
Cluster gap (cm)	0.0484	0.2200	1.2<=X<=13.8	0.9419 + 1.57E-04X	0.9420	0.9440
Boron (10B) plate loading (g/cm2)	0.0028	0.0529	0<=X<=0.067	0.9433 - 8.33E-03X	0.9428	0.9433
Energy of average neutron lethargy causing fission (eV)	0.1723	0.4151	0.0973<=X<=0.760	0.9413 + 1.45E-02X	0.9427	0.9448

6.5.3.3 Critical Benchmarks

From the International Handbook of Evaluated Criticality Safety Benchmark Experiments [8], 186 experiments are selected as basis of the MCNP benchmarking. Experiments were selected for compatibility of materials and geometry with the spent fuel casks. Of particular interest are benchmarks with rectangular arrays of low enriched uranium oxide fuel rods in which reactivity is controlled by soluble boron or borated plates (tubes).

MCNP benchmark cases represent a collection of files composed of inputs directly obtained from references (with cross-section sets adjusted to those used in the cask analysis), NAC modified input files representing unique geometries based on reference input files, and input files constructed from the experimental material and geometry information. All cases were reviewed on a "preparer/checker" principle for modeling consistency with the cask models and the choice of code options. Due to large variations in the benchmark complexities, not all options employed in the cask models are reflected in each of the benchmarks (e.g., UNIVERSE structure). A review of the criticality results did not indicate any result trend due to particular modeling choices (e.g., using the UNIVERSE structure versus a single universe, or employing KSRC versus SDEF sampling).

Key system parameters, the experimental uncertainty, and calculated keff and σ for each experiment are shown in Table 6.5.3-3 and Table 6.5.3-4. Stochastic Monte Carlo error is kept within ±0.2% and each output is checked to assure that the MCNP built-in statistical checks on the results are passed and that all fissile material is sampled.

Scatter plots of keff versus system parameters for 183 data point sets (full set minus three high lethargy points above 0.35 eV) are created (see Figure 6.5.3-1 through Figure 6.5.3-9). Included in these scatter plots are linear regression lines with a corresponding correlation coefficient (R2) to statistically indicate any trend or lack thereof. Scatter plates are created for keff versus the following.

Enrichment in ^{235}U (wt % ^{235}U)
Fuel rod pitch (cm)
Fuel pellet outer diameter (cm)
Fuel rod outer diameter (cm)
Hydrogen/uranium (^{235}U) atom ratio
Soluble boron (ppm by weight)
Cluster gap spacing (spacing between assemblies in cm)
Boron (^{10}B) plate loading (g/cm^2)
Energy of average neutron lethargy causing fission (eV)

Figure 6.5.3-1 LEU Fresh Fuel k_{eff} versus Fuel Enrichment for MCNP6.2

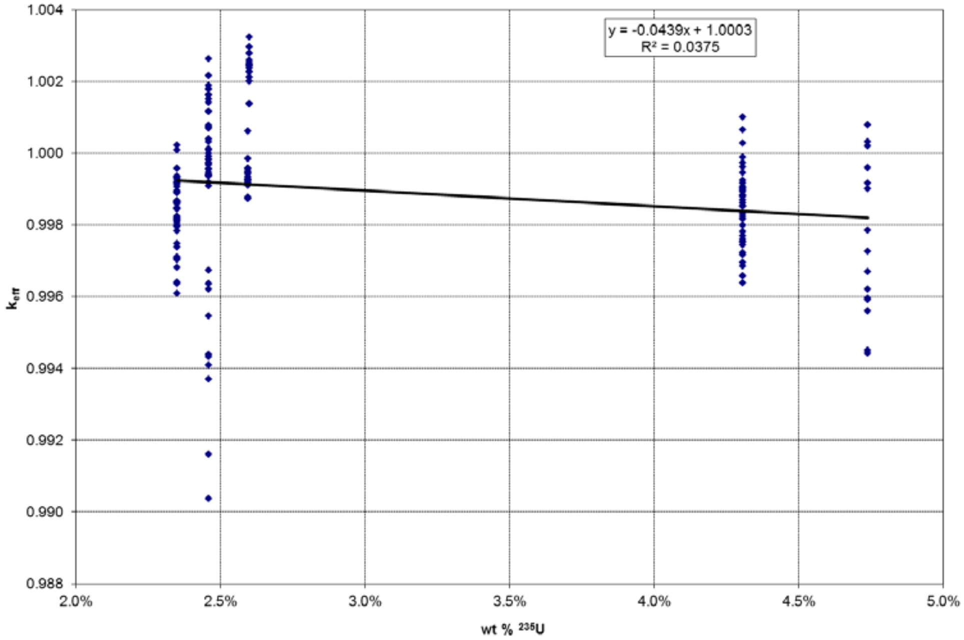

Figure 6.5.3-2 LEU Fresh Fuel k_{eff} versus Rod Pitch for MCNP6.2

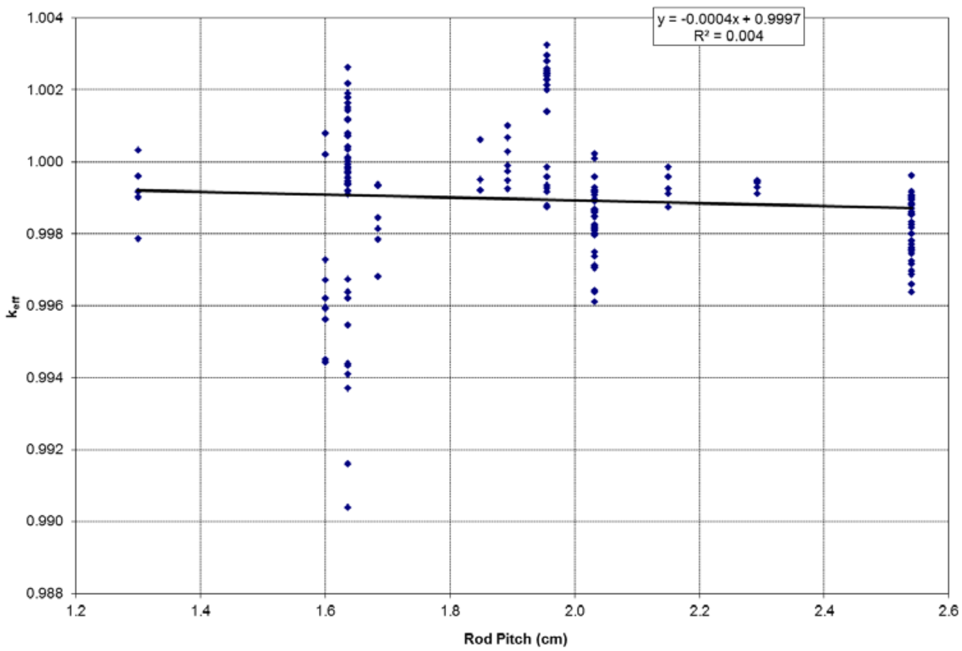

Figure 6.5.3-3 LEU Fresh Fuel k_{eff} versus Fuel Pellet Diameter for MCNP6.2

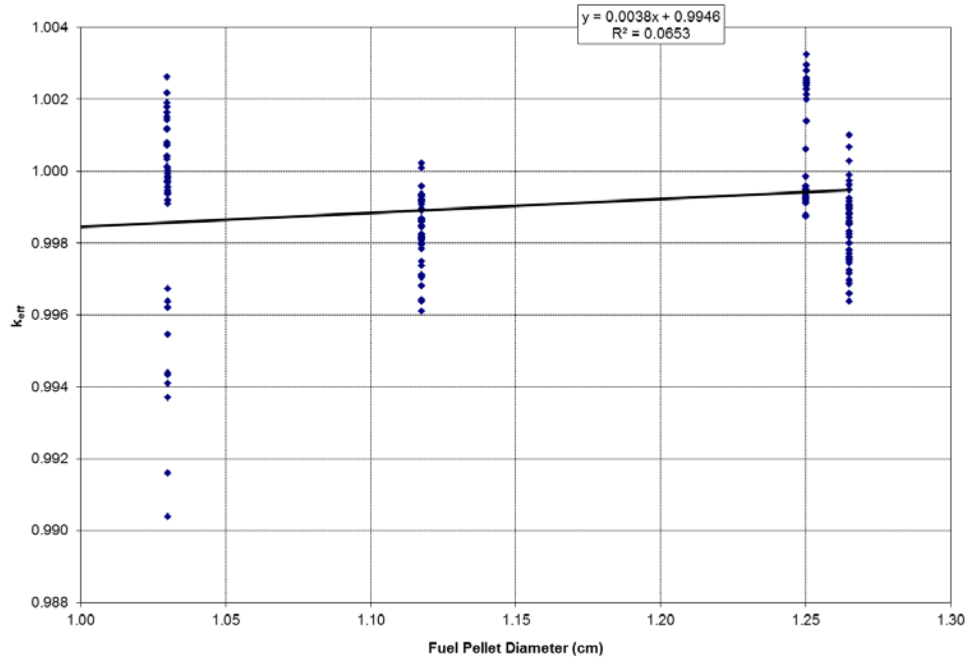

Figure 6.5.3-4 LEU Fresh Fuel k_{eff} versus Fuel Rod Outside Diameter for MCNP6.2

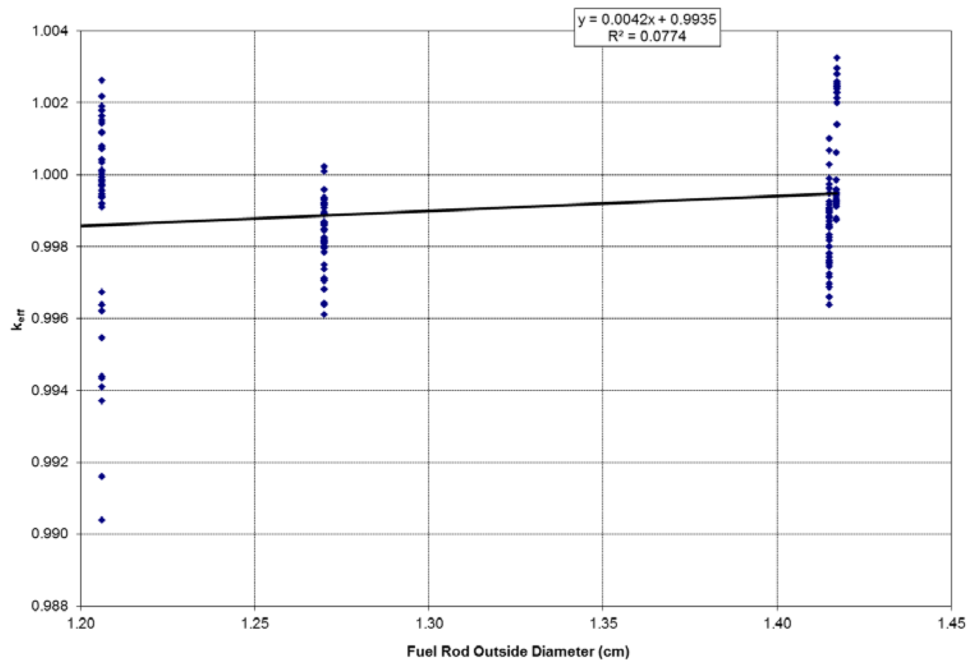

Figure 6.5.3-5 LEU Fresh Fuel k_{eff} versus Hydrogen/^{235}U Atom Ratio for MCNP6.2

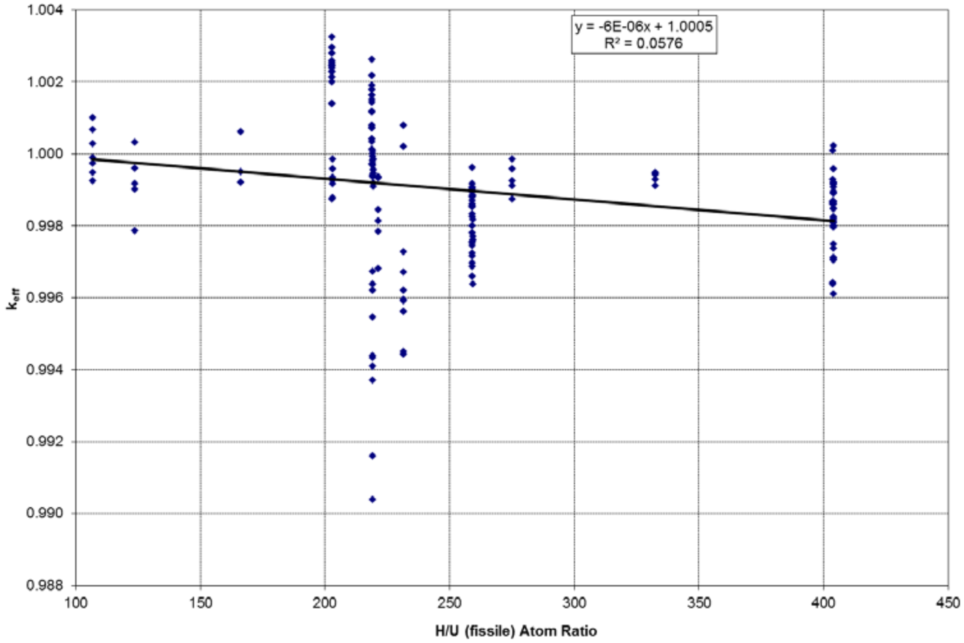

Figure 6.5.3-6 LEU Fresh Fuel k_{eff} versus Soluble Boron Concentration for MCNP6.2

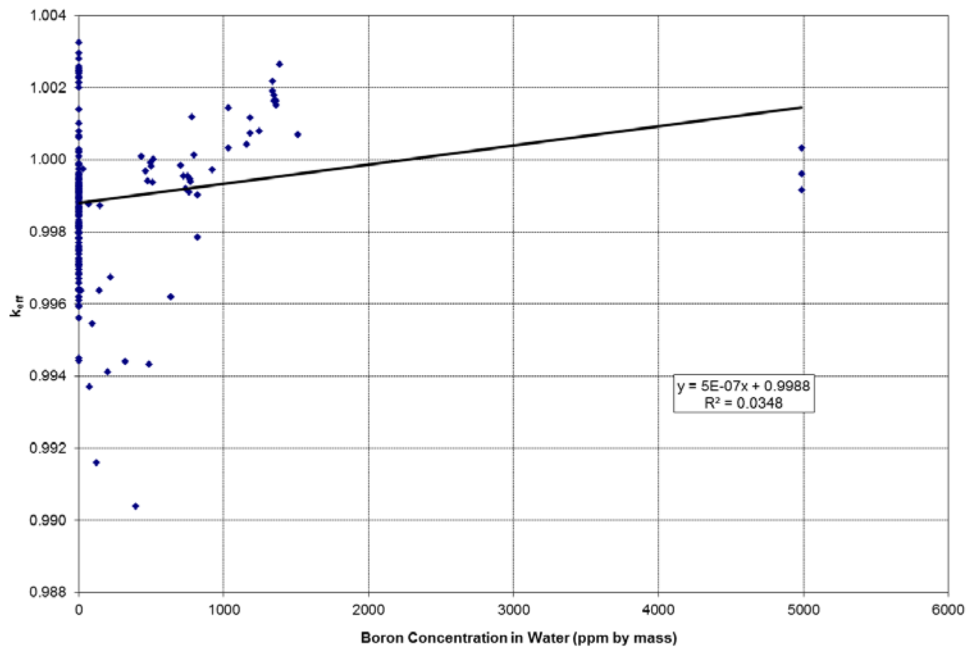

Figure 6.5.3-7 LEU Fresh k_{eff} versus Cluster Gap Thickness for MCNP6.2

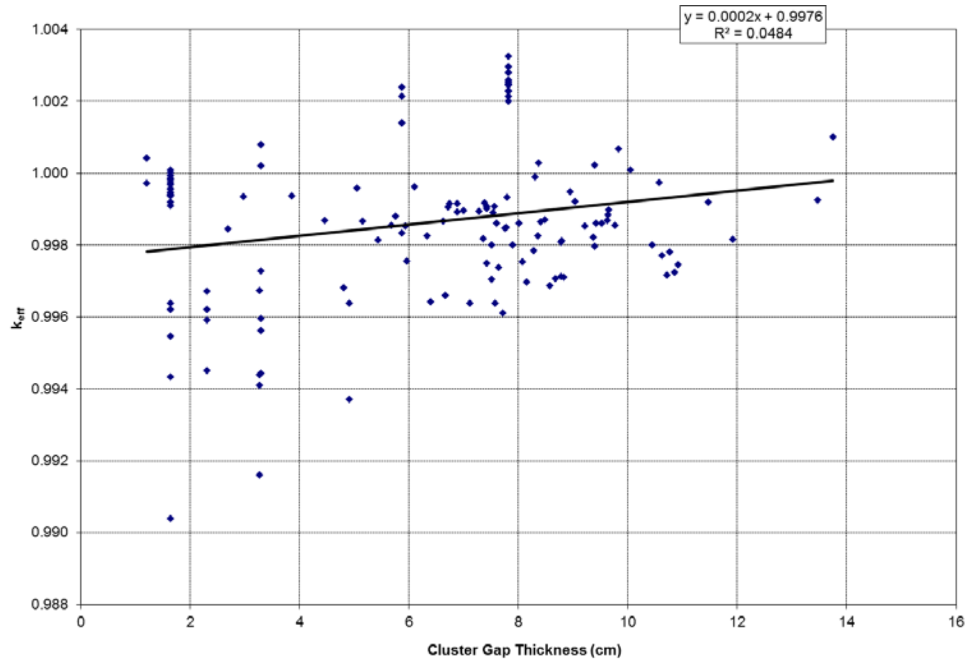

Figure 6.5.3-8 LEU Fresh Fuel k_{eff} versus ^{10}B Plate Loading for MCNP6.2

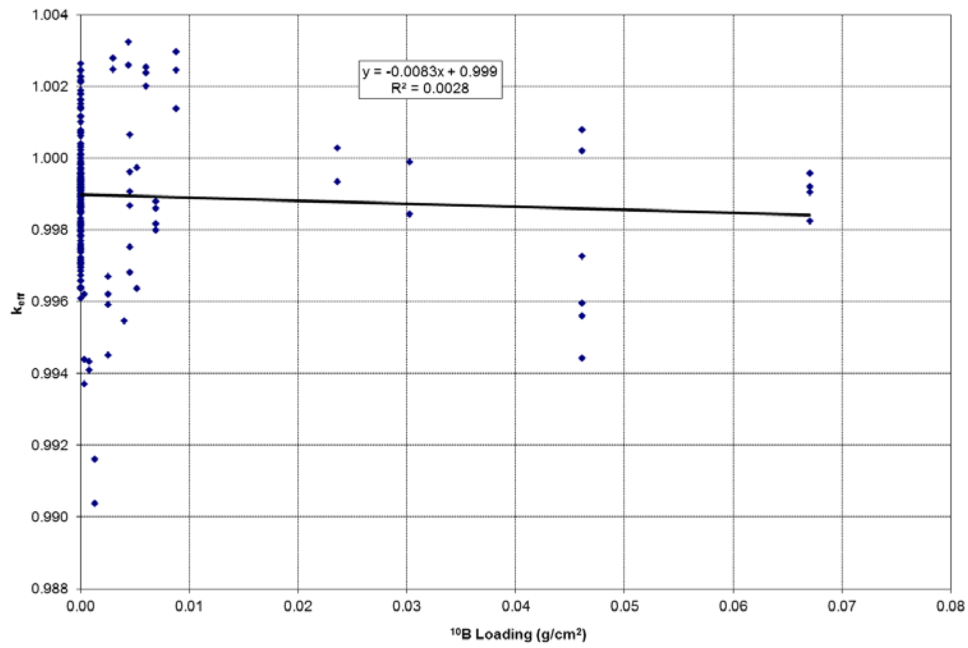

Figure 6.5.3-9 LEU Fresh Fuel k_{eff} versus Energy of Average Neutron Lethargy Causing Fission for MCNP6.2

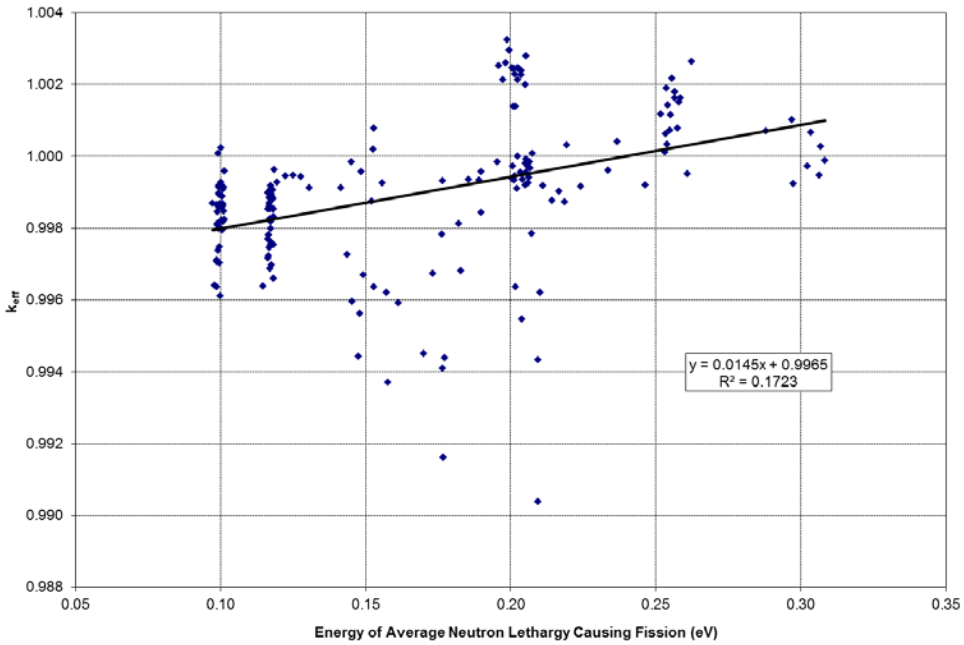

Table 6.5.3-3 MCNP Validation Statistics

Case	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08
Clusters	1	3	3	3	3	3	3	3
Enrichment (wt % ^{235}U)	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%
Pitch (cm)	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032
Fuel OD (cm)	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118
Clad OD (cm)	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270
Clad Mat'l	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	404	404	404	404	404	404	404	404
Soluble B (ppm)	-	-	-	-	-	-	-	-
Absorber Type	-	-	-	-	-	-	-	-
Cluster Gap (cm)	-	11.9	8.4	10.1	6.4	8.0	4.5	7.6
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading (g ^{10}B /cm^2)	-	-	-	-	-	-	-	-
EALCF (MeV)	9.916E-8	1.010E-7	9.838E-8	9.933E-8	9.837E-8	9.874E-8	9.781E-8	9.826E-8
Exp. σ	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0031	0.0030

Table 6.5.3-3 MCNP Validation Statistics (cont.)

Case	6.10	6.11	6.12	6.13	6.14	6.15	6.16	6.17	6.18
Clusters	1	1	1	1	1	1	1	1	1
Enrichment (wt %^{235}U)	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%
Pitch (cm)	2.150	2.150	2.150	2.150	2.293	2.293	2.293	2.293	2.293
Fuel OD (cm)	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250
Clad OD (cm)	1.417	1.417	1.417	1.417	1.417	1.417	1.417	1.417	1.417
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	275	275	275	275	332	332	332	332	332
Soluble B (ppm)	-	-	-	-	-	-	-	-	-
Absorber Type	-	-	-	-	-	-	-	-	-
Cluster Gap (cm)	-	-	-	-	-	-	-	-	-
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading (g^{10}B /cm^2)	-	-	-	-	-	-	-	-	-
EALCF (MeV)	1.453E-7	1.496E-7	1.523E-7	1.568E-7	1.202E-7	1.227E-7	1.257E-7	1.280E-7	1.306E-7
Exp. σ	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020

Table 6.5.3-3 MCNP Validation Statistics (cont.)

Case	8.01	8.02	8.03	8.04	8.05	8.06	8.07	8.08
Clusters	3 x 3	3 x 3	3 x 3	3 x 3	3 x 3	3 x 3	3 x 3	3 x 3
Enrichment (wt % ^{235}U)	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%
Pitch (cm)	1.636	1.636	1.636	1.636	1.636	1.636	1.636	1.636
Fuel OD (cm)	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030
Clad OD (cm)	1.206	1.206	1.206	1.206	1.206	1.206	1.206	1.206
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	219	219	219	219	219	219	219	219
Soluble B (ppm)	1511	1336	1336	1182	1182	1033	1033	794
Absorber Type	-	-	-	-	-	-	-	-
Cluster Gap (cm)	-	-	-	-	-	-	-	-
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading (g ^{10}B /cm ^{2})	-	-	-	-	-	-	-	-
EALCF (MeV)	2.907E-7	2.583E-7	2.559E-7	2.548E-7	2.566E-7	2.568E-7	2.544E-7	2.548E-7
Exp. σ	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012

Table 6.5.3-3 MCNP Validation Statistics (cont.)

Case	8.09	8.10	8.11	8.12	8.13	8.14	8.15	8.16	8.17
Clusters	3 x 3	3 x 3	3 x 3	3 x 3	3 x 3	3 x 3	3 x 3	5	5 x 5
Enrichment (wt %^{235}U)	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%
Pitch (cm)	1.636	1.636	1.636	1.636	1.636	1.636	1.636	1.636	1.636
Fuel OD (cm)	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030
Clad OD (cm)	1.206	1.206	1.206	1.206	1.206	1.206	1.206	1.206	1.206
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	219	219	219	219	219	219	219	219	219
Soluble B (ppm)	779	1245	1384	1348	1348	1363	1363	1158	921
Absorber Type	-	-	-	-	-	-	-	-	-
Cluster Gap (cm)	-	-	-	-	-	-	-	1.2	1.2
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading (g^{10}B /cm^2)	-	-	-	-	-	-	-	-	-
EALCF (MeV)	2.538E-7	2.586E-7	2.647E-7	2.587E-7	2.582E-7	2.600E-7	2.609E-7	2.379E-7	2.063E-7
Exp. σ	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012

Table 6.5.3-3 MCNP Validation Statistics (cont.)

Case	9.01	9.02	9.03	9.04	9.05	9.06	9.07	9.08	9.09	9.10	9.11	9.12	9.13
Clusters	3	3	3	3	3	3	3	3	3	3	3	3	3
Enrichment (wt $\%^{235}U$)	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%
Pitch (cm)	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540
Fuel OD (cm)	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265
Clad OD (cm)	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	259	259	259	259	259	259	259	259	259	259	259	259	259
Soluble B (ppm)	-	-	-	-	-	-	-	-	-	-	-	-	-
Absorber Type	304L SS (no B)	304L SS (no B)	304L SS (no B)	304L SS (no B)	304L SS (1.05% B)	304L SS (1.05% B)	304L SS (1.62% B)	304L SS (1.62% B)	Boral	Cu	Cu	Cu	Cu
Cluster Gap (cm)	8.6	9.7	9.2	9.8	6.1	8.1	5.8	7.9	6.7	8.2	9.4	8.5	9.6
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading ($g^{10}B/cm^2$)	0.00000	0.00000	0.00000	0.00000	0.00455	0.00455	0.00690	0.00690	0.06704	-	-	-	-
EALCF(MeV)	1.183E-7	1.181E-7	1.168E-7	1.179E-7	1.182E-7	1.182E-7	1.191E-7	1.182E-7	1.183E-7	1.173E-7	1.176E-7	1.169E-7	1.163E-7
Exp. σ	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021

Table 6.5.3-3 MCNP Validation Statistics (cont.)

Case	9.14	9.15	9.16	9.17	9.18	9.19	9.20	9.21	9.22	9.23	9.24	9.25	9.26	9.27
Clusters	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Enrichment (wt %^{235}U)	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%
Pitch (cm)	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540
Fuel OD (cm)	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265
Clad OD (cm)	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	259	259	259	259	259	259	259	259	259	259	259	259	259	259
Soluble B (ppm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Absorber Type	Cu (0.989 wt % Cd)	Cu (0.989 wt % Cd)	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Al (no B)	Al (no B)	Zircaloy-4	Zircaloy-4
Cluster Gap (cm)	6.7	8.4	5.9	7.4	6.0	7.4	5.9	7.4	5.7	7.3	10.7	10.8	10.9	10.9
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading (g^{10}B /cm^2)	-	-	-	-	-	-	-	-	-	-	0.00000	0.00000	-	-
EALCF(MeV)	1.186E-7	1.171E-7	1.186E-7	1.183E-7	1.183E-7	1.168E-7	1.182E-7	1.187E-7	1.199E-7	1.173E-7	1.167E-7	1.165E-7	1.181E-7	1.177E-7
Exp. σ	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021

Table 6.5.3-3 MCNP Validation Statistics (cont.)

Case	11.03	11.04	11.05	11.06	11.07	11.08	11.09
Clusters	3	3	3	3	3	3	3
Enrichment (wt % ^{235}U)	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%
Pitch (cm)	1.636	1.636	1.636	1.636	1.636	1.636	1.636
Fuel OD (cm)	1.030	1.030	1.030	1.030	1.030	1.030	1.030
Clad OD (cm)	1.206	1.206	1.206	1.206	1.206	1.206	1.206
Clad Material	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	219	219	219	219	219	219	219
Soluble B (ppm)	769	764	762	753	739	721	702
Absorber Type	-	-	-	-	-	-	-
Cluster Gap (cm)	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading (g ^{10}B /cm ^{2})	-	-	-	-	-	-	-
EALCF [MeV]	2.027E-7	2.020E-7	2.035E-7	2.044E-7	2.065E-7	2.068E-7	2.085E-7
Exp. σ	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032

Table 6.5.3-3 MCNP Validation Statistics (cont.)

Case	13.01	13.02	13.03	13.04	13.05	13.06	13.07
Clusters	3	3	3	3	3	3	3
Enrichment (wt %^{235}U)	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%
Pitch (cm)	1.892	1.892	1.892	1.892	1.892	1.892	1.892
Fuel OD (cm)	1.265	1.265	1.265	1.265	1.265	1.265	1.265
Clad OD (cm)	1.415	1.415	1.415	1.415	1.415	1.415	1.415
Clad Material	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	107	107	107	107	107	107	107
Soluble B (ppm)	-	-	-	-	-	-	-
Absorber Type	304L SS (no B)	304L SS (1.05% B)	Boral B	Boroflex	Cd	Cu	Cu (0.989 wt % Cd)
Cluster Gap (cm)	13.8	9.8	8.3	8.4	8.9	13.5	10.6
Reflector	Steel	Steel	Steel	Steel	Steel	Steel	Steel
Plate Loading (g^{10}B /cm^2)	0.00000	0.00455	0.03022	0.02361	-	-	-
EALCF (MeV)	2.982E-7	3.068E-7	3.111E-7	3.094E-7	3.097E-7	2.998E-7	3.061E-7
Exp. σ	0.0018	0.0018	0.0018	0.0018	0.0032	0.0018	0.0018

Table 6.5.3-3 MCNP Validation Statistics (cont.)

Case	14.01	14.02	14.05	14.06	14.07
Clusters	1	1	1	1	1
Enrichment (wt %^{235}U)	4.31%	4.31%	4.31%	4.31%	4.31%
Pitch (cm)	1.890	1.890	1.890	1.715	1.715
Fuel OD (cm)	1.265	1.265	1.265	1.265	1.265
Clad OD (cm)	1.415	1.415	1.415	1.415	1.415
Clad Material	Al	Al	Al	Al	Al
H/U (fissile)	106	106	106	73	73
Soluble B (ppm)	0	491	2539	0	1030
Absorber Type	-	-	-	-	-
Cluster Gap (cm)	-	-	-	-	-
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading (g^{10}B /cm^2)	-	-	-	-	-
EALCF (MeV)	2.873E-7	3.447E-7	6.003E-7	5.175E-7	7.722E-7
Exp. σ	0.0019	0.0077	0.0069	0.0033	0.0051

Table 6.5.3-3 MCNP Validation Statistics (cont.)

Case	16.01	16.02	16.03	16.04	16.05	16.06	16.07	16.08	16.09	16.10
Clusters	3	3	3	3	3	3	3	3	3	3
Enrichment [wt %^{235}U]	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%
Pitch (cm)	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032
Fuel OD (cm)	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118
Clad OD (cm)	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	404	404	404	404	404	404	404	404	404	404
Soluble B (ppm)	-	-	-	-	-	-	-	-	-	-
Absorber Type	304L SS (no B)	304L SS (no B)	304L SS (no B)	304L SS (no B)	304L SS (no B)	304L SS (no B)	304L SS (no B)	304L SS (1.05% B)	304L SS (1.05% B)	304L SS (1.62% B)
Cluster Gap (cm)	6.9	7.6	7.5	7.4	7.8	10.4	11.5	7.6	9.6	7.4
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading ($g^{10}B /cm^2$)	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00455	0.00455	0.00690
EALCF (MeV)	1.000E-7	9.983E-8	9.947E-8	1.001E-7	1.002E-7	1.009E-7	1.001E-7	9.993E-8	1.004E-7	1.012E-7
Exp. σ	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031

Table 6.5.3-3 MCNP Validation Statistics (cont.)

Case	16.11	16.12	16.13	16.14	16.15	16.16	16.17	16.18	16.19	16.20	16.21	16.22
Clusters	3	3	3	3	3	3	3	3	3	3	3	3
Enrichment [wt %^{235}U]	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%
Pitch(cm)	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032
Fuel OD (cm)	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118
Clad OD (cm)	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	404	404	404	404	404	404	404	404	404	404	404	404
Soluble B (ppm)	-	-	-	-	-	-	-	-	-	-	-	-
Absorber Type	304L SS (1.62% B)	Boral	Boral	Boral	Cu	Cu	Cu	Cu	Cu	Cu (0.989 wt % Cd)	Cd	Cd
Cluster Gap (cm)	9.5	6.3	9.0	5.1	6.6	7.7	7.5	6.9	7.0	5.2	6.7	7.6
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading (g^{10}B /cm^2)	0.00690	0.06704	0.06704	0.06704	-	-	-	-	-	-	-	-
EALCF (MeV)	9.962E-8	1.016E-7	1.006E-7	1.025E-7	1.000E-7	9.944E-8	9.904E-8	9.919E-8	9.971E-8	1.001E-7	1.024E-7	1.014E-7
Exp. σ	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031

Table 6.5.3-3 MCNP Validation Statistics (cont.)

Case	16.23	16.24	16.25	16.26	16.27	16.28	16.29	16.30	16.31	16.32
Clusters	3	3	3	3	3	3	3	3	3	3
Enrichment [wt %^{235}U]	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%
Pitch(cm)	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032
Fuel OD (cm)	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118
Clad OD (cm)	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	404	404	404	404	404	404	404	404	404	404
Soluble B (ppm)	-	-	-	-	-	-	-	-	-	-
Absorber Type	Cd	Cd	Cd	Cd	Cd	Al (no B)	Al (no B)	Al (no B)	Zircaloy-4	Zircaloy-4
Cluster Gap cm)	9.4	7.8	9.4	7.5	9.4	8.7	8.8	8.8	8.8	8.8
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading (g^{10}B /cm^2)	-	-	-	-	-	0.00000	0.00000	0.00000	-	-
EALCF (MeV)	1.010E-7	1.018E-7	1.006E-7	1.019E-7	9.948E-8	9.991E-8	9.843E-8	9.807E-8	9.964E-8	9.834E-8
Exp. σ	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031

Table 6.5.3-3 MCNP Validation Statistics (cont.)

Case	35.01	35.02	40.01	40.02	40.03	40.04	40.05	40.06	40.07	40.08	40.09	40.10
Clusters	1	1	4	4	4	4	4	4	4	4	4	4
Enrichment (wt $\%^{235}U$)	2.60%	2.60%	4.74%	4.74%	4.74%	4.74%	4.74%	4.74%	4.74%	4.74%	4.74%	4.74%
Pitch (cm)	1.956	1.956	1.600	1.600	1.600	1.600	1.600	1.600	1.600	1.600	1.600	1.600
Fuel OD (cm)	1.250	1.250	0.790	0.790	0.790	0.790	0.790	0.790	0.790	0.790	0.790	0.790
Clad OD (cm)	1.417	1.417	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
Clad Material	Al	Al	Al alloy	Al alloy	Al alloy	Al alloy	Al alloy	Al alloy	Al alloy	Al alloy	Al alloy	Al alloy
H/U (fissile)	203	203	231	231	231	231	231	231	231	231	231	231
Soluble B (ppm)	70	148	-	-	-	-	-	-	-	-	-	-
Absorber Type	-	-	Z2 CN18/10 SS (1.10% B)	Z2 CN18/10 SS (1.10% B)	Z2 CN18/10 SS (1.10% B)	Z2 CN18/10 SS (1.10% B)	Boral	Boral	Boral	Boral	Boral	Boral
Cluster Gap (cm)	-	-	2.3	2.3	2.3	2.3	3.3	3.3	3.3	3.3	3.3	3.3
Reflector	H_2O	H_2O	H_2O	Lead	Lead	Lead	H_2O	Lead	Lead	Lead	Steel	Steel
Plate Loading ($g^{10}B/cm^2$)	-	-	0.00252	0.00252	0.00252	0.00252	0.04608	0.04608	0.04608	0.04608	0.04608	0.04608
EALCF (MeV)	2.170E-7	2.202E-7	1.493E-7	1.717E-7	1.625E-7	1.576E-7	1.432E-7	1.515E-7	1.470E-7	1.459E-7	1.537E-7	1.469E-7
Exp. σ	0.0018	0.0019	0.0039	0.0041	0.0041	0.0041	0.0042	0.0044	0.0044	0.0044	0.0046	0.0046

Table 6.5.3-3 MCNP Validation Statistics (cont.)

Case	42.01	42.02	42.03	42.04	42.05	42.06	42.07
Clusters	3	3	3	3	3	3	3
Enrichment (wt %^{235}U)	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%
Pitch (cm)	1.684	1.684	1.684	1.684	1.684	1.684	1.684
Fuel OD (cm)	1.118	1.118	1.118	1.118	1.118	1.118	1.118
Clad OD (cm)	1.270	1.270	1.270	1.270	1.270	1.270	1.270
Clad Materiall	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	221	221	221	221	221	221	221
Soluble B (ppm)	-	-	-	-	-	-	-
Absorber Type	304L SS (no B)	304L SS (1.05% B)	Boral B	Boroflex	Cd	Cu	Cu-Cd
Cluster Gap (cm)	8.3	4.8	2.7	3.0	3.9	7.8	5.4
Reflector	Steel	Steel	Steel	Steel	Steel	Steel	Steel
Plate Loading (g^{10}B /cm^2)	0.00000	0.00455	0.03022	0.02361	-	-	-
EALCF (MeV)	1.813E-7	1.824E-7	1.915E-7	1.887E-7	1.857E-7	1.786E-7	1.833E-7
Exp. σ	0.0016	0.0016	0.0016	0.0017	0.0033	0.0016	0.0018

Table 6.5.3-3 MCNP Validation Statistics (cont.)

Case	50.03	50.03	50.03	50.03	50.03
Clusters	1	1	1	1	1
Enrichment (wt %^{235}U)	4.74%	4.74%	4.74%	4.74%	4.74%
Pitch (cm)	1.300	1.300	1.300	1.300	1.300
Fuel OD (cm)	0.790	0.790	0.790	0.790	0.790
Clad OD (cm)	0.940	0.940	0.940	0.940	0.940
Clad Material	Al alloy	Al alloy	Al alloy	Al alloy	Al alloy
H/U (fissile)	124	124	124	124	124
Soluble B (ppm)	821	821	4986	4986	4986
Absorber Type	-	-	-	-	-
Cluster Gap (cm)	-	-	-	-	-
Reflector	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O
Plate Loading (g^{10}B /cm^2)	-	-	-	-	-
EALCF (MeV)	2.170E-7	2.083E-7	2.318E-7	2.252E-7	2.195E-7
Exp. σ	0.0010	0.0010	0.0010	0.0010	0.0010

Table 6.5.3-3 MCNP Validation Statistics (cont.)

Case	51.01	51.02	51.03	51.04	51.05	51.06	51.07	51.08	51.09
Clusters	9	9	9	9	9	9	9	9	9
Enrichment (wt $\%^{235}U$)	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%
Pitch (cm)	1.636	1.636	1.636	1.636	1.636	1.636	1.636	1.636	1.636
Fuel OD (cm)	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030
Clad OD (cm)	1.206	1.206	1.206	1.206	1.206	1.206	1.206	1.206	1.206
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	219	219	219	219	219	219	219	219	219
Soluble B (ppm)	143	510	514	501	493	474	462	432	217
Absorber Type	none	SS	SS	SS	SS	SS	SS	SS	SS
Cluster Gap (cm)	4.9	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3.3
Reflector	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O
Plate Loading ($g^{10}B$ /cm^2)	0.00000	-	-	-	-	-	-	-	-
EALCF (MeV)	1.535E-7	2.045E-7	2.043E-7	2.067E-7	2.074E-7	2.083E-7	2.085E-7	2.098E-7	1.737E-7
Exp. σ	0.0020	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0019

Table 6.5.3-3 MCNP Validation Statistics (cont.)

Case	51.10	51.11	51.12	51.13	51.14	51.15	51.16	51.17	51.18	51.19
Clusters	9	9	9	9	9	9	9	9	9	9
Enrichment (wt %^{235}U)	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%
Pitch (cm)	1.636	1.636	1.636	1.636	1.636	1.636	1.636	1.636	1.636	1.636
Fuel OD (cm)	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030
Clad OD (cm)	1.206	1.206	1.206	1.206	1.206	1.206	1.206	1.206	1.206	1.206
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	219	219	219	219	219	219	219	219	219	219
Soluble B (ppm)	15	28	92	395	121	487	197	634	320	72
Absorber Type	B/Al Set 5	B/Al Set 5A	B/Al Set 4	B/Al Set 3	B/Al Set 3	B/Al Set 2	B/Al Set 2	B/Al Set 1	B/Al Set 1	B/Al Set 1
Cluster Gap (cm)	1.6	1.6	1.6	1.6	3.3	1.6	3.3	1.6	3.3	4.9
Reflector	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O
Plate Loading (g^{10}B /cm^2)	0.00517	0.00519	0.00403	0.00128	0.00128	0.00078	0.00078	0.00032	0.00032	0.00032
EALCF (MeV)	2.029E-7	2.015E-7	2.056E-7	2.112E-7	1.773E-7	2.106E-7	1.775E-7	2.119E-7	1.780E-7	1.587E-7
Exp. σ	0.0019	0.0019	0.0019	0.0022	0.0019	0.0024	0.0020	0.0027	0.0021	0.0019

Table 6.5.3-3 MCNP Validation Statistics (cont.)

Case	65.01	65.02	65.03	65.04	65.05	65.06	65.07	65.08
Clusters	2	2	2	2	2	2	2	2
Enrichment (wt %^{235}U)	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%
Pitch (cm)	1.956	1.956	1.956	1.956	1.956	1.956	1.956	1.956
Fuel OD (cm)	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250
Clad OD (cm)	1.417	1.417	1.417	1.417	1.417	1.417	1.417	1.417
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	203	203	203	203	203	203	203	203
Soluble B (ppm)	-	-	-	-	-	-	-	-
Absorber Type	none	304L SS (No B)	304L SS (0.67% B)	304L SS (0.98% B)	none	304L SS (No B)	304L SS (No B)	304L SS (No B)
Cluster Gap (cm)	5.9	5.9	5.9	5.9	7.8	7.8	7.8	7.8
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading (g^{10}B /cm^2)	-	0.00000	0.00599	0.00875	-	0.00000	0.00000	0.00000
EALCF [MeV]	2.045E-7	2.030E-7	2.054E-7	2.038E-7	2.049E-7	2.030E-7	2.055E-7	2.040E-7
Exp. σ	0.0014	0.0014	0.0015	0.0015	0.0014	0.0014	0.0014	0.0016
k_{eff}	0.99571	0.99618	0.99534	0.99547	0.99691	0.99614	0.99589	0.99624
σ	0.00023	0.00022	0.00023	0.00023	0.00023	0.00023	0.00023	0.00023

Table 6.5.3-3 MCNP Validation Statistics (cont.)

Case	65.09	65.10	65.11	65.12	65.13	65.14	65.15	65.16	65.17
Clusters	2	2	2	2	2	2	2	2	2
Enrichment (wt %^{235}U)	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%
Pitch (cm)	1.956	1.956	1.956	1.956	1.956	1.956	1.956	1.956	1.956
Fuel OD (cm)	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250
Clad OD (cm)	1.417	1.417	1.417	1.417	1.417	1.417	1.417	1.417	1.417
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	203	203	203	203	203	203	203	203	203
Soluble B (ppm)	-	-	-	-	-	-	-	-	-
Absorber Type	304L SS (No B)	304L SS (0.67% B)	304L SS (0.67% B)	304L SS (0.67% B)	304L SS (0.67% B)	304L SS (0.98% B)	304L SS (0.98% B)	304L SS (0.98% B)	304L SS (0.98% B)
Cluster Gap (cm)	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading (g^{10}B /cm^2)	0.00000	0.00299	0.00299	0.00599	0.00599	0.00438	0.00438	0.00875	0.00875
EALCF [MeV]	1.993E-7	2.050E-7	2.069E-7	2.072E-7	1.977E-7	2.010E-7	2.004E-7	2.027E-7	2.017E-7
Exp. σ	0.0015	0.0016	0.0016	0.0017	0.0016	0.0016	0.0016	0.0017	0.0016
k_{eff}	0.99667	0.99676	0.99637	0.99643	0.99701	0.99650	0.99634	0.99658	0.99645
σ	0.00022	0.00022	0.00023	0.00023	0.00022	0.00023	0.00023	0.00022	0.00023

Table 6.5.3-4 LEU Fresh Fuel MCNP6.2 Validation Statistics

Case	k_{eff}	σ	Case	k_{eff}	σ
1.01	0.99929	0.00054	9.01	0.99687	0.00062
1.02	0.99817	0.00053	9.02	0.99899	0.00060
1.03	0.99865	0.00051	9.03	0.99854	0.00062
1.04	1.00009	0.00054	9.04	0.99855	0.00058
1.05	0.99642	0.00050	9.05	0.99963	0.00058
1.06	0.99861	0.00053	9.06	0.99754	0.00061
1.07	0.99869	0.00052	9.07	0.99881	0.00058
1.08	0.99638	0.00053	9.08	0.99800	0.00062
2.01	0.99761	0.00061	9.09	0.99906	0.00060
2.02	0.99885	0.00063	9.10	0.99697	0.00057
2.03	0.99818	0.00058	9.11	0.99862	0.00063
2.04	0.99771	0.00062	9.12	0.99870	0.00064
2.05	0.99639	0.00056	9.13	0.99885	0.00061
6.01	0.99921	0.00037	9.14	0.99660	0.00063
6.02	1.00063	0.00036	9.15	0.99826	0.00060
6.03	0.99951	0.00036	9.16	0.99854	0.00061
6.04	0.99958	0.00037	9.17	0.99908	0.00060
6.05	0.99986	0.00038	9.18	0.99755	0.00059
6.06	0.99935	0.00037	9.19	0.99903	0.00059
6.07	0.99927	0.00036	9.20	0.99833	0.00061
6.08	0.99918	0.00036	9.21	0.99918	0.00062
6.09	0.99912	0.00036	9.22	0.99855	0.00063
6.10	0.99986	0.00037	9.23	0.99895	0.00057
6.11	0.99958	0.00034	9.24	0.99717	0.00058
6.12	0.99875	0.00036	9.25	0.99782	0.00060
6.13	0.99926	0.00034	9.26	0.99746	0.00058
6.14	0.99929	0.00034	9.27	0.99724	0.00060
6.15	0.99947	0.00035	11.03	0.99939	0.00022
6.16	0.99948	0.00034	11.04	0.99947	0.00022
6.17	0.99944	0.00036	11.05	0.99910	0.00022
6.18	0.99912	0.00035	11.06	0.99956	0.00022
8.01	1.00071	0.00042	11.07	0.99920	0.00022
8.02	1.00218	0.00042	11.08	0.99956	0.00022
8.03	1.00191	0.00043	11.09	0.99985	0.00022
8.04	1.00074	0.00044	13.01	1.00102	0.00045
8.05	1.00117	0.00043	13.02	1.00067	0.00048
8.06	1.00144	0.00044	13.03	0.99990	0.00044
8.07	1.00034	0.00043	13.04	1.00029	0.00045
8.08	1.00013	0.00042	13.05	0.99948	0.00045
8.09	1.00118	0.00042	13.06	0.99925	0.00044
8.10	1.00079	0.00042	13.07	0.99974	0.00042
8.11	1.00264	0.00042	16.01	0.99893	0.00053
8.12	1.00164	0.00041	16.02	0.99739	0.00054
8.13	1.00180	0.00042	16.03	0.99800	0.00050
8.14	1.00152	0.00044	16.04	0.99749	0.00052
8.15	1.00163	0.00044	16.05	0.99847	0.00053
8.16	1.00042	0.00045	16.06	0.99801	0.00056
8.17	0.99972	0.00042	16.07	0.99919	0.00053

Table 6.5.3-4 LEU Fresh Fuel MCNP6.2 Validation Statistics (Cont.)

Case	k_{eff}	σ	Case	k_{eff}	σ
16.08	0.99908	0.00051	42.07	0.99814	0.00057
16.09	0.99868	0.00051	50.03	0.99903	0.00040
16.10	0.99818	0.00052	50.04	0.99786	0.00037
16.11	0.99861	0.00054	50.05	0.99961	0.00040
16.12	0.99825	0.00055	50.06	0.99917	0.00039
16.13	0.99921	0.00051	50.07	1.00033	0.00039
16.14	0.99959	0.00054	51.01	0.99638	0.00032
16.15	0.99867	0.00053	51.02	0.99937	0.00034
16.16	0.99611	0.00053	51.03	1.00001	0.00033
16.17	0.99704	0.00055	51.04	0.99982	0.00033
16.18	0.99915	0.00054	51.05	0.99993	0.00033
16.19	0.99897	0.00052	51.06	0.99942	0.00034
16.20	0.99867	0.00051	51.07	0.99968	0.00034
16.21	0.99915	0.00052	51.08	1.00009	0.00033
16.22	0.99862	0.00051	51.09	0.99674	0.00034
16.23	0.99822	0.00051	51.10	0.99638	0.00035
16.24	0.99849	0.00052	51.11	0.99974	0.00035
16.25	1.00024	0.00054	51.12	0.99547	0.00034
16.26	0.99890	0.00053	51.13	0.99039	0.00035
16.27	0.99796	0.00055	51.14	0.99161	0.00035
16.28	0.99707	0.00051	51.15	0.99433	0.00035
16.29	0.99809	0.00051	51.16	0.99411	0.00034
16.30	0.99710	0.00053	51.17	0.99621	0.00034
16.31	0.99813	0.00053	51.18	0.99440	0.00032
16.32	0.99712	0.00053	51.19	0.99371	0.00034
35.01	0.99878	0.00037	65.01	1.00214	0.00023
35.02	0.99874	0.00039	65.02	1.00140	0.00023
40.01	0.99671	0.00065	65.03	1.00239	0.00023
40.02	0.99451	0.00062	65.04	1.00140	0.00023
40.03	0.99592	0.00064	65.05	1.00246	0.00023
40.04	0.99621	0.00066	65.06	1.00245	0.00023
40.05	0.99728	0.00069	65.07	1.00228	0.00023
40.06	1.00021	0.00067	65.08	1.00230	0.00022
40.07	0.99562	0.00066	65.09	1.00214	0.00023
40.08	0.99596	0.00065	65.10	1.00248	0.00023
40.09	1.00080	0.00064	65.11	1.00281	0.00023
40.10	0.99443	0.00065	65.12	1.00201	0.00023
42.01	0.99784	0.00054	65.13	1.00254	0.00023
42.02	0.99682	0.00055	65.14	1.00325	0.00023
42.03	0.99845	0.00057	65.15	1.00260	0.00022
42.04	0.99935	0.00060	65.16	1.00247	0.00023
42.05	0.99937	0.00057	65.17	1.00297	0.00023
42.06	0.99933	0.00059			

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6.7 Additional BWR Evaluation Including Damaged Fuel

This section includes the evaluations associated with modification of fuel assembly parameters associated with several 8×8 and 9×9 BWR fuel types, the addition of a 9×9 and two 10×10 BWR fuel types and the evaluation associated with a damaged fuel BWR fuel basket. Damaged fuel is only evaluated for the fuel types discussed in this section and not for all fuel types included in Section 6.2.

6.7.1 Discussion and Results

The NAC-UMS storage and transfer system were evaluated using MCNP 6.2. The calculation includes a set of fuel types previously evaluated, some with slightly modified characteristics, and three new fuel types shown in Section 6.7.2. Additionally, an optional 90% neutron absorber credit was evaluated versus a 75% credit previously applied in the KENO and MONK evaluations. The 90% credit may be applied to metal matrix neutron absorbers tested using neutron attenuation methods.

The maximum planar average initial enrichment of BWR fuel is summarized in Table 6.7.1-1 for undamaged fuel and in 6.7.1-2 for damaged fuel basket content (only applicable when damaged fuel is in the basket, otherwise undamaged limits may be applied). The USL for this analysis is 0.9427 as discussed in Section 6.5.3.

Consisted with the evaluation results documented in Section 6.5 key evaluated system characteristics are:

1. Fuel assemblies and fuel tubes are both moved towards the center of the cask.
2. Hypothetical accident conditions – full interior, exterior and fuel clad gap water intrusion.

In addition to uniform loading (i.e., same enrichment in all assemblies) a preferential loading basket with B10_91A assemblies at 2 different initial enrichments was also evaluated. The maximum enrichment for preferentially loaded B10_91A fuel assemblies' is summarized in Table 6.7.1-3. Only undamaged evaluations were performed for the preferential loading scenario.

Table 6.7.1-1 Summary of Undamaged Fuel Maximum Initial Enrichment – Additional/Modified BWR Assembly

Fuel Type	75% Neutron Absorber Credit		90% Neutron Absorber Credit	
	Enrichment (^{235}U wt%)	$k_{eff}+2\sigma$	Enrichment (^{235}U wt%)	$k_{eff}+2\sigma$
ge08n	4.80	0.93801	5.00	0.93776
ge08k	4.70	0.94030	4.90	0.93985
ge08i	4.70	0.94248	4.90	0.94057
ex08b	4.70	0.93838	4.90	0.93652
ex09c	4.60	0.94228	4.70	0.93785
B9_72A	4.50	0.94109	4.70	0.94023
B10_91A	4.50	0.94178	4.70	0.94149
B10_92A	4.40	0.93731	4.60	0.93885

Note: Capitalized fuel type identifiers are new assembly types for Section 6.7.

Table 6.7.1-2 Maximum Initial Enrichment with four BWR DFCs loaded with Damaged Fuel

Fuel Type	Maximum Initial Enrichment (^{235}U wt%)	
	75% Neutron Absorber Credit	90% Neutron Absorber Credit
ge08n	4.80	5.00
ge08k	4.70	4.90
ge08i	4.60*	4.90
ex08b	4.70	4.90
ex09c	4.50*	4.70
B9_72A	4.40*	4.60*
B10_91A	4.40*	4.60*
B10_92A	4.40	4.60

* The asterisk indicates that the Maximum Initial Enrichment for payloads with four DFC is lower by 0.1 wt% than payload with undamaged fuel.

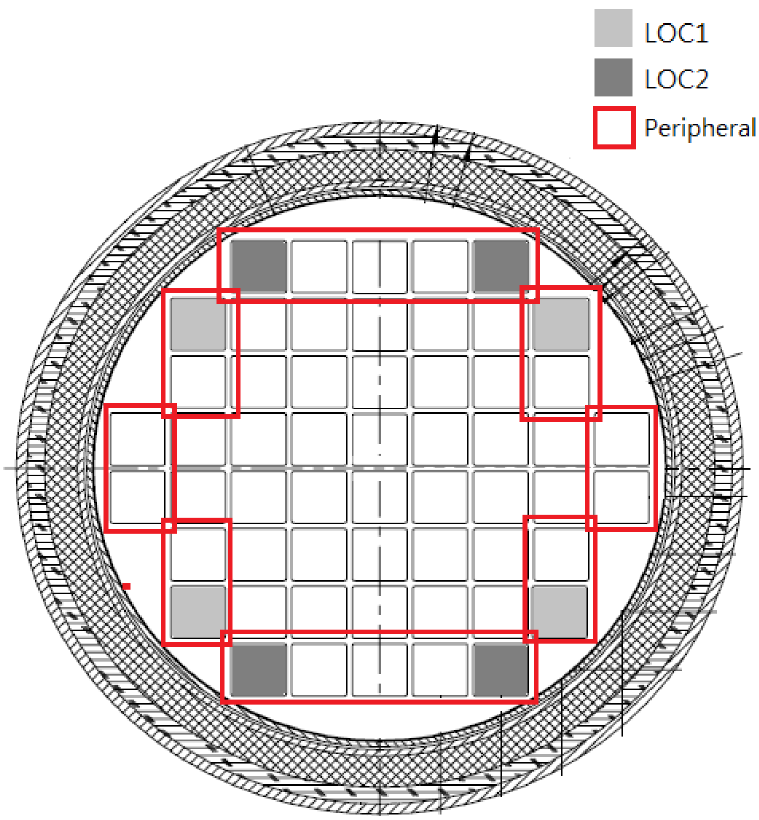
Table 6.7.1-3 Summary of Preferentially Loaded Fuel Enrichment Combinations

Outer Locations*	**Outer Locations Maximum Enrichment (^{235}U wt%)**	**Remaining Locations Maximum Enrichment (^{235}U wt%)**	**$k_{eff}+2\sigma$**
LOC1 (Option 1)	4.6	4.5	0.94117
LOC1 (Option 2)	5.0	4.4	0.93787
LOC2 (Option 1)	4.6	4.5	0.94248
LOC2 (Option 2)	5.0	4.4	0.93756
Peripheral (Option 1)	4.6	4.5	0.94173
Peripheral (Option 2)	5.0	4.4	0.93990

*The three possibilities of outer locations are defined in Figure 6.7.1-1.

Note: Preferential load patterns are only evaluated for 75% absorber credit.

Figure 6.7.1-1 Preferential BWR Fuel Assembly Load Locations -Three Outer Location Possibilities for Higher Enrichment Fuel Assemblies



6.7.2 Updated BWR Spent Fuel Loading

Key fuel design characteristics applied in Section 6.7 are listed in Table 6.7.2-1. The table includes the information of three new fuel types (B9_72A, B10_91A and B10_92A) and five previously evaluated fuel types (ge08n, ge08k, ge08i, ex08b and ex09c) with modified characteristics.

Table 6.7.2-1 Additional and Modified BWR Fuel Assembly Characteristics

Fuel Type	**ge08n**	**ge08k**	**ge08i**	**ex08b**	**ex09c**	**B9_72A**	**B10_91A**	**B10_92A**
No. of Fuel Rods[1]	63	62	60	62	79	72	91/83	92/78
Max Pitch	0.64 in.	0.64 in.	0.64 in.	0.641 in.	0.572 in.	0.572 in.	0.51 in.	0.51 in.
Min Rod OD	0.493 in.	0.483 in.	***0.483 in.***	0.484 in.	0.424 in.	0.433 in.	0.3957 in.	0.404 in.
Min Clad Thick	0.034 in.	0.032 in.	0.032 in.	***0.035 in***	0.03 in.	0.026 in.	0.02385 in.	0.026 in
Max Fuel Pellet OD	0.416 in.	0.41 in.	0.41 in.	***0.4055 in***	0.3565 in.	0.374 in.	0.342 in.	0.3455 in.
Max Active Fuel Length	146 in.	150 in.	150 in.	150 in.	150 in.	150 in.	150 in.	150 in.
Max Loading [MTU]	***0.192***	***0.1886***	***0.1825***	***0.1845***	***0.1817***	0.1803	0.1906	0.1966
Water Rod OD	0.493 in.	0.591 in.	1.34 in.	0.484 in.	0.425 in.	1.516 in.	1.378 in.	0.98 in.
Water Rod Thick	0.034 in.	0.03 in.	0.04 in.	***0.035 in.***	***0.0305 in.***	0.0285 in.	0.0285 in.	0.03 in.

Note: Modified parameters are identified by bold/italic text.

[1] B10-91A has 8 partial-length rods. B10-92A has 14 partial length rods.

6.7.3 Methodology and Model Specifications

Method

MCNP6.2 and ENDF/B-VII library is used to perform the criticality analysis. 8 BWR fuel types are included in this analysis. Three of them are added in Section 6.7.2 (B9_72A, B10_91A, B10_92A) and the others are taken from Section 6.2 and modified as necessary (ge08n, ge08k, ge08i, ex08b and ex09c).

Normal, off-normal, and hypothetical accident conditions are evaluated to determine the most reactive condition. For discussion in this Chapter water condition 'wet' denotes water density of 0.9982 g/cm3, and 'dry' denotes water density of 0.001 g/cm3. For the transfer (TFR) cask, during the normal operation the canister inside and outside may be wet or dry, the fuel is intact so the pellet-clad gap is dry. The accident condition is hypothetical in that the water intrudes inside pellet-clad gap. For the storage cask (VCC), the normal condition is defined as canister inside and outside are dry, as well as pellet-clad gap is dry. In off-normal condition the water can intrude inside and outside of the canister. The accident condition of VCC is hypothetical in that water intrudes inside pellet-clad gap. This analysis description set is consistent with previous UMS licensing analysis terminology. It should be noted that the system allows undamaged fuel to have clad pinhole and hairline cracks allowing for potential water incursion into the pellet to clad gap under normal condition of operations. As the analysis limit ($k_{eff} + 2\sigma \leq USL$) is the same for normal and accident condition there is no impact on the allowed enrichment or maximum keff reported associated with the normal cases applying a dry gap.

The analysis includes a limited set of moderator density studies and a partial flooding analysis which checks on the reactivity impact of a change in reflector conditions above the active fuel region during the water draining procedure.

The maximum initial enrichment is determined by increasing enrichment until the USL has been reached for all fuel types. The analysis is performed under 75% and 90% credit of 0.011 g/cm^2 ^{10}B content absorber sheets for uniform enrichment and at 75% only for the preferential loading. As one of the BWR fuel types may have a higher enrichment then permitted under uniform loading, a preferentially loaded basket analysis with higher and lower enrichment combinations is performed to allow higher enrichment assemblies to be loaded.

For evaluations of the damaged fuel basket, the four corner assembly fuel tubes are replaced by DFCs instead of oversized fuel tubes. The top weldment and bottom weldment openings are slightly larger than the oversized fuel tube in order to accommodate the damaged fuel can. Because

of the different basket design, some basket surface and cell descriptions (universes) are modified in MCNP to model the geometry.

Three scenarios of damaged BWR fuel are modeled in the DFC. The undamaged assembly case contains an undamaged assembly in the DFC. In the unclad array case, an array without clad or nozzles is modeled in the DFC with an increased pitch, such that the array fills the DFC. The mixture case models a homogenized mixture of fuel and moderator up to various heights of the DFC cavity. DFC evaluations are limited to the 75% credit neutron absorber configuration.

Model

The MCNP cask model is based on the BWR basket assembly, fuel canister, and transfer and storage cask dimensions and is in principal identical in construction to the MONK model applied in Section 6.4. The UMS BWR basket is built from a set of carbon steel disks and aluminum heat transfer disks spaced 1.35 inch face-to-face. The disks contain 56 captivated fuel tubes. Each fuel tube can contain one BWR fuel assembly. The MCNP universe structure is used to place the basket into the TSC and into its overpack.

An outer cylindrical body allows reflecting boundary conditions to be applied at specified distances surrounding each cask model. Due to the size of the transfer and storage radiation shields, cask surface neutron currents are low. This, in turn, results in baskets that are neutronically isolated from cask exterior conditions and from other casks in an array configuration. However, the cylindrical reflecting boundary condition is spaced 30.48 cm from the cask body to fulfill the “close reflection” concept of a single cask.

Material composition with the exception of fuel, neutron absorber, and NS-4-FR are obtained from SCALE 6 standard composition library. Unlike previous analysis in this chapter the initial material composition for the uranium oxide includes a trace of ^{234}U (0.008 times the weight percent of ^{235}U). To increase the 10B credit from 75% to 90% the atomic number density in atoms/barn-cm was simply recalculated by reverting to nominal condition by dividing by 0.75 and then multiplying by 0.9 to obtain 90% credit.

All MCNP outputs have been confirmed to pass the Shannon entropy convergence test (i.e., skipped generation were set to assure proper fission distribution prior to active cycles).

6.7.4 Uniform Enrichment Undamaged Fuel Calculations

6.7.4-1 Assembly Reactivity Comparison

Evaluations comparing k_{eff} of the various assembly types listed in Section 6.7.2 are shown in Table 6.7.4-1. Evaluation in Table 6.7.4-1 were performed at an enrichment of 4.0 wt % ^{235}U. Also included is a comparison between the k_{eff} based on Section 6.7.2 fuel characteristics (labeled "new") and those produced by Section 6.2 (labeled "original") characteristics. As expected, the changes either produce small increases in reactivity, or are within the Monte Carlo uncertainty of the evaluation. For the remaining cases in Section 6.7 the "new" designation is removed from the assembly type designation with all cases evaluated with the Section 6.7.2 characteristics. BWR 10x10 assemblies contain partial length rods. Cases are evaluated with either the full number of rods (lower section) or reduced number of rods (representing the upper section). The lower-part of fuel containing solid partial-length rods are denoted as B10_91As and B10_92As. The upper-part of fuel containing vanished partial-length rods (empty space) are denoted as B10_91Av and B10_92Av. As can be seen from the results, the fuel containing vanished partial-length rods is more reactive than the fuel containing solid partial-length rods for both B10_91A and B10_92A assemblies. For the following analysis B10_91Av is denoted as B10_91A and B10_92Av is denoted as B10_92A.

The most reactive assembly among 8 fuel types is B10_92Av. The B10_92Av in TFR cask is chosen to perform the following two analyses: (1) criticality analysis under normal condition, off-normal condition and hypothetical accident condition and (2) partial flooding.

6.7.4.2 Optimum Moderator Density and Cask Configuration Confirmation Evaluation

The analysis is performed to demonstrate that the most reactive moderator condition remains a fully flooded TSC, with water in the pellet to clad gap and that the cask has very small impact on reactivity. Included is a preferential flood evaluation. Configuration evaluated is 4.0 wt % ^{235}U in a B10_92A fuel assembly.

For the TFR cask, calculations are performed under normal condition (wet or dry canister with a wet or dry cask exterior) and accident condition (full interior, exterior and fuel clad gap water intrusion). The results are shown in Table 6.7.4-2. For the VCC cask, calculations are performed under normal condition (dry basket, dry transfer annulus and dry exterior), off-normal condition (dry basket, with the transfer annulus and cask exterior flooded), and accident condition (full interior, exterior and fuel clad gap water intrusion). The results are shown in Table 6.7.4-3. As can be seen from the results, full water intrusion into canister and fuel clad gap is the most reactive condition. The water outside the canister has no effect on reactivity.

The partial flooding case drains the TSC to the top of the active fuel. The analysis evaluates reactivity difference of reflection from a water reflector above the active fuel and from the steel lid. The results shown in Table 6.7.4-4 demonstrate that there is no reactivity effect on partial flooding.

6.7.4.3 Maximum Allowed Enrichment and Reactivity Summary

Each of the BWR fuel assemblies is evaluated at enrichments ranging from 4.0 wt. % 235U to 5.0 wt. % ^{235}U. The calculated keff+2σ is compared to the USL of 0.9427. The analysis is performed on the most reactive configuration, hypothetical accident condition and 75% and 90% neutron absorber credit. The results are shown in Table 6.7.4-5.

Table 6.7.4-1 Added/Modified BWR Fuel Type - Most Reactive Assembly Analysis Results

Assembly	Number Rods		TFR		VCC	
Type	Fuel	Water	k_{eff}	σ	k_{eff}	σ
B10_91As	91	1	0.91495	0.00079	0.91143	0.00076
B10_91Av	83	1	0.91320	0.00075	0.91559	0.00077
B10_92As	92	2	0.91278	0.00075	0.91417	0.00073
B10_92Av	78	2	0.91688	0.00076	0.91670	0.00074
B9_72A	72	1	0.91584	0.00076	0.91662	0.00075
ex08bNew	62	2	0.90276	0.00077	0.90458	0.00079
ex08bOriginal	62	2	0.90137	0.00079	0.90082	0.00080
ex09c	79	2	0.91126	0.00077	0.91266	0.00078
ge08iNew	60	1	0.90568	0.00073	0.90657	0.00073
ge08iOriginal	60	1	0.90524	0.00075	0.90530	0.00075
ge08k	62	2	0.90632	0.00075	0.90819	0.00075
ge08n	63	1	0.90032	0.00078	0.90150	0.00074

Table 6.7.4-2 Added/Modified BWR Fuel Type - TFR Normal and Accident Condition

Condition	Water Condition Inside/Outside/Gap	k_{eff}	σ
Normal	Dry/Dry/Dry	0.33270	0.00056
	Dry/Wet/Dry	0.33963	0.00062
	Wet/Dry/Dry	0.91232	0.00077
	Wet/Wet/Dry	0.91366	0.00075
Accident	Wet/Wet/Wet	0.91564	0.00075

Table 6.7.4-3 Added/Modified BWR Fuel Type -VCC Normal, Off-Normal and Accident Condition

Condition	Water Condition Inside/Outside/Gap	k_{eff}	σ
Normal	Dry/Dry/Dry	0.31563	0.00055
Off-Normal	Dry/Wet/Dry	0.31688	0.00065
Accident	Wet/Wet/Wet	0.91670	0.00074

Table 6.7.4-4 Added/Modified BWR Fuel Type -Partial Flooding Evaluation

Condition	keff	σ
Full Flood	0.91688	0.00076
Partial Flood	0.91745	0.00076

Table 6.7.4-5 Added/Modified BWR Fuel Type -Maximum Allowed Enriched Summary

Fuel Type	**75% Absorber Credit**		**90% Absorber Credit**	
	Enrichment (^{235}U wt%)	**k_{eff}+2σ**	**Enrichment (^{235}U wt%)**	**k_{eff}+2σ**
ge08n	4.80	0.94100	5.00	0.93805
ge08k	4.70	0.94076	4.90	0.93934
ge08i	4.70	0.94263	4.90	0.94121
ex08b	4.70	0.93844	4.90	0.93836
ex09c	4.60	0.94231	4.70	0.93702
B9_72A	4.50	0.94255	4.70	0.94059
B10_91A	4.50	0.94247	4.70	0.94218
B10_92A	4.40	0.93673	4.60	0.93865

6.7.5 Preferential Loading Enrichment Undamaged Fuel Calculations

This analysis demonstrates that loading of higher enrichments than allowed by uniform loading constraints can be accomplished by preferentially loading higher and lower enrichment fuel assemblies. Select outer locations are loaded with higher enrichment fuel assemblies and the other locations are loaded with lower enrichment fuel assemblies. For the outer locations there are three loading possibilities. The first one is the 4 locations with oversized fuel tubes (LOC1). The second is the 4 corner locations next to the oversized fuel tubes' positions (LOC2). The third loading is all the 22 peripheral locations. These 3 loading possibilities are shown in Figure 6.7.5-1.

As the higher enrichment fuel assemblies have higher reactivity, the radial-in (RIN) movement may not be the most reactive configuration. Moving assemblies close to the higher enrichment assemblies (CTH) is considered. A sketch of moving assemblies towards LOC1 is shown in Figure 6.7.5-2. The results of these evaluations are shown in Table 6.7.5-1. Several different enrichment combinations are evaluated, and the results demonstrate that the radial-in movement is still the most reactive configuration.

Table 6.7.5-2 shows maximum allowable enrichment for preferentially loaded fuel assemblies in the three loading possibilities. As seen in Table 6.7.5-2 reducing the enrichment of assemblies at inner locations can allow the enrichment of assemblies at outer locations up to 5.0 wt%.

Figure 6.7.5-1 Three Outer Location Possibilities for Higher Enrichment Fuel Assemblies

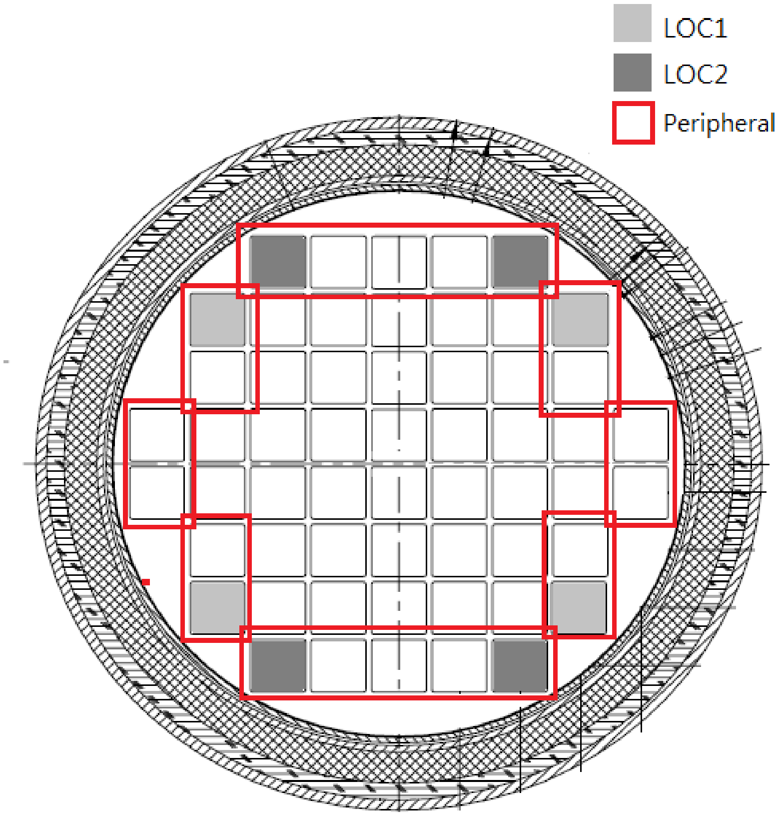


Figure 6.7.5-2 Close to Higher Enrichment (CTH) Movement

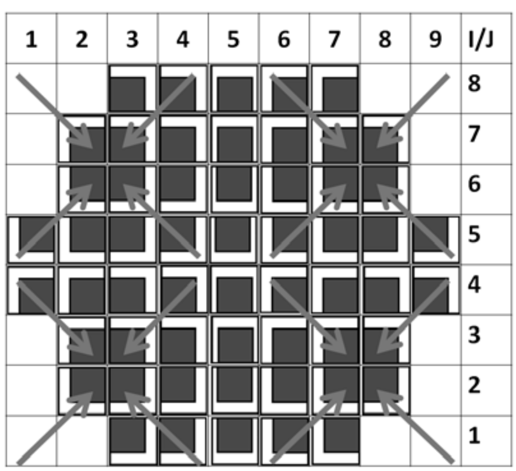


Table 6.7.5-1 Preferential Load Pattern – Assembly Shift (Movement) Analysis Results

Enrichment			CTH	RIN	$\Delta k/\sigma$ (CTH-RIN)
LOC1	**LOC2**	**Remaining**	$k_{eff}+2\sigma$	$k_{eff}+2\sigma$	
4.6	-	4.4	0.92038	0.93802	-23.47
4.7	-	4.4	0.92073	0.93655	-20.65
4.8	-	4.4	0.92070	0.93744	-22.21
4.9	-	4.4	0.92182	0.93596	-18.34
5.0	-	4.4	0.92089	0.93820	-22.53
4.6	-	4.5	0.92407	0.94005	-20.78
-	4.6	4.5	0.92295	0.93966	-21.40
-	5.0	4.4	0.91919	0.93735	-24.16

Table 6.7.5-2 Maximum Initial Enrichment of Preferentially Loaded Fuel Assemblies

Outer Locations	Outer Locations Maximum Enrichment (U-235 wt%)	Remaining Locations Maximum Enrichment (U-235 wt%)	k_{eff}	σ	$k_{eff}+2\sigma$
LOC1 (Option 1)	4.6	4.5	0.93853	0.00076	0.94005
LOC1 (Option 2)	5.0	4.4	0.93670	0.00075	0.93820
LOC2 (Option 1)	4.6	4.5	0.93808	0.00079	0.93966
LOC2 (Option 2)	5.0	4.4	0.93581	0.00077	0.93735
Peripheral (Option 1)	4.6	4.5	0.94017	0.00079	0.94175
Peripheral (Option 2)	5.0	4.4	0.93916	0.00078	0.94072

6.7.6 Uniform Enrichment Damaged Fuel Calculations

The cask reactivity evaluation is divided into seven primary sections. Four sections are for the three DFC configuration analysis, one is for summary of loading limits, one is for moderator studies, nd one is for the storage cask and one is for the absorber sheets height. While the results of the various evaluations indicate a reduced enrichment requirement for some of the scenarios this is the result of the statistical fluctuations in the MCNP result set. Enrichments were set for the undamaged fuel basket analysis when keff + 2σ results were less than the USL. Some cases resulted in very small margins to the USL. In these cases, minor statistical fluctuations can result in the keff + 2σ going slightly over the USL and requiring lower enrichment in the DFC cases. This was confirmed by rerunning a test case with modified random number seed. Rather than justifying that statistically no change in enrichment should be required the lower enrichments are implemented for the cases where the MCNP default random number seed and generator produced results (keff + 2σ) over the USL. Bold text is applied to enrichment limits lower than those of the undamaged fuel basket analysis.

6.7.6.1 Clad Rods – Grid Undamaged

Table 6.7.6-1 demonstrates that the DFC material results in no significant change in system reactivity associated with replacement of the fuel tube by a DFC. This is expected as the systems are similar over the active fuel region. The Δk/σ in the table is the reactivity change compare to the undamaged basket evaluation. The average of the absolute value of the reactivity change (｜Δk/σ｜)is 1.59 (average is -0.98). A slight reduction in keff can be postulated associated with the increased number of neutron absorber panels. Undamaged rods within a nominal lattice/pitch configuration are identified by the acronym “IAA” in the DFC content description.

6.7.6.2 Unclad Rods – Rod Array Pitch Study

Damaged fuel is postulated to lose its cladding. As BWR assemblies are typically under-moderated, the removal of cladding from the array is evaluated. Fuel pellet stacks without clad use the acronym “URA” in the DFC content description.

A study on the unclad array pitch is performed. The pitch is modeled at the nominal pitch, the average of the nominal and maximum pitch, and the maximum pitch. All assemblies were run with 75% and 90% boron credit of 0.011 g/cm2 ^{10}B absorber sheets.

Modifying pitch affects system reactivity by varying moderator between fuel rods, therefore changing neutron moderation and absorption, while simultaneously varying the worth of absorber sheets in the form of distance between fuel rods and absorber sheets. As shown in Table 6.7.6-2 and Table 6.7.6-3, these offsetting effects result in no statistical significant change in system reactivity as a function of rod pitch. All final URA cases are modeled at a nominal pitch.

If the increase in reactivity results in a k-eff over the USL (0.9427), the enrichment is lowered by 0.1% and the case is rerun. The lowered enrichment is the limiting configuration. All configurations are under the USL with enrichments at or 0.1% under the previous limits.

6.7.6.3 Unclad Rods – Missing Rod Study

Rods are removed from the lattice to evaluate various “missing rod” geometries. The missing rod study is performed for all 8 BWR fuel types on their limiting enrichment for both 75% and 90% boron credit of 0.011 10B g/cm2 absorber sheets.

As B10_91A and B10_92A have partial-length rods, the missing rod study covers the solid partial-length rods. The B10_91A and B10_92A in this section are based on solid partial-length rods design, i.e., B10_91A has 91 fuel rods and B10_92A has 92 fuel rods. Figure 6.7.6-1 shows four different missing rods position of B10_92A and analysis results demonstrate that the position of missing rods will not lead to significant increase on reactivity.

If the increase in reactivity results in a k-eff over the USL, the enrichment is lowered by 0.1% and the case is rerun. Table 6.7.6-4 shows results only for those cases that reduced allowed enrichment. Other cases either showed no significant increase or decrease in reactivity. The lowered enrichment is the limiting configuration. All configurations are under the USL with enrichments at or 0.1% under the previous limits.

6.7.6.4 Homogenized Fuel – Mixture

A set of homogenized fuel and water mixture cases are run. Mixtures are modeled to fill various fractions of the DFC canister cavity and simulate small fuel rubble inside the canister and transfer cask. The remaining space inside canister is filled with water. Mixtures of water and fuel material are identified by the acronym “MIX” in the DFC content description. The mixture does not contain clad or fuel structural material. The maximum k-eff is not reached at the same mixture height for all fuels. Therefore, initial runs at DFC mixture heights of 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100% are run to determine the maximum mixture height for each assembly. The maximum resulting configuration is the highest k-eff for the limiting enrichment and the corresponding DFC mixture height. Table 6.7.6-5 shows reactivity for various mixture heights.

If the mixture k-effs are over the USL, the enrichment is lowered 0.1% and the case is run again for that particular DFC height. All configurations are under the USL with enrichments at or 0.1% under the previous limits. This lowered enrichment is the limiting enrichment for the assembly.

6.7.6.5 Moderator Studies

To confirm that maximum reactivity was established at bounding conditions moderator density variations are considered. Moderator density studies are performed on the preferentially flooded

DFC, partially flooded cask, and mixture moderator density. Based on typical spent fuel transfer and storage system behavior, and the under-moderated nature of a BWR fuel assembly, it is expected that a uniform reduction in moderator density reduces reactivity.

Preferential flooding cases consider:

- TSC cavity is wet and the DFC moderator density varies,
- TSC cavity is void (low density moderator) and the DFC moderator density varies,
- TSC cavity varies with a wet DFC, and
- TSC cavity varies with a dry DFC.

Preferential flooding, partial flooding, and moderator density studies are performed on the B10_92A 4.4 wt% assembly with a 75% boron credit of 0.011 ^{10}B g/cm2 in absorber sheets as it represents the highest MTU for fuel evaluated. Results of the preferential flood configurations for IAA, URA and MIX80 configuration are listed in Figures 6.7.6-2 thru 6.7.6-4, respectively. Maximum reactivity is achieved with maximum density moderator within the DFC and maximum density moderator in the TSC cavity.

Within the scope of the moderator density evaluations is a partial drain down of the TSC to the top of the active fuel, which is also called partial flooding. Draining the canister to the top of the active fuel region changes the axial reflection from water to the steel TSC lid. The partial flooding study in the undamaged basket determined that there is no statistically significant reactivity change due to partial flooding. It follows that there would not be a statistically significant change for the DFC configurations where the active fuel is below the active fuel in the canister. Mixture cases at 90% and 100% of the DFC have fuel above the top of the undamaged active fuel region.

A study on the mixture cases where the mixture and partial flooding levels are below the active fuel of the undamaged assemblies were performed. The results, shown in Figure 6.7.6-5, indicate that partial flooding results in insignificant difference on reactivity. The reactivity remains below the USL and no decrease in maximum enrichment is needed. For mixture heights of 90% and 100%, part of the fuel mixture is above the flood elevation, and less fuel is in the region below the flood elevation. Given the study results, it follows that the unmoderated fuel mixture above the flood elevation and smaller mass of fuel in the undamaged active fuel region reduce the reactivity of the DFC mixture for partially flooded 90% and 100% of DFC mixture height cases.

Decreasing the density of the moderator in the mixture configuration lowers the system reactivity. This is seen in Figure 6.7.6-6. The moderator in the canister is not adjusted for this study. It is at 0.9982 g/cc. Result shows that there is no statistically significant increase in reactivity due to lowering the density of the moderator in fuel/water mixture.

6.7.6.6 Storage Cask Evaluations

An additional set of runs for the maximum reactivity assembly with 75% and 90% boron credit of 0.011 g/cm2 10B absorber sheets are performed for the storage cask under normal, off-normal, and accident conditions. The B10_92A assembly at its maximum enrichment was chosen because it has the highest MTU. Transfer cask results are significantly higher than the storage cask at normal and off-normal conditions. The reactivity difference between the transfer cask and hypothetical accident condition of the storage cask, both having a flooded TSC, is not significant.

6.7.6.7 Summary of Loading Limits

Table 6.7.6-6 summarizes the loading limits for damaged fuel at 75% and 90% boron credit of 0.011 g/cm2 10B in absorber sheets. The numbers shown in italics indicates that the Maximum Initial Enrichment for payloads with four DFCs is lower by 0.1 wt% than payload with 56 undamaged fuel assemblies. The loading limits apply to all loaded assemblies (4 damaged assemblies and 52 undamaged assemblies).

Figure 6.7.6-1 Different Position of Missing Rods Study

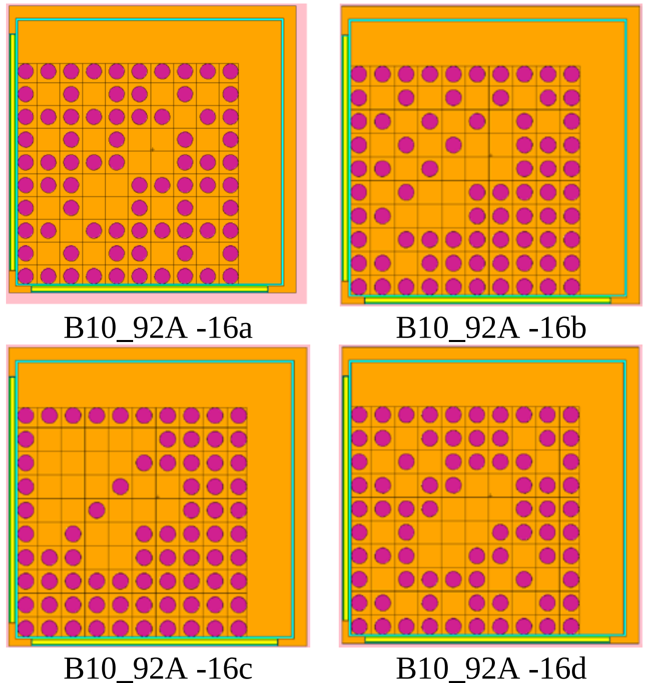


Figure 6.7.6-2 DFC Cask System Reactivity versus Water Density – IAA

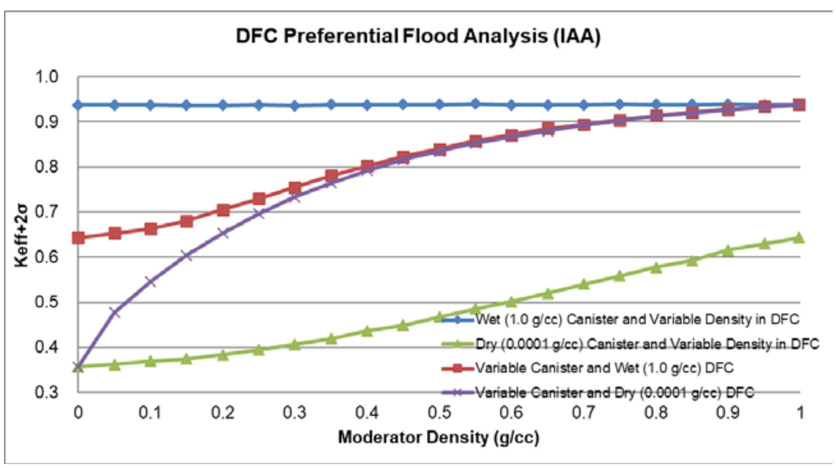


Figure 6.7.6-3 BWR DFC Cask System Reactivity versus Water Density – URA

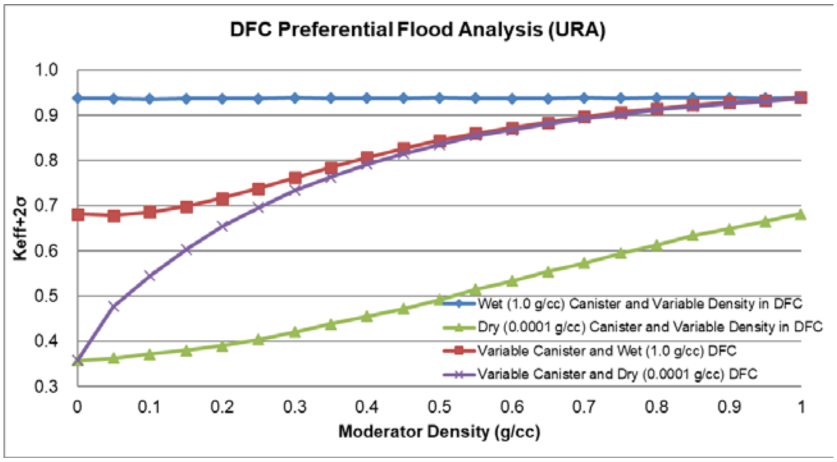


Figure 6.7.6-4 BWR DFC Cask System Reactivity versus Water Density – MIX80

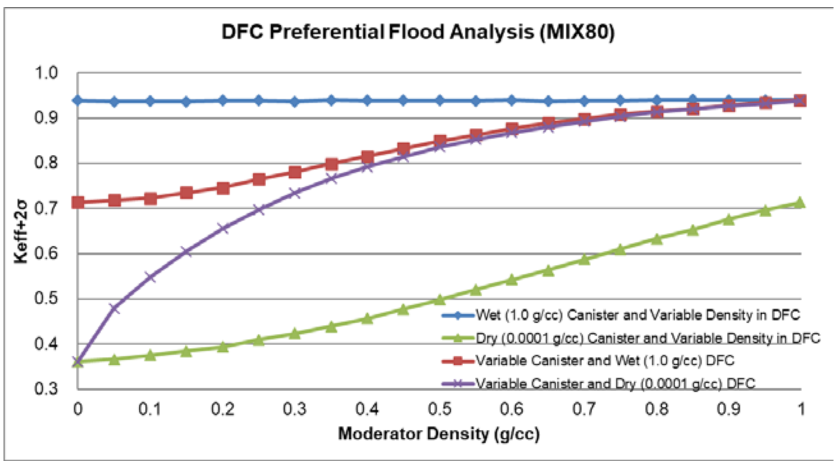


Figure 6.7.6-5 BWR DFC Partial Flooding Study

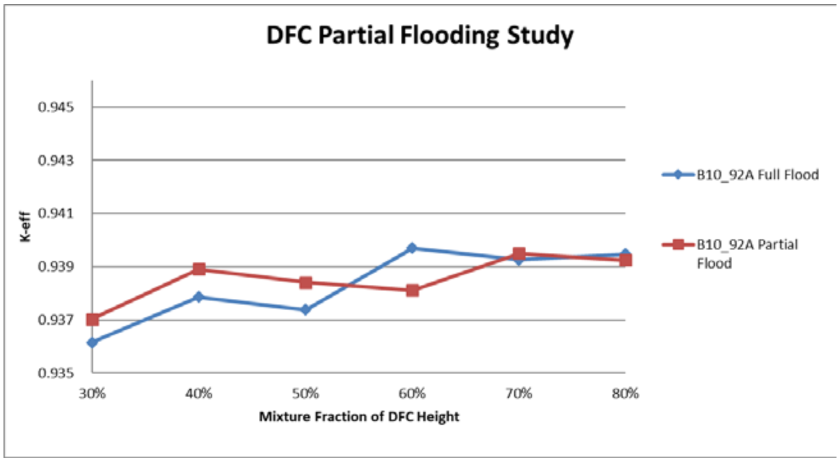


Figure 6.7.6-6 BWR DFC Moderator Density in Fuel/Water Mixture

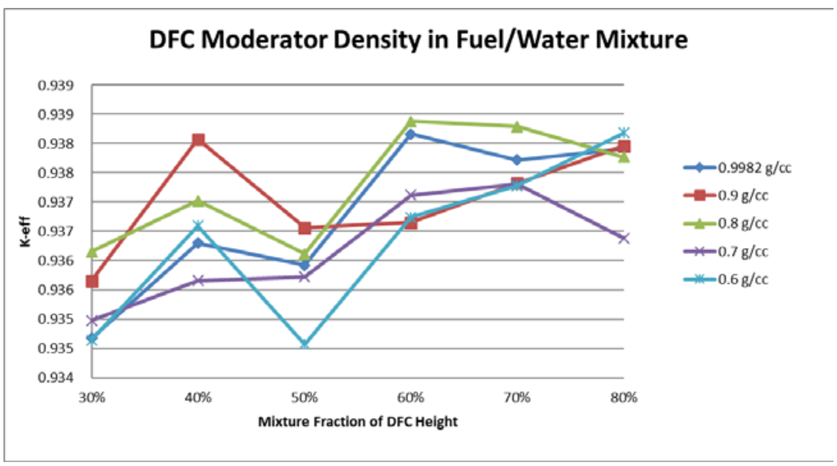


Table 6.7.6-1 DFC Undamaged Assembly Results – 75% Boron Credit for Absorber Sheets

		75% Boron Credit			90% Boron Credit		
Fuel Type	**DFC Config.**	**Enrichment (wt% ^{235}U)**	**k-eff+2σ**	**Δk/σ**	**Enrichment (wt% ^{235}U)**	**k-eff+2σ**	**Δk/σ**
ge08n	IAA	4.80	0.93816	-3.8	5.00	0.93710	-1.2
ge08k	IAA	4.70	0.93995	-0.9	4.90	0.93986	0.6
ge08i	IAA	4.70	0.94098	-2.1	4.90	0.94084	-0.4
ex08b	IAA	4.70	0.93693	-1.8	4.90	0.93659	-2.2
ex09c	IAA	4.60	0.94129	-1.3	4.70	0.93514	-2.4
B9_72A	IAA	4.50	0.94091	-2.2	4.70	0.94142	1.3
B10_91A	IAA	4.50	0.94136	-1.4	4.70	0.94164	-0.7
B10_92A	IAA	4.40	0.93818	2.0	4.60	0.93924	0.9

Table 6.7.6-2 Rod Array Pitch Study - 75% Boron Credit for Absorber Sheets

Fuel Type	Nominal Rod Array Pitch				Average Rod Array Pitch				Maximum Rod Array Pitch			
	Enrichment (U-235 wt%)	**k-eff**	**σ**	**k-eff+2σ**	**Enrichment (U-235 wt%)**	**k-eff**	**σ**	**k-eff+2σ**	**Enrichment (U-235 wt%)**	**k-eff**	**σ**	**k-eff+2σ**
ge08n	4.80	0.93829	0.00081	0.93991	4.80	0.93894	0.00080	0.94054	4.80	0.93700	0.00080	0.93860
ge08k	4.70	0.94031	0.00079	0.94189	4.70	0.94016	0.00079	0.94174	4.70	0.93784	0.00085	0.93954
ge08i	4.70	0.94081	0.00080	0.94241	4.70	0.94083	0.00076	0.94235	4.70	0.94024	0.00082	0.94188
ex08b	4.70	0.93594	0.00082	0.93758	4.70	0.93740	0.00082	0.93904	4.70	0.93776	0.00076	0.93928
ex09c	4.60	0.93979	0.00073	0.94125	4.60	0.94044	0.00073	0.94190	4.60	0.94081	0.00078	0.94237
B9_72A	4.50	0.94103	0.00073	0.94249	4.50	0.94026	0.00077	0.94180	**4.40**	0.93723	0.00074	0.93871
B10_91A	4.50	0.93842	0.00079	0.94000	4.50	0.93906	0.00077	0.94060	4.50	0.93826	0.00077	0.93980
B10_92A	4.40	0.93766	0.00078	0.93922	4.40	0.93790	0.00076	0.93942	4.40	0.93868	0.00074	0.94016

Table 6.7.6-3 Rod Array Pitch Study - 90% Boron Credit for Absorber Sheets

Fuel Type	Nominal Rod Array Pitch				Average Rod Array Pitch				Maximum Rod Array Pitch			
	Enrichment (U-235 wt%)	**k-eff**	**σ**	**k-eff+2σ**	**Enrichment (U-235 wt%)**	**k-eff**	**σ**	**k-eff+2σ**	**Enrichment (U-235 wt%)**	**k-eff**	**σ**	**k-eff+2σ**
ge08n	5.00	0.93748	0.00081	0.93910	5.00	0.93813	0.00080	0.93973	5.00	0.93679	0.00080	0.93839
ge08k	4.90	0.93881	0.00079	0.94039	4.90	0.93814	0.00076	0.93966	4.90	0.93726	0.00079	0.93884
ge08i	4.90	0.93956	0.00077	0.94110	4.90	0.94008	0.00077	0.94162	4.90	0.93907	0.00074	0.94055
ex08b	4.90	0.93512	0.00081	0.93674	4.90	0.93416	0.00082	0.93580	4.90	0.93510	0.00075	0.93660
ex09c	4.70	0.93444	0.00077	0.93598	4.70	0.93659	0.00076	0.93811	4.70	0.93557	0.00074	0.93705
B9_72A	4.70	0.94069	0.00078	0.94225	**4.60** (1)	0.93537	0.00076	0.93689	**4.60** (1)	0.93549	0.00078	0.93705
B10_91A	4.70	0.93855	0.00075	0.94005	4.70	0.93999	0.00080	0.94159	**4.60**	0.93508	0.00079	0.93666
B10_92A	4.60	0.93675	0.00075	0.93825	4.60	0.93765	0.00076	0.93917	4.60	0.93678	0.00079	0.93836

Note (1): Sample analysis was performed with modified random number seed. Two random number seeds were applied both producing $k_{eff} + 2\sigma$ below USL 0.9427 for average and maximum pitch. Default seed results exceeded 0.9427 and required a reduced enrichment.

Table 6.7.6-4 Missing Rod Study Damaged Fuel

# Missing Rods	B9_72A 75 % Boron Credit of Absorber Sheets					B9_72A 90 % Boron Credit of Absorber Sheets				
	Enrichment (U-235 wt%)	k-eff	σ	k-eff+2σ	Δk/σ	Enrichment (U-235 wt%)	k-eff	σ	k-eff+2σ	Δk/σ
0	4.50	0.94103	0.00073	0.94249	0.0	4.70	0.94069	0.00078	0.94225	0.0
1	4.50	0.93993	0.00075	0.94143	-1.5	**4.60**	0.93684	0.00075	0.93834	-5.1
4	**4.40**	0.93551	0.00076	0.93703	-7.6	4.70	0.93900	0.00075	0.94050	-2.3
8	4.50	0.94075	0.00080	0.94235	-0.4	4.70	0.94004	0.00076	0.94156	-0.9
12	4.50	0.93914	0.00080	0.94074	-2.6	4.70	0.93998	0.00077	0.94152	-0.9
16	**4.40**	0.93434	0.00074	0.93582	-9.2	4.70	0.93995	0.00078	0.94151	-0.9
20	4.50	0.94028	0.00079	0.94186	-1.0	4.70	0.94078	0.00074	0.94226	0.1
24	4.50	0.94023	0.00074	0.94171	-1.1	4.70	0.93725	0.00071	0.93867	-4.8
28	4.50	0.94002	0.00071	0.94144	-1.4	4.70	0.94012	0.00080	0.94172	-0.7
32	4.50	0.94005	0.00074	0.94153	-1.3	4.70	0.93956	0.00079	0.94114	-1.4
36	4.50	0.93958	0.00077	0.94112	-2.0	4.70	0.94020	0.00076	0.94172	-0.6
# Missing Rods	ex09c 75 % Boron Credit of Absorber Sheets					ge08i 75 % Boron Credit of Absorber Sheets				
	Enrichment (U-235 wt%)	k-eff	σ	k-eff+2σ	Δk/σ	Enrichment (U-235 wt%)	k-eff	σ	k-eff+2σ	Δk/σ
0	4.60	0.93979	0.00073	0.94125	0.0	4.70	0.94081	0.00080	0.94241	0.0
1	4.60	0.93898	0.00076	0.94050	-1.1	4.70	0.94053	0.00077	0.94207	0.8
4	**4.50**	0.93589	0.00074	0.93737	-5.3	4.70	0.93885	0.00073	0.94031	1.4
8	4.60	0.93980	0.00080	0.94140	0.0	4.70	0.94010	0.00076	0.94162	0.2
12	4.60	0.94065	0.00077	0.94219	1.2	4.70	0.93842	0.00079	0.94000	-0.8
16	4.60	0.93862	0.00076	0.94014	-1.6	4.70	0.93883	0.00075	0.94033	-1.1
20	4.60	0.93894	0.00078	0.94050	-1.2	**4.60**	0.93496	0.00076	0.93648	0.5
24	4.60	0.93958	0.00078	0.94114	-0.3	4.70	0.93867	0.00079	0.94025	-0.9
28	4.60	0.94060	0.00074	0.94208	1.1	4.70	0.93881	0.00075	0.94031	0.0
30	--	--	--	--	--	4.70	0.94041	0.00077	0.94195	-2.0
32	4.60	0.93911	0.00081	0.94073	-0.9	--	--	--	--	--
36	4.60	0.94079	0.00080	0.94239	1.4	--	--	--	--	--
39	4.60	0.93845	0.00079	0.94003	-1.8	--	--	--	--	--

Table 6.7.6-5 DFC Fuel Mixture Height Study Results

Fuel Type	DFC Configuration	75 % Boron Credit of Absorber Sheets				90 % Boron Credit of Absorber Sheets			
		Enrichment (U-235 wt%)	k-eff	σ	k-eff+2σ	Enrichment (U-235 wt%)	k-eff	σ	k-eff+2σ
B10_92A	MIX30	4.40	0.93467	0.00074	0.93615	4.60	0.93639	0.00082	0.93803
	MIX40	4.40	0.93630	0.00078	0.93786	4.60	0.93615	0.00076	0.93767
	MIX50	4.40	0.93592	0.00073	0.93738	4.60	0.93712	0.00076	0.93864
	MIX60	4.40	0.93816	0.00077	0.93970	4.60	0.93872	0.00078	0.94028
	MIX70	4.40	0.93772	0.00077	0.93926	4.60	0.93711	0.00072	0.93855
	MIX80	4.40	0.93872	0.00078	0.93947	4.60	0.93765	0.00074	0.93913
	MIX90	4.40	0.93664	0.00076	0.94024	4.60	0.93762	0.00078	0.93918
	MIX100	4.40	0.93800	0.00076	0.93952	4.60	0.93934	0.00077	0.94088
B10_91A	MIX30	4.50	0.93700	0.00073	0.93846	4.70	0.93868	0.00081	0.94030
	MIX40	4.50	0.93948	0.00070	0.94088	4.70	0.93811	0.00077	0.93965
	MIX50	4.50	0.93780	0.00078	0.93936	4.70	0.93928	0.00080	0.94088
	MIX60	4.50	0.93968	0.00082	0.94132	4.70	0.93959	0.00076	0.94111
	MIX70	**4.40**	0.93597	0.00075	0.93747	4.70	0.93926	0.00076	0.94078
	MIX80	4.50	0.93956	0.00077	0.94110	4.70	0.94085	0.00079	0.94243
	MIX90	4.50	0.94010	0.00077	0.94164	4.70	0.93848	0.00078	0.94004
	MIX100	4.50	0.93952	0.00073	0.94098	4.70	0.93909	0.00076	0.94061
B9_72A	MIX30	4.50	0.93751	0.00075	0.93901	4.70	0.93850	0.00075	0.94000
	MIX40	4.50	0.94042	0.00077	0.94196	4.70	0.93945	0.00075	0.94095
	MIX50	**4.40**	0.93724	0.00075	0.93874	4.70	0.94014	0.00077	0.94168
	MIX60	**4.40**	0.93591	0.00076	0.93743	4.70	0.94101	0.00082	0.94265
	MIX70	**4.40**	0.93488	0.00077	0.93642	**4.60**	0.93838	0.00071	0.93980
	MIX80	4.50	0.94118	0.00074	0.94266	4.70	0.94089	0.00079	0.94247
	MIX90	4.50	0.94046	0.00074	0.94194	4.70	0.94038	0.00079	0.94196
	MIX100	4.50	0.94047	0.00079	0.94205	**4.60**	0.93625	0.00069	0.93763
ex08b	MIX30	4.70	0.93635	0.00084	0.93803	4.90	0.93266	0.00077	0.93420
	MIX40	4.70	0.93671	0.00076	0.93823	4.90	0.93428	0.00076	0.93580
	MIX50	4.70	0.93639	0.00081	0.93801	4.90	0.93473	0.00080	0.93633
	MIX60	4.70	0.93604	0.00073	0.93750	4.90	0.93447	0.00080	0.93607
	MIX70	4.70	0.93713	0.00071	0.93855	4.90	0.93652	0.00080	0.93812
	MIX80	4.70	0.93805	0.00081	0.93967	4.90	0.93531	0.00077	0.93685
	MIX90	4.70	0.93606	0.00077	0.93760	4.90	0.93519	0.00080	0.93679
	MIX100	4.70	0.93839	0.00080	0.93999	4.90	0.93566	0.00073	0.93712

Table 6.7.6-5 DFC Fuel Mixture Height Study Results (continued)

Fuel Type	DFC Configuration	75 % Boron Credit of Absorber Sheets				90 % Boron Credit of Absorber Sheets			
		Enrichment (U-235 wt%)	k-eff	σ	k-eff+2σ	Enrichment (U-235 wt%)	k-eff	σ	k-eff+2σ
ex09c	MIX30	4.60	0.93793	0.00081	0.93955	4.70	0.93320	0.00080	0.93480
	MIX40	4.60	0.93969	0.00076	0.94121	4.70	0.93308	0.00076	0.93460
	MIX50	4.60	0.93995	0.00076	0.94147	4.70	0.93465	0.00077	0.93619
	MIX60	4.60	0.93953	0.00082	0.94117	4.70	0.93520	0.00081	0.93682
	MIX70	4.50	0.93572	0.00080	0.93732	4.70	0.93579	0.00080	0.93739
	MIX80	4.50	0.93619	0.00076	0.93771	4.70	0.93464	0.00076	0.93616
	MIX90	4.60	0.94037	0.00076	0.94189	4.70	0.93617	0.00079	0.93775
	MIX100	4.60	0.94072	0.00079	0.94230	4.70	0.93715	0.00075	0.93865
ge08i	MIX30	4.70	0.93888	0.00073	0.94034	4.90	0.93686	0.00076	0.93838
	MIX40	4.70	0.93700	0.00080	0.93860	4.90	0.93628	0.00078	0.93784
	MIX50	4.70	0.93932	0.00076	0.94084	4.90	0.93939	0.00081	0.94101
	MIX60	4.70	0.94023	0.00077	0.94177	4.90	0.93815	0.00074	0.93963
	MIX70	4.70	0.93966	0.00079	0.94124	4.90	0.93901	0.00076	0.94053
	MIX80	4.70	0.93881	0.00073	0.94027	4.90	0.93904	0.00083	0.94070
	MIX90	4.70	0.94081	0.00076	0.94233	4.90	0.93854	0.00079	0.94012
	MIX100	4.70	0.93934	0.00072	0.94078	4.90	0.93943	0.00071	0.94085
ge08k	MIX30	4.70	0.93807	0.00077	0.93961	4.90	0.93521	0.00078	0.93677
	MIX40	4.70	0.93702	0.00077	0.93856	4.90	0.93552	0.00078	0.93708
	MIX50	4.70	0.93892	0.00076	0.94044	4.90	0.93724	0.00074	0.93872
	MIX60	4.70	0.93965	0.00081	0.94127	4.90	0.93689	0.00078	0.93845
	MIX70	4.60	0.93375	0.00077	0.93529	4.90	0.93898	0.00081	0.94060
	MIX80	4.70	0.93850	0.00073	0.93996	4.90	0.93751	0.00077	0.93905
	MIX90	4.60	0.93459	0.93459	0.00081	4.90	0.93880	0.00077	0.94034
	MIX100	4.70	0.93936	0.00074	0.94084	4.90	0.93911	0.00080	0.94071
ge08n	MIX30	4.80	0.93446	0.00078	0.93602	5.00	0.93316	0.00076	0.93468
	MIX40	4.80	0.93784	0.00073	0.93930	5.00	0.93450	0.00081	0.93612
	MIX50	4.80	0.93721	0.00079	0.93879	5.00	0.93497	0.00081	0.93659
	MIX60	4.80	0.93881	0.00077	0.94035	5.00	0.93507	0.00079	0.93665
	MIX70	4.80	0.93892	0.00079	0.94050	5.00	0.93609	0.00079	0.93767
	MIX80	4.80	0.93646	0.00078	0.93802	5.00	0.93614	0.00075	0.93764
	MIX90	4.80	0.93729	0.00084	0.93897	5.00	0.93616	0.00079	0.93774
	MIX100	4.80	0.93886	0.00077	0.94032	5.00	0.93543	0.00077	0.93855

Table 6.7.6-6 Loading Limits for BWR Damaged Fuel

Fuel Type	75% Boron Credit	90% Boron Credit
	Enrichment(U-235 wt%)	**Enrichment(U-235 wt%)**
ge08n	4.80	5.00
ge08k	*4.60*	4.90
ge08i	*4.60*	4.90
ex08b	4.70	4.90
ex09c	*4.50*	4.70
B9_72A	*4.40*	*4.60*
B10_91A	*4.40*	*4.60*
B10_92A	4.40	4.60

Note: Numbers in italics indicate a 0.1 wt% ^{235}U reduction from uniformly loaded undamaged limits.

6.7.7 Range of Applicability Check

The MCNP USL has a documented range of applicability. Output was checked to confirm that results were within the validated range. Table 6.7.7-1 contains a sample comparison. Note that comparison to the range are only made for maximum reactivity (i.e., wet) configurations. Dry configurations have a higher lethargy but very low reactivities.

Table 6.7.7-1 Range of Applicability Comparison for MCNP 6.2 Bias versus the BWR Evaluations

Parameter	Minimum	Maximum	R^2	Sample Case*[2]
Enrichment (wt% ^{235}U)	2.350%	4.738%	0.0375	4.0%
Fuel rod pitch (cm)	1.30	2.54	0.0040	1.2954
Fuel pellet outside diameter (cm)	0.790	1.265	0.0653	0.87757
Fuel rod outer diameter (cm)	0.9400	1.4170	0.0774	1.02616
$H/^{235}U$ atom ratio	72.7	403.9	0.0576	98.1
Soluble boron (ppm by weight)	0	4986	0.0348	0
Cluster gap (cm)	1.206	13.750	0.0484	1.651*[3]
Boron (^{10}B) plate loading (g/cm^2)	0.0000	0.0670	0.0028	0.011
Energy of average neutron lethargy causing fission (eV)	0.09729	0.76013	0.1723	0.19086

*[2] The sample case is for B10_92Av .
*[3] The cluster gap is calculated as minimum distance between tube outer wall to its adjacent tube outer wall, the radial-in tube movement is applied since it will reduce the gap further.

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6.8 References

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8. ORNL/NUREG/CSD-2/V2/R5, Section F2, "BONAMI: Resonance Self-Shielding by the Bondarenko Method," Greene, M., September 1995.

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12. ANSI/ANS - 8.17-1984, “Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors,” American Nuclear Society.

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14. NUREG/CR-1547, “Criticality Experiments with Subcritical Clusters of 2.35 Wt % and 4.31 Wt % ^{235}U Enriched UO_2 Rods in Water at a Water-to-Fuel Volume Ratio of 1.6,” Bierman, S.R., Clayton, E.D., July 1980.

15. Bierman, S.R., and E. D. Clayton, “Criticality Experiments with Subcritical Clusters of 2.35 Wt % and 4.31 Wt % ^{235}U Enriched UO_2 Rods in Water with Steel Reflecting Walls,” Nuclear Technology, Volume 54, pp 131-144, August 1981.

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17. Bierman, B.M., “Criticality Experiments to Provide Benchmark Data on Neutron Flux Traps,” PNL-6205/UC-714, June 1988.

18. Manaranche, J.C. et al, “Dissolution and Storage Experiment with 4.75 Wt % U^{235} Enriched UO2 Rods,” Nuclear Technology, Volume 50, September 1980.

19. Owen, D. B., “Factors for One-Sided Tolerance Limits and for Variables Sampling Plans,” SCR-607, 1963.

20. SERCO Assurance, “MONK, A Monte Carlo Program for Nuclear Criticality Safety and Reactor Physics Analysis, Version 8A.”

21. “Monte Carlo N–Particle Transport Code System Version 6.2”, CCC-850, ORNL, March 2018.

6.9 CSAS Inputs

The CSAS25 input files for the criticality analyses of the Universal Storage System standard transfer and concrete casks containing PWR or BWR fuel, under normal and accident conditions, are provided in Figures 6.9-1 through 6.9-8. A standard transfer cask PWR Westinghouse 17×17 OFA (we17b) input file containing soluble boron at 1000 ppm, with a fuel initial enrichment of 5.0 wt. % ^{235}U, is shown in Figure 6.9-9. A BWR standard transfer cask model input containing 56 Exxon/ANF 9×9 79-fuel rod assemblies (ex09c) at 4.4 wt. % ^{235}U is shown in Figure 6.9-10.

Figure 6.9-1 CSAS Input for Normal Conditions - Transfer Cask Containing PWR Fuel

```
=CSAS25
UMS PWR TFR; NORMAL OP; ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 250 CM PITCH
27GROUPNDF4 LATTICECELL
UO2  1  0.95 293.0 92235 4.20 92238 95.80 END
ZIRCALLOY   2  1.0  293.0  END
H2O  3  1.0  293.0  END
AL   4  1.0  293.0  END
SS304 5 1.0  293.0  END
AL    6 DEN=2.6000 0.4627 293.0 END
B-10  6 DEN=2.6000 0.0568 293.0 END
B-11  6 DEN=2.6000 0.3449 293.0 END
C     6 DEN=2.6000 0.1167 293.0 END
PB    7 1.0 293.O  END
B-10  8 0.0 8.553-5 293.0 END
B-11  8 0.0 3.422-4 293.0 END
AL    8 0.0 7.763-3 293.0 END
H     8 0.0 5.854-2 293.0 END
O     8 0.0 2.609-2 293.0 END
C     8 0.0 2.264-2 293.0 END
N     8 0.0 1.394-3 293.0 END
H2O   9 1.0 293.0 END
H2O  10 1.0 293.0 END
CARBONSTEEL 11 1.0 293.0 END
END COMP
SQUAREPITCH  1.2598 0.7844 1 3 0.9144 2 0.8001 0 END
UMS PWR TFR; NORMAL OP; ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 250 CM PITCH
READ PARAM RUN=YES PLT=NO TME=5000 GEN=203 NPG=1000 END PARAM
READ GEOM
UNIT  1
COM='FUEL PIN CELL - BETWEEN DISKS'
CYLINDER   1 1  0.3922   2P2.4892
CYLINDER   0 1  0.4001   2P2.4892
CYLINDER   2 1  0.4572   2P2.4892
CUBOID     3 1  4P0.6299 2P2.4892
UNIT  2
COM='WATER ROD CELL - BETWEEN DISKS'
CYLINDER  3 1  0.5715   2P2.4892
CYLINDER  2 1  0.6121   2P2.4892
CUBOID    3 1  4P0.6299 2P2.4892
UNIT  3
COM='FUEL PIN CELL - FOR DISK SLICE OF CASK'
CYLINDER   1 1  0.3922   2P0.6350
CYLINDER   0 1  0.4001   2P0.6350
CYLINDER   2 1  0.4572   2P0.6350
CUBOID     3 1  4P0.6299 2P0.6350
UNIT  4
COM='WATER ROD CELL - FOR DISK SLICE OF CASK'
CYLINDER  3 1  0.5715   2P0.6350
CYLINDER  2 1  0.6121   2P0.6350
CUBOID    3 1  4P0.6299 2P0.6350
UNIT 5
COM='X-X BORAL SHEET BETWEEN DISKS'
CUBOID 6 1 2P10.4140 2P0.0635 2P2.4892
CUBOID 4 1 2P10.4140 2P0.0951 2P2.4892
UNIT 6
COM='Y-Y BORAL SHEET BETWEEN DISKS'
CUBOID 6 1 2P0.0635 2P10.4140 2P2.4892
CUBOID 4 1 2P0.0951 2P10.4140 2P2.4892
UNIT 7
COM='X-X BORAL SHEET WITH DISKS'
CUBOID 6 1 2P10.4140 2P0.0635 2P0.6350
CUBOID 4 1 2P10.4140 2P0.0951 2P0.6350
UNIT 8
COM='Y-Y BORAL SHEET WITH DISKS'
CUBOID 6 1 2P0.0635 2P10.4140 2P0.6350
CUBOID 4 1 2P0.0951 2P10.4140 2P0.6350
UNIT 10
COM='TUBE CELL IN H2O BETWEEN DISKS (A)'
ARRAY  1  -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE  5 0.0 +11.4308 0.0
HOLE  5 0.0 -11.4308 0.0
HOLE  6 +11.4308 0.0 0.0
HOLE  6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +12.0176 -11.5715 +12.0176 -11.5715 2P2.4892
UNIT 11
COM='TUBE CELL IN H2O BETWEEN DISKS (B)'
ARRAY  1  -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE  5 0.0 +11.4308 0.0
HOLE  5 0.0 -11.4308 0.0
HOLE  6 +11.4308 0.0 0.0
HOLE  6 -11.4308 0.0 0.0
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Figure 6.9-1 (continued)

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CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +11.5715 -12.0176 +12.0176 -11.5715 2P2.4892
UNIT 12
COM='TUBE CELL IN H2O BETWEEN DISKS (C)'
ARRAY  1  -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE  5 0.0 +11.4308 0.0
HOLE  5 0.0 -11.4308 0.0
HOLE  6 +11.4308 0.0 0.0
HOLE  6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +11.5715 -12.0176 +11.5715 -12.0176 2P2.4892
UNIT 13
COM='TUBE CELL IN H2O BETWEEN DISKS (D)'
ARRAY  1  -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE  5 0.0 +11.4308 0.0
HOLE  5 0.0 -11.4308 0.0
HOLE  6 +11.4308 0.0 0.0
HOLE  6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +12.0176 -11.5715 +11.5715 -12.0176 2P2.4892
UNIT 14
COM='WEB UNIT (1.5" WEB) - BETWEEN DISKS'
CUBOID 3 1  2P11.7946 2P1.8725 2P2.4892
UNIT 15
COM='WEB UNIT (1.0" WEB) - BETWEEN DISKS'
CUBOID 3 1  2P11.7946 2P1.2510 2P2.4892
UNIT 16
COM='WEB UNIT (0.875" WEB) - BETWEEN DISKS'
CUBOID 3 1  2P11.7946 2P1.0923 2P2.4892
UNIT 17
COM='6X1 FUEL TUBE STACK BETWEEN DISKS (-X)'
ARRAY 10 -11.7946 -77.3262 -2.4892
UNIT 18
COM='6X1 FUEL TUBE STACK BETWEEN DISKS (+X)'
ARRAY 11 -11.7946 -77.3262 -2.4892
UNIT 19
COM='2X1 FUEL TUBE STACK OF TUBES BETWEEN DISKS (-X)'
ARRAY 12 -11.7946 -25.4616 -2.4892
UNIT 20
COM='2X1 FUEL TUBE STACK OF TUBES BETWEEN DISKS (+X)'
ARRAY 13 -11.7946 -25.4616 -2.4892
UNIT 30
COM='TUBE CELL IN ST DISK (A)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +12.0176 -11.5715 2P0.6350
UNIT 31
COM='TUBE CELL IN ST DISK (B)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +12.0176 -11.5715 2P0.6350
UNIT 32
COM='TUBE CELL IN ST DISK (C)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +11.5715 -12.0176 2P0.6350
UNIT 33
COM='TUBE CELL IN ST DISK (D)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +11.5715 -12.0176 2P0.6350
UNIT 34
COM='WEB UNIT (1.5" WEB) - ST DISKS'
CUBOID 5 1  2P11.7946 2P1.8725 2P0.6350
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Figure 6.9-1 (continued)

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UNIT 35
COM='WEB UNIT (1.0" WEB) - ST DISKS'
CUBOID 5 1  2P11.7946 2P1.2510 2P0.6350
UNIT 36
COM='WEB UNIT (0.875" WEB) - ST DISKS'
CUBOID 5 1  2P11.7946 2P1.0923 2P0.6350
UNIT 37
COM='6x1 FUEL TUBE STACK ST DISK (-X)'
ARRAY 20 -11.7946 -77.3262 -0.6350
UNIT 38
COM='6x1 FUEL TUBE STACK ST DISK (+X)'
ARRAY 21 -11.7946 -77.3262 -0.6350
UNIT 39
COM='2X1 FUEL TUB STACK OF TUBES ST DISK (-X)'
ARRAY 22 -11.7946 -25.4616 -0.6350
UNIT 40
COM='2X1 FUEL TUB STACK OF TUBES ST DISK (+X)'
ARRAY 23 -11.7946 -25.4616 -0.6350
UNIT 50
COM='TUBE CELL IN AL DISK (A)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +12.0176 -11.5715 2P0.6350
UNIT 51
COM='TUBE CELL IN AL DISK (B)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +12.0176 -11.5715 2P0.6350
UNIT 52
COM='TUBE CELL IN AL DISK (C)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +11.5715 -12.0176 2P0.6350
UNIT 53
COM='TUBE CELL IN AL DISK (D)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +11.5715 -12.0176 2P0.6350
UNIT 54
COM='WEB UNIT (1.5" WEB) - AL DISKS'
CUBOID 4 1  2P11.7946 2P1.8725 2P0.6350
UNIT 55
COM='WEB UNIT (1.0" WEB) - AL DISKS'
CUBOID 4 1  2P11.7946 2P1.2510 2P0.6350
UNIT 56
COM='WEB UNIT (0.875" WEB) - AL DISKS'
CUBOID 4 1  2P11.7946 2P1.0923 2P0.6350
UNIT 57
COM='6X1 FUEL TUBE STACK AL DISK'
ARRAY 30 -11.7946 -77.3262 -0.6350
UNIT 58
COM='6X1 FUEL TUBE STACK AL DISK'
ARRAY 31 -11.7946 -77.3262 -0.6350
UNIT 59
COM='2X1 FUEL TUBE STACK OF TUBES AL DISK'
ARRAY 32 -11.7946 -25.4616 -0.6350
UNIT 60
COM='2X1 FUEL TUBE STACK OF TUBES AL DISK'
ARRAY 33 -11.7946 -25.4616 -0.6350
UNIT 70
COM='BASKET STRUCTURE IN TRANSFER CASK - WATER DISK'
CYLINDER 3 1 +83.5787 2P2.4892
HOLE 17  -13.6669 0.0 0.0
HOLE 18  +13.6669 0.0 0.0
HOLE 19  -39.7578 0.0 0.0
HOLE 20  +39.7578 0.0 0.0
HOLE 19  -65.5312 0.0 0.0
HOLE 20  +65.5312 0.0 0.0
HOLE 10  +40.8048 +40.8048 0.0
HOLE 11  -40.8048 +40.8048 0.0
```

Figure 6.9-1 (continued)

```
HOLE 12  -40.8048 -40.8048 0.0
HOLE 13  +40.8048 -40.8048 0.0
CYLINDER  5 1  +85.1662 2P2.4892
CYLINDER   9 1  +86.0425 2P2.4892
CYLINDER  11 1  +87.9475 2P2.4892
CYLINDER   7 1  +97.4725 2P2.4892
CYLINDER   8 1 +102.5525 2P2.4892
CYLINDER  11 1 +105.7275 2P2.4892
CUBOID     9 1 4P125.0   2P2.4892
UNIT 71
COM='BASKET STRUCTURE IN TRANSFER CASK - ST DISK'
CYLINDER  5 1 +83.1850 2P0.6350
HOLE 37  -13.6669 0.0 0.0
HOLE 38  +13.6669 0.0 0.0
HOLE 39  -39.7578 0.0 0.0
HOLE 40  +39.7578 0.0 0.0
HOLE 39  -65.5312 0.0 0.0
HOLE 40  +65.5312 0.0 0.0
HOLE 30  +40.8048 +40.8048 0.0
HOLE 31  -40.8048 +40.8048 0.0
HOLE 32  -40.8048 -40.8048 0.0
HOLE 33  +40.8048 -40.8048 0.0
CYLINDER  3 1  +83.5787 2P0.6350
CYLINDER  5 1  +85.1662 2P0.6350
CYLINDER   9 1  +86.0425 2P0.6350
CYLINDER  11 1  +87.9475 2P0.6350
CYLINDER   7 1  +97.4725 2P0.6350
CYLINDER   8 1 +102.5525 2P0.6350
CYLINDER  11 1 +105.7275 2P0.6350
CUBOID     9 1 4P125.0   2P0.6350
UNIT 72
COM='BASKET STRUCTURE IN TRANSFER CASK - AL DISK'
CYLINDER  4 1 +82.8675 2P0.6350
HOLE 57  -13.6669 0.0 0.0
HOLE 58  +13.6669 0.0 0.0
HOLE 59  -39.7578 0.0 0.0
HOLE 60  +39.7578 0.0 0.0
HOLE 59  -65.5312 0.0 0.0
HOLE 60  +65.5312 0.0 0.0
HOLE 50  +40.8048 +40.8048 0.0
HOLE 51  -40.8048 +40.8048 0.0
HOLE 52  -40.8048 -40.8048 0.0
HOLE 53  +40.8048 -40.8048 0.0
CYLINDER  3 1  +83.5787 2P0.6350
CYLINDER  5 1  +85.1662 2P0.6350
CYLINDER   9 1  +86.0425 2P0.6350
CYLINDER  11 1  +87.9475 2P0.6350
CYLINDER   7 1  +97.4725 2P0.6350
CYLINDER   8 1 +102.5525 2P0.6350
CYLINDER  11 1 +105.7275 2P0.6350
CUBOID     9 1 4P125.0   2P0.6350
GLOBAL UNIT 73
COM='DISK SLICE STACK'
ARRAY  40 -125.0 -125.0 0.0
END GEOM
READ ARRAY
ARA=1   NUX=17 NUY=17 NUZ=1  FILL
                        34R1
          5R1   2   2R1   2   2R1   2   5R1
               3R1   2   9R1   2   3R1
                        17R1
2R1   2   2R1   2   2R1   2   2R1   2   2R1   2   2R1
                        34R1
2R1   2   2R1   2   2R1   2   2R1   2   2R1   2   2R1
                        34R1
2R1   2   2R1   2   2R1   2   2R1   2   2R1   2   2R1
                        17R1
               3R1   2   9R1   2   3R1
          5R1   2   2R1   2   2R1   2   5R1
                        34R1
END FILL
ARA=2  NUX=17 NUY=17 NUZ=1  FILL
                        34R3
          5R3   4   2R3   4   2R3   4   5R3
               3R3   4   9R3   4   3R3
                        17R3
2R3   4   2R3   4   2R3   4   2R3   4   2R3   4   2R3
                        34R3
2R3   4   2R3   4   2R3   4   2R3   4   2R3   4   2R3
                        34R3
2R3   4   2R3   4   2R3   4   2R3   4   2R3   4   2R3
                        17R3
               3R3   4   9R3   4   3R3
          5R3   4   2R3   4   2R3   4   5R3
                        34R3
END FILL
ARA=10 NUX=1 NUY=11 NUZ=1 FILL 12 16 12 15 12 14 11 15 11 16 11 END FILL
ARA=11 NUX=1 NUY=11 NUZ=1 FILL 13 16 13 15 13 14 10 15 10 16 10 END FILL
ARA=12 NUX=1 NUY=3  NUZ=1 FILL 12 14 11 END FILL
ARA=13 NUX=1 NUY=3  NUZ=1 FILL 13 14 10 END FILL
ARA=20 NUX=1 NUY=11 NUZ=1 FILL 32 36 32 35 32 34 31 35 31 36 31 END FILL
ARA=21 NUX=1 NUY=11 NUZ=1 FILL 33 36 33 35 33 34 30 35 30 36 30 END FILL
ARA=22 NUX=1 NUY=3  NUZ=1 FILL 32 34 31 END FILL
ARA=23 NUX=1 NUY=3  NUZ=1 FILL 33 34 30 END FILL
ARA=30 NUX=1 NUY=11 NUZ=1 FILL 52 56 52 55 52 54 51 55 51 56 51 END FILL
ARA=31 NUX=1 NUY=11 NUZ=1 FILL 53 56 53 55 53 54 50 55 50 56 50 END FILL
ARA=32 NUX=1 NUY=3  NUZ=1 FILL 52 54 51 END FILL
ARA=33 NUX=1 NUY=3  NUZ=1 FILL 53 54 50 END FILL
```

Figure 6.9-1 (continued)

```
  ARA=40 NUX=1 NUY=1 NUZ=4 FILL 70 71 70 72 END FILL
  END ARRAY
  READ BOUNDS ZFC=PER YXF=MIRROR END BOUNDS
  END DATA
  END

SECONDARY MODULE 000008   HAS BEEN CALLED.
```

Figure 6.9-2 CSAS Input for Accident Conditions– Transfer Cask Containing PWR Fuel

```
=CSAS25
UMS PWR TFR; ACCIDENT; ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 250 CM PITCH
27GROUPNDF4 LATTICECELL
UO2  1  0.95 293.0 92235 4.20 92238 95.80 END
ZIRCALLOY   2  1.0  293.0  END
H2O  3  1.0  293.0  END
AL   4  1.0  293.0  END
SS304 5 1.0  293.0  END
AL    6 DEN=2.6000 0.4627 293.0 END
B-10  6 DEN=2.6000 0.0568 293.0 END
B-11  6 DEN=2.6000 0.3449 293.0 END
C     6 DEN=2.6000 0.1167 293.0 END
PB    7 1.0 293.O  END
B-10  8 0.0 8.553-5 293.0 END
B-11  8 0.0 3.422-4 293.0 END
AL    8 0.0 7.763-3 293.0 END
H     8 0.0 5.854-2 293.0 END
O     8 0.0 2.609-2 293.0 END
C     8 0.0 2.264-2 293.0 END
N     8 0.0 1.394-3 293.0 END
H2O   9 1.0 293.0 END
H2O  10 1.0 293.0 END
CARBONSTEEL 11 1.0 293.0 END
END COMP
SQUAREPITCH  1.2598 0.7844 1 3 0.9144 2 0.8001 10 END
UMS PWR TFR; ACCIDENT; ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 250 CM PITCH
READ PARAM RUN=YES PLT=NO TME=5000 GEN=803 NPG=1000 END PARAM
READ GEOM
UNIT  1
COM='FUEL PIN CELL - BETWEEN DISKS'
CYLINDER   1 1  0.3922   2P2.4892
CYLINDER  10 1  0.4001   2P2.4892
CYLINDER   2 1  0.4572   2P2.4892
CUBOID     3 1  4P0.6299 2P2.4892
UNIT  2
COM='WATER ROD CELL - BETWEEN DISKS'
CYLINDER  3 1  0.5715   2P2.4892
CYLINDER  2 1  0.6121   2P2.4892
CUBOID    3 1  4P0.6299 2P2.4892
UNIT  3
COM='FUEL PIN CELL - FOR DISK SLICE OF CASK'
CYLINDER   1 1  0.3922   2P0.6350
CYLINDER  10 1  0.4001   2P0.6350
CYLINDER   2 1  0.4572   2P0.6350
CUBOID     3 1  4P0.6299 2P0.6350
UNIT  4
COM='WATER ROD CELL - FOR DISK SLICE OF CASK'
CYLINDER  3 1  0.5715   2P0.6350
CYLINDER  2 1  0.6121   2P0.6350
CUBOID    3 1  4P0.6299 2P0.6350
UNIT 5
COM='X-X BORAL SHEET BETWEEN DISKS'
CUBOID 6 1 2P10.4140 2P0.0635 2P2.4892
CUBOID 4 1 2P10.4140 2P0.0951 2P2.4892
UNIT 6
COM='Y-Y BORAL SHEET BETWEEN DISKS'
CUBOID 6 1 2P0.0635 2P10.4140 2P2.4892
CUBOID 4 1 2P0.0951 2P10.4140 2P2.4892
UNIT 7
COM='X-X BORAL SHEET WITH DISKS'
CUBOID 6 1 2P10.4140 2P0.0635 2P0.6350
CUBOID 4 1 2P10.4140 2P0.0951 2P0.6350
UNIT 8
COM='Y-Y BORAL SHEET WITH DISKS'
CUBOID 6 1 2P0.0635 2P10.4140 2P0.6350
CUBOID 4 1 2P0.0951 2P10.4140 2P0.6350
UNIT 10
COM='TUBE CELL IN H2O BETWEEN DISKS (A)'
ARRAY  1  -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE  5 0.0 +11.4308 0.0
HOLE  5 0.0 -11.4308 0.0
HOLE  6 +11.4308 0.0 0.0
HOLE  6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +12.0176 -11.5715 +12.0176 -11.5715 2P2.4892
UNIT 11
COM='TUBE CELL IN H2O BETWEEN DISKS (B)'
ARRAY  1  -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE  5 0.0 +11.4308 0.0
HOLE  5 0.0 -11.4308 0.0
HOLE  6 +11.4308 0.0 0.0
HOLE  6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
```

Figure 6.9-2 (continued)

```
CUBOID 3 1 +11.5715 -12.0176 +12.0176 -11.5715 2P2.4892
UNIT 12
COM='TUBE CELL IN H2O BETWEEN DISKS (C)'
ARRAY  1  -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE  5 0.0 +11.4308 0.0
HOLE  5 0.0 -11.4308 0.0
HOLE  6 +11.4308 0.0 0.0
HOLE  6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +11.5715 -12.0176 +11.5715 -12.0176 2P2.4892
UNIT 13
COM='TUBE CELL IN H2O BETWEEN DISKS (D)'
ARRAY  1  -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE  5 0.0 +11.4308 0.0
HOLE  5 0.0 -11.4308 0.0
HOLE  6 +11.4308 0.0 0.0
HOLE  6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +12.0176 -11.5715 +11.5715 -12.0176 2P2.4892
UNIT 14
COM='WEB UNIT (1.5" WEB) - BETWEEN DISKS'
CUBOID 3 1  2P11.7946 2P1.8725 2P2.4892
UNIT 15
COM='WEB UNIT (1.0" WEB) - BETWEEN DISKS'
CUBOID 3 1  2P11.7946 2P1.2510 2P2.4892
UNIT 16
COM='WEB UNIT (0.875" WEB) - BETWEEN DISKS'
CUBOID 3 1  2P11.7946 2P1.0923 2P2.4892
UNIT 17
COM='6X1 FUEL TUBE STACK BETWEEN DISKS (-X)'
ARRAY 10 -11.7946 -77.3262 -2.4892
UNIT 18
COM='6X1 FUEL TUBE STACK BETWEEN DISKS (+X)'
ARRAY 11 -11.7946 -77.3262 -2.4892
UNIT 19
COM='2X1 FUEL TUBE STACK OF TUBES BETWEEN DISKS (-X)'
ARRAY 12 -11.7946 -25.4616 -2.4892
UNIT 20
COM='2X1 FUEL TUBE STACK OF TUBES BETWEEN DISKS (+X)'
ARRAY 13 -11.7946 -25.4616 -2.4892
UNIT 30
COM='TUBE CELL IN ST DISK (A)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +12.0176 -11.5715 2P0.6350
UNIT 31
COM='TUBE CELL IN ST DISK (B)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +12.0176 -11.5715 2P0.6350
UNIT 32
COM='TUBE CELL IN ST DISK (C)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +11.5715 -12.0176 2P0.6350
UNIT 33
COM='TUBE CELL IN ST DISK (D)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +11.5715 -12.0176 2P0.6350
UNIT 34
COM='WEB UNIT (1.5" WEB) - ST DISKS'
CUBOID 5 1  2P11.7946 2P1.8725 2P0.6350
UNIT 35
```

Figure 6.9-2 (continued)

```
COM='WEB UNIT (1.0" WEB) - ST DISKS'
CUBOID 5 1  2P11.7946 2P1.2510 2P0.6350
UNIT 36
COM='WEB UNIT (0.875" WEB) - ST DISKS'
CUBOID 5 1  2P11.7946 2P1.0923 2P0.6350
UNIT 37
COM='6x1 FUEL TUBE STACK ST DISK (-X)'
ARRAY 20 -11.7946 -77.3262 -0.6350
UNIT 38
COM='6x1 FUEL TUBE STACK ST DISK (+X)'
ARRAY 21 -11.7946 -77.3262 -0.6350
UNIT 39
COM='2X1 FUEL TUB STACK OF TUBES ST DISK (-X)'
ARRAY 22 -11.7946 -25.4616 -0.6350
UNIT 40
COM='2X1 FUEL TUB STACK OF TUBES ST DISK (+X)'
ARRAY 23 -11.7946 -25.4616 -0.6350
UNIT 50
COM='TUBE CELL IN AL DISK (A)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +12.0176 -11.5715 2P0.6350
UNIT 51
COM='TUBE CELL IN AL DISK (B)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +12.0176 -11.5715 2P0.6350
UNIT 52
COM='TUBE CELL IN AL DISK (C)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +11.5715 -12.0176 2P0.6350
UNIT 53
COM='TUBE CELL IN AL DISK (D)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +11.5715 -12.0176 2P0.6350
UNIT 54
COM='WEB UNIT (1.5" WEB) - AL DISKS'
CUBOID 4 1  2P11.7946 2P1.8725 2P0.6350
UNIT 55
COM='WEB UNIT (1.0" WEB) - AL DISKS'
CUBOID 4 1  2P11.7946 2P1.2510 2P0.6350
UNIT 56
COM='WEB UNIT (0.875" WEB) - AL DISKS'
CUBOID 4 1  2P11.7946 2P1.0923 2P0.6350
UNIT 57
COM='6X1 FUEL TUBE STACK AL DISK'
ARRAY 30 -11.7946 -77.3262 -0.6350
UNIT 58
COM='6X1 FUEL TUBE STACK AL DISK'
ARRAY 31 -11.7946 -77.3262 -0.6350
UNIT 59
COM='2X1 FUEL TUBE STACK OF TUBES AL DISK'
ARRAY 32 -11.7946 -25.4616 -0.6350
UNIT 60
COM='2X1 FUEL TUBE STACK OF TUBES AL DISK'
ARRAY 33 -11.7946 -25.4616 -0.6350
UNIT 70
COM='BASKET STRUCTURE IN TRANSFER CASK - WATER DISK'
CYLINDER 3 1 +83.5787 2P2.4892
HOLE 17  -13.6669 0.0 0.0
HOLE 18  +13.6669 0.0 0.0
HOLE 19  -39.7578 0.0 0.0
HOLE 20  +39.7578 0.0 0.0
HOLE 19  -65.5312 0.0 0.0
HOLE 20  +65.5312 0.0 0.0
HOLE 10  +40.8048 +40.8048 0.0
HOLE 11  -40.8048 +40.8048 0.0
HOLE 12  -40.8048 -40.8048 0.0
```

Figure 6.9-2 (continued)

```
HOLE 13  +40.8048 -40.8048 0.0
CYLINDER  5 1  +85.1662 2P2.4892
CYLINDER   9 1  +86.0425 2P2.4892
CYLINDER  11 1  +87.9475 2P2.4892
CYLINDER   7 1  +97.4725 2P2.4892
CYLINDER   8 1 +102.5525 2P2.4892
CYLINDER  11 1 +105.7275 2P2.4892
CUBOID     9 1 4P125.0   2P2.4892
UNIT 71
COM='BASKET STRUCTURE IN TRANSFER CASK - ST DISK'
CYLINDER  5 1 +83.1850 2P0.6350
HOLE 37  -13.6669 0.0 0.0
HOLE 38  +13.6669 0.0 0.0
HOLE 39  -39.7578 0.0 0.0
HOLE 40  +39.7578 0.0 0.0
HOLE 39  -65.5312 0.0 0.0
HOLE 40  +65.5312 0.0 0.0
HOLE 30  +40.8048 +40.8048 0.0
HOLE 31  -40.8048 +40.8048 0.0
HOLE 32  -40.8048 -40.8048 0.0
HOLE 33  +40.8048 -40.8048 0.0
CYLINDER  3 1  +83.5787 2P0.6350
CYLINDER  5 1  +85.1662 2P0.6350
CYLINDER   9 1  +86.0425 2P0.6350
CYLINDER  11 1  +87.9475 2P0.6350
CYLINDER   7 1  +97.4725 2P0.6350
CYLINDER   8 1 +102.5525 2P0.6350
CYLINDER  11 1 +105.7275 2P0.6350
CUBOID     9 1 4P125.0   2P0.6350
UNIT 72
COM='BASKET STRUCTURE IN TRANSFER CASK - AL DISK'
CYLINDER  4 1 +82.8675 2P0.6350
HOLE 57  -13.6669 0.0 0.0
HOLE 58  +13.6669 0.0 0.0
HOLE 59  -39.7578 0.0 0.0
HOLE 60  +39.7578 0.0 0.0
HOLE 59  -65.5312 0.0 0.0
HOLE 60  +65.5312 0.0 0.0
HOLE 50  +40.8048 +40.8048 0.0
HOLE 51  -40.8048 +40.8048 0.0
HOLE 52  -40.8048 -40.8048 0.0
HOLE 53  +40.8048 -40.8048 0.0
CYLINDER  3 1  +83.5787 2P0.6350
CYLINDER  5 1  +85.1662 2P0.6350
CYLINDER   9 1  +86.0425 2P0.6350
CYLINDER  11 1  +87.9475 2P0.6350
CYLINDER   7 1  +97.4725 2P0.6350
CYLINDER   8 1 +102.5525 2P0.6350
CYLINDER  11 1 +105.7275 2P0.6350
CUBOID     9 1 4P125.0   2P0.6350
GLOBAL UNIT 73
COM='DISK SLICE STACK'
ARRAY  40 -125.0 -125.0 0.0
END GEOM
READ ARRAY
ARA=1   NUX=17 NUY=17 NUZ=1  FILL
                        34R1
          5R1   2   2R1   2   2R1   2   5R1
               3R1   2   9R1   2   3R1
                        17R1
2R1   2   2R1   2   2R1   2   2R1   2   2R1   2   2R1
                        34R1
2R1   2   2R1   2   2R1   2   2R1   2   2R1   2   2R1
                        34R1
2R1   2   2R1   2   2R1   2   2R1   2   2R1   2   2R1
                        17R1
               3R1   2   9R1   2   3R1
          5R1   2   2R1   2   2R1   2   5R1
                        34R1
END FILL
ARA=2  NUX=17 NUY=17 NUZ=1  FILL
                        34R3
          5R3   4   2R3   4   2R3   4   5R3
               3R3   4   9R3   4   3R3
                        17R3
2R3   4   2R3   4   2R3   4   2R3   4   2R3   4   2R3
                        34R3
2R3   4   2R3   4   2R3   4   2R3   4   2R3   4   2R3
                        34R3
2R3   4   2R3   4   2R3   4   2R3   4   2R3   4   2R3
                        17R3
               3R3   4   9R3   4   3R3
          5R3   4   2R3   4   2R3   4   5R3
                        34R3
END FILL
ARA=10 NUX=1 NUY=11 NUZ=1 FILL 12 16 12 15 12 14 11 15 11 16 11 END FILL
ARA=11 NUX=1 NUY=11 NUZ=1 FILL 13 16 13 15 13 14 10 15 10 16 10 END FILL
ARA=12 NUX=1 NUY=3  NUZ=1 FILL 12 14 11 END FILL
ARA=13 NUX=1 NUY=3  NUZ=1 FILL 13 14 10 END FILL
ARA=20 NUX=1 NUY=11 NUZ=1 FILL 32 36 32 35 32 34 31 35 31 36 31 END FILL
ARA=21 NUX=1 NUY=11 NUZ=1 FILL 33 36 33 35 33 34 30 35 30 36 30 END FILL
ARA=22 NUX=1 NUY=3  NUZ=1 FILL 32 34 31 END FILL
ARA=23 NUX=1 NUY=3  NUZ=1 FILL 33 34 30 END FILL
ARA=30 NUX=1 NUY=11 NUZ=1 FILL 52 56 52 55 52 54 51 55 51 56 51 END FILL
ARA=31 NUX=1 NUY=11 NUZ=1 FILL 53 56 53 55 53 54 50 55 50 56 50 END FILL
ARA=32 NUX=1 NUY=3  NUZ=1 FILL 52 54 51 END FILL
ARA=33 NUX=1 NUY=3  NUZ=1 FILL 53 54 50 END FILL
ARA=40 NUX=1 NUY=1 NUZ=4 FILL 70 71 70 72 END FILL
```

Figure 6.9-2 (continued)

```
END ARRAY
READ BOUNDS ZFC=PER YXF=MIRROR END BOUNDS
END DATA
END
```

Figure 6.9-3 CSAS Input for Normal Conditions–Vertical Concrete Cask Containing PWR Fuel

```
=CSAS25
UMS PWR SC; NORMAL OP; ARRAY; 0.0001 GM/CC IN - 0.0001 GM/CC EX; 460 CM PITCH
27GROUPNDF4 LATTICECELL
UO2  1  0.95 293.0 92235 4.20 92238 95.80 END
ZIRCALLOY   2  1.0  293.0  END
H2O  3  0.0001  293.0  END
AL   4  1.0  293.0  END
SS304 5 1.0  293.0  END
AL    6 DEN=2.6000 0.4627 293.0 END
B-10  6 DEN=2.6000 0.0568 293.0 END
B-11  6 DEN=2.6000 0.3449 293.0 END
C     6 DEN=2.6000 0.1167 293.0 END
CARBONSTEEL  7 1.0    293.O  END
REG-CONCRETE 8 0.9750 293.0 END
H2O   9 0.0001 293.0 END
H2O  10 0.0001 293.0 END
END COMP
SQUAREPITCH  1.2598 0.7844 1 3 0.9144 2 0.8001 0 END
UMS PWR SC; NORMAL OP; ARRAY; 0.0001 GM/CC IN - 0.0001 GM/CC EX; 460 CM PITCH
READ PARAM RUN=YES PLT=NO TME=5000 GEN=203 NPG=1000 END PARAM
READ GEOM
UNIT  1
COM='FUEL PIN CELL - BETWEEN DISKS'
CYLINDER   1 1  0.3922   2P2.4892
CYLINDER   0 1  0.4001   2P2.4892
CYLINDER   2 1  0.4572   2P2.4892
CUBOID     3 1  4P0.6299 2P2.4892
UNIT  2
COM='WATER ROD CELL - BETWEEN DISKS'
CYLINDER  3 1  0.5715   2P2.4892
CYLINDER  2 1  0.6121   2P2.4892
CUBOID    3 1  4P0.6299 2P2.4892
UNIT  3
COM='FUEL PIN CELL - FOR DISK SLICE OF CASK'
CYLINDER   1 1  0.3922   2P0.6350
CYLINDER   0 1  0.4001   2P0.6350
CYLINDER   2 1  0.4572   2P0.6350
CUBOID     3 1  4P0.6299 2P0.6350
UNIT  4
COM='WATER ROD CELL - FOR DISK SLICE OF CASK'
CYLINDER  3 1  0.5715   2P0.6350
CYLINDER  2 1  0.6121   2P0.6350
CUBOID    3 1  4P0.6299 2P0.6350
UNIT 5
COM='X-X BORAL SHEET BETWEEN DISKS'
CUBOID 6 1 2P10.4140 2P0.0635 2P2.4892
CUBOID 4 1 2P10.4140 2P0.0951 2P2.4892
UNIT 6
COM='Y-Y BORAL SHEET BETWEEN DISKS'
CUBOID 6 1 2P0.0635 2P10.4140 2P2.4892
CUBOID 4 1 2P0.0951 2P10.4140 2P2.4892
UNIT 7
COM='X-X BORAL SHEET WITH DISKS'
CUBOID 6 1 2P10.4140 2P0.0635 2P0.6350
CUBOID 4 1 2P10.4140 2P0.0951 2P0.6350
UNIT 8
COM='Y-Y BORAL SHEET WITH DISKS'
CUBOID 6 1 2P0.0635 2P10.4140 2P0.6350
CUBOID 4 1 2P0.0951 2P10.4140 2P0.6350
UNIT 10
COM='TUBE CELL IN H2O BETWEEN DISKS (A)'
ARRAY  1  -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE  5 0.0 +11.4308 0.0
HOLE  5 0.0 -11.4308 0.0
HOLE  6 +11.4308 0.0 0.0
HOLE  6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +12.0176 -11.5715 +12.0176 -11.5715 2P2.4892
UNIT 11
COM='TUBE CELL IN H2O BETWEEN DISKS (B)'
ARRAY  1  -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE  5 0.0 +11.4308 0.0
HOLE  5 0.0 -11.4308 0.0
HOLE  6 +11.4308 0.0 0.0
HOLE  6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +11.5715 -12.0176 +12.0176 -11.5715 2P2.4892
UNIT 12
COM='TUBE CELL IN H2O BETWEEN DISKS (C)'
ARRAY  1  -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE  5 0.0 +11.4308 0.0
HOLE  5 0.0 -11.4308 0.0
HOLE  6 +11.4308 0.0 0.0
HOLE  6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +11.5715 -12.0176 +11.5715 -12.0176 2P2.4892
```

Figure 6.9-3 (continued)

```
UNIT 13
COM='TUBE CELL IN H2O BETWEEN DISKS (D)'
ARRAY  1  -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE  5 0.0 +11.4308 0.0
HOLE  5 0.0 -11.4308 0.0
HOLE  6 +11.4308 0.0 0.0
HOLE  6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +12.0176 -11.5715 +11.5715 -12.0176 2P2.4892
UNIT 14
COM='WEB UNIT (1.5" WEB) - BETWEEN DISKS'
CUBOID 3 1  2P11.7946 2P1.8725 2P2.4892
UNIT 15
COM='WEB UNIT (1.0" WEB) - BETWEEN DISKS'
CUBOID 3 1  2P11.7946 2P1.2510 2P2.4892
UNIT 16
COM='WEB UNIT (0.875" WEB) - BETWEEN DISKS'
CUBOID 3 1  2P11.7946 2P1.0923 2P2.4892
UNIT 17
COM='6X1 FUEL TUBE STACK BETWEEN DISKS (-X)'
ARRAY 10 -11.7946 -77.3262 -2.4892
UNIT 18
COM='6X1 FUEL TUBE STACK BETWEEN DISKS (+X)'
ARRAY 11 -11.7946 -77.3262 -2.4892
UNIT 19
COM='2X1 FUEL TUBE STACK OF TUBES BETWEEN DISKS (-X)'
ARRAY 12 -11.7946 -25.4616 -2.4892
UNIT 20
COM='2X1 FUEL TUBE STACK OF TUBES BETWEEN DISKS (+X)'
ARRAY 13 -11.7946 -25.4616 -2.4892
UNIT 30
COM='TUBE CELL IN ST DISK (A)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +12.0176 -11.5715 2P0.6350
UNIT 31
COM='TUBE CELL IN ST DISK (B)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +12.0176 -11.5715 2P0.6350
UNIT 32
COM='TUBE CELL IN ST DISK (C)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +11.5715 -12.0176 2P0.6350
UNIT 33
COM='TUBE CELL IN ST DISK (D)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +11.5715 -12.0176 2P0.6350
UNIT 34
COM='WEB UNIT (1.5" WEB) - ST DISKS'
CUBOID 5 1  2P11.7946 2P1.8725 2P0.6350
UNIT 35
COM='WEB UNIT (1.0" WEB) - ST DISKS'
CUBOID 5 1  2P11.7946 2P1.2510 2P0.6350
UNIT 36
COM='WEB UNIT (0.875" WEB) - ST DISKS'
CUBOID 5 1  2P11.7946 2P1.0923 2P0.6350
UNIT 37
COM='6x1 FUEL TUBE STACK ST DISK (-X)'
ARRAY 20 -11.7946 -77.3262 -0.6350
UNIT 38
COM='6x1 FUEL TUBE STACK ST DISK (+X)'
ARRAY 21 -11.7946 -77.3262 -0.6350
UNIT 39
COM='2X1 FUEL TUB STACK OF TUBES ST DISK (-X)'
```

Figure 6.9-3 (continued)

```
ARRAY 22 -11.7946 -25.4616 -0.6350
UNIT 40
COM='2X1 FUEL TUB STACK OF TUBES ST DISK (+X)'
ARRAY 23 -11.7946 -25.4616 -0.6350
UNIT 50
COM='TUBE CELL IN AL DISK (A)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +12.0176 -11.5715 2P0.6350
UNIT 51
COM='TUBE CELL IN AL DISK (B)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +12.0176 -11.5715 2P0.6350
UNIT 52
COM='TUBE CELL IN AL DISK (C)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +11.5715 -12.0176 2P0.6350
UNIT 53
COM='TUBE CELL IN AL DISK (D)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +11.5715 -12.0176 2P0.6350
UNIT 54
COM='WEB UNIT (1.5" WEB) - AL DISKS'
CUBOID 4 1  2P11.7946 2P1.8725 2P0.6350
UNIT 55
COM='WEB UNIT (1.0" WEB) - AL DISKS'
CUBOID 4 1  2P11.7946 2P1.2510 2P0.6350
UNIT 56
COM='WEB UNIT (0.875" WEB) - AL DISKS'
CUBOID 4 1  2P11.7946 2P1.0923 2P0.6350
UNIT 57
COM='6X1 FUEL TUBE STACK AL DISK'
ARRAY 30 -11.7946 -77.3262 -0.6350
UNIT 58
COM='6X1 FUEL TUBE STACK AL DISK'
ARRAY 31 -11.7946 -77.3262 -0.6350
UNIT 59
COM='2X1 FUEL TUBE STACK OF TUBES AL DISK'
ARRAY 32 -11.7946 -25.4616 -0.6350
UNIT 60
COM='2X1 FUEL TUBE STACK OF TUBES AL DISK'
ARRAY 33 -11.7946 -25.4616 -0.6350
UNIT 70
COM='BASKET STRUCTURE IN STORAGE CASK - WATER DISK'
CYLINDER 3 1 +83.5787 2P2.4892
HOLE 17  -13.6669 0.0 0.0
HOLE 18  +13.6669 0.0 0.0
HOLE 19  -39.7578 0.0 0.0
HOLE 20  +39.7578 0.0 0.0
HOLE 19  -65.5312 0.0 0.0
HOLE 20  +65.5312 0.0 0.0
HOLE 10  +40.8048 +40.8048 0.0
HOLE 11  -40.8048 +40.8048 0.0
HOLE 12  -40.8048 -40.8048 0.0
HOLE 13  +40.8048 -40.8048 0.0
CYLINDER  5 1  +85.1662 2P2.4892
CYLINDER  9 1  +94.615 2P2.4892
CYLINDER  7 1 +100.965 2P2.4892
CYLINDER  8 1 +172.72 2P2.4892
CUBOID    9 1 4P230.0 2P2.4892
UNIT 71
COM='BASKET STRUCTURE IN STORAGE CASK - ST DISK'
CYLINDER  5 1 +83.1850 2P0.6350
HOLE 37  -13.6669 0.0 0.0
HOLE 38  +13.6669 0.0 0.0
HOLE 39  -39.7578 0.0 0.0
HOLE 40  +39.7578 0.0 0.0
HOLE 39  -65.5312 0.0 0.0
```


Figure 6.9-3 (continued)

```
HOLE 40  +65.5312 0.0 0.0
HOLE 30  +40.8048 +40.8048 0.0
HOLE 31  -40.8048 +40.8048 0.0
HOLE 32  -40.8048 -40.8048 0.0
HOLE 33  +40.8048 -40.8048 0.0
CYLINDER  3 1  +83.5787 2P0.6350
CYLINDER  5 1  +85.1662 2P0.6350
CYLINDER  9 1  +94.615 2P0.6350
CYLINDER  7 1 +100.965 2P0.6350
CYLINDER  8 1 +172.72 2P0.6350
CUBOID    9 1 4P230.0 2P0.6350
UNIT 72
COM='BASKET STRUCTURE IN STORAGE CASK - AL DISK'
CYLINDER  4 1 +82.8675 2P0.6350
HOLE 57  -13.6669 0.0 0.0
HOLE 58  +13.6669 0.0 0.0
HOLE 59  -39.7578 0.0 0.0
HOLE 60  +39.7578 0.0 0.0
HOLE 59  -65.5312 0.0 0.0
HOLE 60  +65.5312 0.0 0.0
HOLE 50  +40.8048 +40.8048 0.0
HOLE 51  -40.8048 +40.8048 0.0
HOLE 52  -40.8048 -40.8048 0.0
HOLE 53  +40.8048 -40.8048 0.0
CYLINDER  3 1  +83.5787 2P0.6350
CYLINDER  5 1  +85.1662 2P0.6350
CYLINDER  9 1  +94.615 2P0.6350
CYLINDER  7 1 +100.965 2P0.6350
CYLINDER  8 1 +172.72 2P0.6350
CUBOID    9 1 4P230.0 2P0.6350
GLOBAL UNIT 73
COM='DISK SLICE STACK'
ARRAY  40 -230.0 -230.0 0.0
END GEOM
READ ARRAY
ARA=1   NUX=17 NUY=17 NUZ=1  FILL
                        34R1
          5R1   2   2R1   2   2R1   2   5R1
               3R1   2   9R1   2   3R1
                        17R1
2R1   2   2R1   2   2R1   2   2R1   2   2R1   2   2R1
                        34R1
2R1   2   2R1   2   2R1   2   2R1   2   2R1   2   2R1
                        34R1
2R1   2   2R1   2   2R1   2   2R1   2   2R1   2   2R1
                        17R1
               3R1   2   9R1   2   3R1
          5R1   2   2R1   2   2R1   2   5R1
                        34R1
END FILL
ARA=2  NUX=17 NUY=17 NUZ=1  FILL
                        34R3
          5R3   4   2R3   4   2R3   4   5R3
               3R3   4   9R3   4   3R3
                        17R3
2R3   4   2R3   4   2R3   4   2R3   4   2R3   4   2R3
                        34R3
2R3   4   2R3   4   2R3   4   2R3   4   2R3   4   2R3
                        34R3
2R3   4   2R3   4   2R3   4   2R3   4   2R3   4   2R3
                        17R3
               3R3   4   9R3   4   3R3
          5R3   4   2R3   4   2R3   4   5R3
                        34R3
END FILL
ARA=10 NUX=1 NUY=11 NUZ=1 FILL 12 16 12 15 12 14 11 15 11 16 11 END FILL
ARA=11 NUX=1 NUY=11 NUZ=1 FILL 13 16 13 15 13 14 10 15 10 16 10 END FILL
ARA=12 NUX=1 NUY=3  NUZ=1 FILL 12 14 11 END FILL
ARA=13 NUX=1 NUY=3  NUZ=1 FILL 13 14 10 END FILL
ARA=20 NUX=1 NUY=11 NUZ=1 FILL 32 36 32 35 32 34 31 35 31 36 31 END FILL
ARA=21 NUX=1 NUY=11 NUZ=1 FILL 33 36 33 35 33 34 30 35 30 36 30 END FILL
ARA=22 NUX=1 NUY=3  NUZ=1 FILL 32 34 31 END FILL
ARA=23 NUX=1 NUY=3  NUZ=1 FILL 33 34 30 END FILL
ARA=30 NUX=1 NUY=11 NUZ=1 FILL 52 56 52 55 52 54 51 55 51 56 51 END FILL
ARA=31 NUX=1 NUY=11 NUZ=1 FILL 53 56 53 55 53 54 50 55 50 56 50 END FILL
ARA=32 NUX=1 NUY=3  NUZ=1 FILL 52 54 51 END FILL
ARA=33 NUX=1 NUY=3  NUZ=1 FILL 53 54 50 END FILL
ARA=40 NUX=1 NUY=1 NUZ=4 FILL 70 71 70 72 END FILL
END ARRAY
READ BOUNDS ZFC=PER YXF=MIRROR END BOUNDS
END DATA
END
```

Figure 6.9-4 CSAS Input for Accident Conditions– Vertical Concrete Cask Containing PWR Fuel

```
=CSAS25
UMS PWR SC; ACCIDENT; ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 460 CM PITCH
27GROUPNDF4 LATTICECELL
UO2  1  0.95 293.0 92235 4.20 92238 95.80 END
ZIRCALLOY   2  1.0  293.0  END
H2O  3  1.0  293.0  END
AL   4  1.0  293.0  END
SS304 5 1.0  293.0  END
AL    6 DEN=2.6000 0.4627 293.0 END
B-10  6 DEN=2.6000 0.0568 293.0 END
B-11  6 DEN=2.6000 0.3449 293.0 END
C     6 DEN=2.6000 0.1167 293.0 END
CARBONSTEEL  7 1.0    293.O  END
REG-CONCRETE 8 0.9750 293.0 END
H2O   9 1.0 293.0 END
H2O  10 1.0 293.0 END
END COMP
SQUAREPITCH  1.2598 0.7844 1 3 0.9144 2 0.8001 10 END
UMS PWR SC; ACCIDENT; ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 460 CM PITCH
READ PARAM RUN=YES PLT=NO TME=5000 GEN=803 NPG=1000 END PARAM
READ GEOM
UNIT  1
COM='FUEL PIN CELL - BETWEEN DISKS'
CYLINDER   1 1  0.3922   2P2.4892
CYLINDER  10 1  0.4001   2P2.4892
CYLINDER   2 1  0.4572   2P2.4892
CUBOID     3 1  4P0.6299 2P2.4892
UNIT  2
COM='WATER ROD CELL - BETWEEN DISKS'
CYLINDER  3 1  0.5715   2P2.4892
CYLINDER  2 1  0.6121   2P2.4892
CUBOID    3 1  4P0.6299 2P2.4892
UNIT  3
COM='FUEL PIN CELL - FOR DISK SLICE OF CASK'
CYLINDER   1 1  0.3922   2P0.6350
CYLINDER  10 1  0.4001   2P0.6350
CYLINDER   2 1  0.4572   2P0.6350
CUBOID     3 1  4P0.6299 2P0.6350
UNIT  4
COM='WATER ROD CELL - FOR DISK SLICE OF CASK'
CYLINDER  3 1  0.5715   2P0.6350
CYLINDER  2 1  0.6121   2P0.6350
CUBOID    3 1  4P0.6299 2P0.6350
UNIT 5
COM='X-X BORAL SHEET BETWEEN DISKS'
CUBOID 6 1 2P10.4140 2P0.0635 2P2.4892
CUBOID 4 1 2P10.4140 2P0.0951 2P2.4892
UNIT 6
COM='Y-Y BORAL SHEET BETWEEN DISKS'
CUBOID 6 1 2P0.0635 2P10.4140 2P2.4892
CUBOID 4 1 2P0.0951 2P10.4140 2P2.4892
UNIT 7
COM='X-X BORAL SHEET WITH DISKS'
CUBOID 6 1 2P10.4140 2P0.0635 2P0.6350
CUBOID 4 1 2P10.4140 2P0.0951 2P0.6350
UNIT 8
COM='Y-Y BORAL SHEET WITH DISKS'
CUBOID 6 1 2P0.0635 2P10.4140 2P0.6350
CUBOID 4 1 2P0.0951 2P10.4140 2P0.6350
UNIT 10
COM='TUBE CELL IN H2O BETWEEN DISKS (A)'
ARRAY  1  -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE  5 0.0 +11.4308 0.0
HOLE  5 0.0 -11.4308 0.0
HOLE  6 +11.4308 0.0 0.0
HOLE  6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +12.0176 -11.5715 +12.0176 -11.5715 2P2.4892
UNIT 11
COM='TUBE CELL IN H2O BETWEEN DISKS (B)'
ARRAY  1  -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE  5 0.0 +11.4308 0.0
HOLE  5 0.0 -11.4308 0.0
HOLE  6 +11.4308 0.0 0.0
HOLE  6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +11.5715 -12.0176 +12.0176 -11.5715 2P2.4892
UNIT 12
COM='TUBE CELL IN H2O BETWEEN DISKS (C)'
ARRAY  1  -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
```

Figure 6.9-4 (continued)

```
HOLE  5 0.0 +11.4308 0.0
HOLE  5 0.0 -11.4308 0.0
HOLE  6 +11.4308 0.0 0.0
HOLE  6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +11.5715 -12.0176 +11.5715 -12.0176 2P2.4892
UNIT 13
COM='TUBE CELL IN H2O BETWEEN DISKS (D)'
ARRAY  1  -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE  5 0.0 +11.4308 0.0
HOLE  5 0.0 -11.4308 0.0
HOLE  6 +11.4308 0.0 0.0
HOLE  6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +12.0176 -11.5715 +11.5715 -12.0176 2P2.4892
UNIT 14
COM='WEB UNIT (1.5" WEB) - BETWEEN DISKS'
CUBOID 3 1  2P11.7946 2P1.8725 2P2.4892
UNIT 15
COM='WEB UNIT (1.0" WEB) - BETWEEN DISKS'
CUBOID 3 1  2P11.7946 2P1.2510 2P2.4892
UNIT 16
COM='WEB UNIT (0.875" WEB) - BETWEEN DISKS'
CUBOID 3 1  2P11.7946 2P1.0923 2P2.4892
UNIT 17
COM='6X1 FUEL TUBE STACK BETWEEN DISKS (-X)'
ARRAY 10 -11.7946 -77.3262 -2.4892
UNIT 18
COM='6X1 FUEL TUBE STACK BETWEEN DISKS (+X)'
ARRAY 11 -11.7946 -77.3262 -2.4892
UNIT 19
COM='2X1 FUEL TUBE STACK OF TUBES BETWEEN DISKS (-X)'
ARRAY 12 -11.7946 -25.4616 -2.4892
UNIT 20
COM='2X1 FUEL TUBE STACK OF TUBES BETWEEN DISKS (+X)'
ARRAY 13 -11.7946 -25.4616 -2.4892
UNIT 30
COM='TUBE CELL IN ST DISK (A)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +12.0176 -11.5715 2P0.6350
UNIT 31
COM='TUBE CELL IN ST DISK (B)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +12.0176 -11.5715 2P0.6350
UNIT 32
COM='TUBE CELL IN ST DISK (C)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +11.5715 -12.0176 2P0.6350
UNIT 33
COM='TUBE CELL IN ST DISK (D)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +11.5715 -12.0176 2P0.6350
UNIT 34
COM='WEB UNIT (1.5" WEB) - ST DISKS'
CUBOID 5 1  2P11.7946 2P1.8725 2P0.6350
UNIT 35
COM='WEB UNIT (1.0" WEB) - ST DISKS'
CUBOID 5 1  2P11.7946 2P1.2510 2P0.6350
UNIT 36
COM='WEB UNIT (0.875" WEB) - ST DISKS'
CUBOID 5 1  2P11.7946 2P1.0923 2P0.6350
UNIT 37
COM='6x1 FUEL TUBE STACK ST DISK (-X)'
ARRAY 20 -11.7946 -77.3262 -0.6350
```

Figure 6.9-4 (continued)

```
UNIT 38
COM='6x1 FUEL TUBE STACK ST DISK (+X)'
ARRAY 21 -11.7946 -77.3262 -0.6350
UNIT 39
COM='2X1 FUEL TUB STACK OF TUBES ST DISK (-X)'
ARRAY 22 -11.7946 -25.4616 -0.6350
UNIT 40
COM='2X1 FUEL TUB STACK OF TUBES ST DISK (+X)'
ARRAY 23 -11.7946 -25.4616 -0.6350
UNIT 50
COM='TUBE CELL IN AL DISK (A)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +12.0176 -11.5715 2P0.6350
UNIT 51
COM='TUBE CELL IN AL DISK (B)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +12.0176 -11.5715 2P0.6350
UNIT 52
COM='TUBE CELL IN AL DISK (C)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +11.5715 -12.0176 2P0.6350
UNIT 53
COM='TUBE CELL IN AL DISK (D)'
ARRAY  2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE  7 0.0 +11.4308 0.0
HOLE  7 0.0 -11.4308 0.0
HOLE  8 +11.4308 0.0 0.0
HOLE  8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +11.5715 -12.0176 2P0.6350
UNIT 54
COM='WEB UNIT (1.5" WEB) - AL DISKS'
CUBOID 4 1  2P11.7946 2P1.8725 2P0.6350
UNIT 55
COM='WEB UNIT (1.0" WEB) - AL DISKS'
CUBOID 4 1  2P11.7946 2P1.2510 2P0.6350
UNIT 56
COM='WEB UNIT (0.875" WEB) - AL DISKS'
CUBOID 4 1  2P11.7946 2P1.0923 2P0.6350
UNIT 57
COM='6X1 FUEL TUBE STACK AL DISK'
ARRAY 30 -11.7946 -77.3262 -0.6350
UNIT 58
COM='6X1 FUEL TUBE STACK AL DISK'
ARRAY 31 -11.7946 -77.3262 -0.6350
UNIT 59
COM='2X1 FUEL TUBE STACK OF TUBES AL DISK'
ARRAY 32 -11.7946 -25.4616 -0.6350
UNIT 60
COM='2X1 FUEL TUBE STACK OF TUBES AL DISK'
ARRAY 33 -11.7946 -25.4616 -0.6350
UNIT 70
COM='BASKET STRUCTURE IN STORAGE CASK - WATER DISK'
CYLINDER 3 1 +83.5787 2P2.4892
HOLE 17  -13.6669 0.0 0.0
HOLE 18  +13.6669 0.0 0.0
HOLE 19  -39.7578 0.0 0.0
HOLE 20  +39.7578 0.0 0.0
HOLE 19  -65.5312 0.0 0.0
HOLE 20  +65.5312 0.0 0.0
HOLE 10  +40.8048 +40.8048 0.0
HOLE 11  -40.8048 +40.8048 0.0
HOLE 12  -40.8048 -40.8048 0.0
HOLE 13  +40.8048 -40.8048 0.0
CYLINDER  5 1  +85.1662 2P2.4892
CYLINDER  9 1  +94.615 2P2.4892
CYLINDER  7 1 +100.965 2P2.4892
CYLINDER  8 1 +172.72 2P2.4892
CUBOID    9 1 4P230.0 2P2.4892
UNIT 71
COM='BASKET STRUCTURE IN STORAGE CASK - ST DISK'
CYLINDER  5 1 +83.1850 2P0.6350
```

Figure 6.9-4 (continued)

```
HOLE 37  -13.6669 0.0 0.0
HOLE 38  +13.6669 0.0 0.0
HOLE 39  -39.7578 0.0 0.0
HOLE 40  +39.7578 0.0 0.0
HOLE 39  -65.5312 0.0 0.0
HOLE 40  +65.5312 0.0 0.0
HOLE 30  +40.8048 +40.8048 0.0
HOLE 31  -40.8048 +40.8048 0.0
HOLE 32  -40.8048 -40.8048 0.0
HOLE 33  +40.8048 -40.8048 0.0
CYLINDER  3 1  +83.5787 2P0.6350
CYLINDER  5 1  +85.1662 2P0.6350
CYLINDER  9 1  +94.615 2P0.6350
CYLINDER  7 1 +100.965 2P0.6350
CYLINDER  8 1 +172.72 2P0.6350
CUBOID    9 1 4P230.0 2P0.6350
UNIT 72
COM='BASKET STRUCTURE IN STORAGE CASK - AL DISK'
CYLINDER  4 1 +82.8675 2P0.6350
HOLE 57  -13.6669 0.0 0.0
HOLE 58  +13.6669 0.0 0.0
HOLE 59  -39.7578 0.0 0.0
HOLE 60  +39.7578 0.0 0.0
HOLE 59  -65.5312 0.0 0.0
HOLE 60  +65.5312 0.0 0.0
HOLE 50  +40.8048 +40.8048 0.0
HOLE 51  -40.8048 +40.8048 0.0
HOLE 52  -40.8048 -40.8048 0.0
HOLE 53  +40.8048 -40.8048 0.0
CYLINDER  3 1  +83.5787 2P0.6350
CYLINDER  5 1  +85.1662 2P0.6350
CYLINDER  9 1  +94.615 2P0.6350
CYLINDER  7 1 +100.965 2P0.6350
CYLINDER  8 1 +172.72 2P0.6350
CUBOID    9 1 4P230.0 2P0.6350
GLOBAL UNIT 73
COM='DISK SLICE STACK'
ARRAY  40 -230.0 -230.0 0.0
END GEOM
READ ARRAY
ARA=1   NUX=17 NUY=17 NUZ=1  FILL
                        34R1
          5R1   2   2R1   2   2R1   2   5R1
               3R1   2   9R1   2   3R1
                        17R1
2R1   2   2R1   2   2R1   2   2R1   2   2R1   2   2R1
                        34R1
2R1   2   2R1   2   2R1   2   2R1   2   2R1   2   2R1
                        34R1
2R1   2   2R1   2   2R1   2   2R1   2   2R1   2   2R1
                        17R1
               3R1   2   9R1   2   3R1
          5R1   2   2R1   2   2R1   2   5R1
                        34R1
END FILL
ARA=2  NUX=17 NUY=17 NUZ=1  FILL
                        34R3
          5R3   4   2R3   4   2R3   4   5R3
               3R3   4   9R3   4   3R3
                        17R3
2R3   4   2R3   4   2R3   4   2R3   4   2R3   4   2R3
                        34R3
2R3   4   2R3   4   2R3   4   2R3   4   2R3   4   2R3
                        34R3
2R3   4   2R3   4   2R3   4   2R3   4   2R3   4   2R3
                        17R3
               3R3   4   9R3   4   3R3
          5R3   4   2R3   4   2R3   4   5R3
                        34R3
END FILL
ARA=10 NUX=1 NUY=11 NUZ=1 FILL 12 16 12 15 12 14 11 15 11 16 11 END FILL
ARA=11 NUX=1 NUY=11 NUZ=1 FILL 13 16 13 15 13 14 10 15 10 16 10 END FILL
ARA=12 NUX=1 NUY=3  NUZ=1 FILL 12 14 11 END FILL
ARA=13 NUX=1 NUY=3  NUZ=1 FILL 13 14 10 END FILL
ARA=20 NUX=1 NUY=11 NUZ=1 FILL 32 36 32 35 32 34 31 35 31 36 31 END FILL
ARA=21 NUX=1 NUY=11 NUZ=1 FILL 33 36 33 35 33 34 30 35 30 36 30 END FILL
ARA=22 NUX=1 NUY=3  NUZ=1 FILL 32 34 31 END FILL
ARA=23 NUX=1 NUY=3  NUZ=1 FILL 33 34 30 END FILL
ARA=30 NUX=1 NUY=11 NUZ=1 FILL 52 56 52 55 52 54 51 55 51 56 51 END FILL
ARA=31 NUX=1 NUY=11 NUZ=1 FILL 53 56 53 55 53 54 50 55 50 56 50 END FILL
ARA=32 NUX=1 NUY=3  NUZ=1 FILL 52 54 51 END FILL
ARA=33 NUX=1 NUY=3  NUZ=1 FILL 53 54 50 END FILL
ARA=40 NUX=1 NUY=1 NUZ=4 FILL 70 71 70 72 END FILL
END ARRAY
READ BOUNDS ZFC=PER YXF=MIRROR END BOUNDS
END DATA
END
```

Figure 6.9-5 CSAS Input for Normal Conditions – Transfer Cask Containing BWR Fuel

```
=CSAS25
UMS BWR TFR; NORMAL OP; CASK ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 75%B10
27GROUPNDF4 LATTICECELL
UO2   1 0.95 293.0 92235 4.00 92238 96.00 END
ZIRCALLOY  2 1.0  293.0  END
H2O   3 1.0  293.0  END
AL    4 1.0  293.0  END
SS304 5 1.0  293.0  END
AL    6 DEN=2.6849 0.8706 293.O END
B-10  6 DEN=2.6849 0.0137 293.O END
B-11  6 DEN=2.6849 0.0830 293.O END
C     6 DEN=2.6849 0.0281 293.O END
CARBONSTEEL 7 1.0 293.0 END
PB    8 1.0 293.O  END
B-10  9 0.0 8.553-5 END
B-11  9 0.0 3.422-4 END
AL    9 0.0 7.763-3 END
H     9 0.0 5.854-2 END
O     9 0.0 2.609-2 END
C     9 0.0 2.264-2 END
N     9 0.0 1.394-3 END
H2O  10 1.0 293.0 END
END COMP
SQUAREPITCH  1.4529 0.9055 1 3 1.0770 2 0.9246 0 END
UMS BWR TFR; NORMAL OP; CASK ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 75%B10
READ PARAM RUN=YES PLT=NO TME=5000 GEN=803 NPG=1000 END PARAM
READ GEOM
UNIT  1
COM='FUEL PIN CELL - WITH H2O'
CYLINDER  1 1  0.4528   2P1.7145
CYLINDER  0 1  0.4623   2P1.7145
CYLINDER  2 1  0.5385   2P1.7145
CUBOID    3 1  4P0.7264 2P1.7145
UNIT  2
COM='WATER ROD CELL - WITH H2O'
CYLINDER  3 1  0.4623   2P1.7145
CYLINDER  2 1  0.5385   2P1.7145
CUBOID    3 1  4P0.7264 2P1.7145
UNIT  3
COM='FUEL PIN CELL - WITH ST DISK'
CYLINDER  1 1  0.4528   2P0.7938
CYLINDER  0 1  0.4623   2P0.7938
CYLINDER  2 1  0.5385   2P0.7938
CUBOID    3 1  4P0.7264 2P0.7938
UNIT  4
COM='WATER ROD CELL - WITH ST DISK'
CYLINDER  3 1  0.4623   2P0.7938
CYLINDER  2 1  0.5385   2P0.7938
CUBOID    3 1  4P0.7264 2P0.7938
UNIT  5
COM='FUEL PIN CELL - WITH AL DISK'
CYLINDER  1 1  0.4528   2P0.6350
CYLINDER  0 1  0.4623   2P0.6350
CYLINDER  2 1  0.5385   2P0.6350
CUBOID    3 1  4P0.7264 2P0.6350
UNIT  6
COM='WATER ROD CELL - WITH AL DISK'
CYLINDER  3 1  0.4623   2P0.6350
CYLINDER  2 1  0.5385   2P0.6350
CUBOID    3 1  4P0.7264 2P0.6350
UNIT  7
COM='FUEL PIN ARRAY + CHANNEL - BETWEEN DISKS'
ARRAY  1   -6.5376 -6.5376 -1.7145
CUBOID 3 1 4P6.7031 2P1.7145
CUBOID 2 1 4P6.9063 2P1.7145
UNIT  8
COM='FUEL PIN ARRAY + CHANNEL - ST DISKS'
ARRAY  2   -6.5376 -6.5376 -0.7938
CUBOID 3 1 4P6.7031 2P0.7938
CUBOID 2 1 4P6.9063 2P0.7938
UNIT  9
COM='FUEL PIN ARRAY + CHANNEL - AL DISKS'
ARRAY  3   -6.5376 -6.5376 -0.6350
CUBOID 3 1 4P6.7031 2P0.6350
CUBOID 2 1 4P6.9063 2P0.6350
UNIT 10
COM='X-X BORAL + COVER SHEET BETWEEN DISKS'
CUBOID 6 1 2P6.7310 2P0.1124 2P1.7145
CUBOID 4 1 2P6.7310 2P0.1714 2P1.7145
CUBOID 5 1 2P6.7765 +0.2168 -0.1714 2P1.7145
UNIT 11
COM='Y-Y BORAL + COVER SHEET BETWEEN DISKS'
CUBOID 6 1 2P0.1124 2P6.7310 2P1.7145
CUBOID 4 1 2P0.1714 2P6.7310 2P1.7145
CUBOID 5 1 +0.2168 -0.1714 2P6.7765 2P1.7145
UNIT 12
COM='X-X BORAL + COVER SHEET WITH ST DISKS'
CUBOID 6 1 2P6.7310 2P0.1124 2P0.7938
CUBOID 4 1 2P6.7310 2P0.1714 2P0.7938
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Figure 6.9-5 (continued)

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CUBOID 5 1 2P6.7765 +0.2168 -0.1714 2P0.7938
UNIT 13
COM='Y-Y BORAL + COVER SHEET WITH ST DISKS'
CUBOID 6 1 2P0.1124 2P6.7310 2P0.7938
CUBOID 4 1 2P0.1714 2P6.7310 2P0.7938
CUBOID 5 1 +0.2168 -0.1714 2P6.7765 2P0.7938
UNIT 14
COM='X-X BORAL + COVER SHEET WITH AL DISKS'
CUBOID 6 1 2P6.7310 2P0.1124 2P0.6350
CUBOID 4 1 2P6.7310 2P0.1714 2P0.6350
CUBOID 5 1 2P6.7765 +0.2168 -0.1714 2P0.6350
UNIT 15
COM='Y-Y BORAL + COVER SHEET WITH AL DISKS'
CUBOID 6 1 2P0.1124 2P6.7310 2P0.6350
CUBOID 4 1 2P0.1714 2P6.7310 2P0.6350
CUBOID 5 1 +0.2168 -0.1714 2P6.7765 2P0.6350
UNIT 20
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (TR)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 +0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 21
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 22
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 23
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 24
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (T)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 0.0 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 25
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 26
COM='FUEL TUBE CELL TOP BORAL SHEETS - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
UNIT 27
COM='FUEL TUBE CELL TOP BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
UNIT 28
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P1.7145
HOLE   11 +7.7859 0.0 0.0
UNIT 29
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P1.7145
HOLE   11 +7.7859 0.0 0.0
UNIT 30
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P1.7145
HOLE   11 +7.7859 0.0 0.0
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Figure 6.9-5 (continued)

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UNIT 31
COM='FUEL TUBE CELL NO BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
UNIT 40
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (TR)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 +0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 41
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 42
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 43
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 44
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (T)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 0.0 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 45
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 46
COM='FUEL TUBE CELL TOP BORAL SHEETS - STEEL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
UNIT 47
COM='FUEL TUBE CELL TOP BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
UNIT 48
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.7938
HOLE   13 +7.7859 0.0 0.0
UNIT 49
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - STEEL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.7938
HOLE   13 +7.7859 0.0 0.0
UNIT 50
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - STEEL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.7938
HOLE   13 +7.7859 0.0 0.0
UNIT 51
COM='FUEL TUBE CELL NO BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
UNIT 60
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (TR)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 +0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
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Figure 6.9-5 (continued)

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HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 61
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 62
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 63
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 64
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (T)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 0.0 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 65
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 66
COM='FUEL TUBE CELL TOP BORAL SHEETS - AL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
UNIT 67
COM='FUEL TUBE CELL TOP BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
UNIT 68
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.6350
HOLE   15 +7.7859 0.0 0.0
UNIT 69
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - AL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.6350
HOLE   15 +7.7859 0.0 0.0
UNIT 70
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - AL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.6350
HOLE   15 +7.7859 0.0 0.0
UNIT 71
COM='FUEL TUBE CELL NO BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
UNIT 80
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (TR)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   20  -0.0297 -0.0297 0.0
UNIT 81
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   21  -0.3586 -0.0297 0.0
UNIT 82
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   22  -0.3586 -0.3586 0.0
UNIT 83
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   23  -0.0297 -0.3586 0.0
UNIT 84
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Figure 6.9-5 (continued)

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COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (T)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   24  -0.1942 -0.0297 0.0
UNIT 85
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   25  -0.1942 -0.3586 0.0
UNIT 86
COM='DISK OPENING TOP BORAL SHEET TUBE - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   26  -0.3586 -0.0297 0.0
UNIT 87
COM='DISK OPENING TOP BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   27  -0.3586 -0.3586 0.0
UNIT 88
COM='DISK OPENING RIGHT BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   28  -0.3586 -0.3586 0.0
UNIT 89
COM='DISK OPENING RIGHT BORAL SHEET TUBE - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   29  -0.1942 -0.3586 0.0
UNIT 90
COM='DISK OPENING RIGHT BORAL SHEET TUBE - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   30  -0.0297 -0.3586 0.0
UNIT 91
COM='DISK OPENING NO BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   31  -0.3586 -0.3586 0.0
UNIT 100
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (TR)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   40  -0.0297 -0.0297 0.0
UNIT 101
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   41  -0.3586 -0.0297 0.0
UNIT 102
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   42  -0.3586 -0.3586 0.0
UNIT 103
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   43  -0.0297 -0.3586 0.0
UNIT 104
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (T)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   44  -0.1942 -0.0297 0.0
UNIT 105
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   45  -0.1942 -0.3586 0.0
UNIT 106
COM='DISK OPENING TOP BORAL SHEET TUBE - STEEL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   46  -0.3586 -0.0297 0.0
UNIT 107
COM='DISK OPENING TOP BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   47  -0.3586 -0.3586 0.0
UNIT 108
COM='DISK OPENING RIGHT BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   48  -0.3586 -0.3586 0.0
UNIT 109
COM='DISK OPENING RIGHT BORAL SHEET TUBE - STEEL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   49  -0.1942 -0.3586 0.0
UNIT 110
COM='DISK OPENING RIGHT BORAL SHEET TUBE - STEEL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   50  -0.0297 -0.3586 0.0
UNIT 111
COM='DISK OPENING NO BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   51  -0.3586 -0.3586 0.0
UNIT 120
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (TR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   60  -0.0297 -0.0297 0.0
UNIT 121
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   61  -0.3586 -0.0297 0.0
UNIT 122
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   62  -0.3586 -0.3586 0.0
UNIT 123
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   63  -0.0297 -0.3586 0.0
UNIT 124
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (T)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   64  -0.1942 -0.0297 0.0
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Figure 6.9-5 (continued)

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UNIT 125
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   65  -0.1942 -0.3586 0.0
UNIT 126
COM='DISK OPENING TOP BORAL SHEET TUBE - AL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   66  -0.3586 -0.0297 0.0
UNIT 127
COM='DISK OPENING TOP BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   67  -0.3586 -0.3586 0.0
UNIT 128
COM='DISK OPENING RIGHT BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   68  -0.3586 -0.3586 0.0
UNIT 129
COM='DISK OPENING RIGHT BORAL SHEET TUBE - AL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   69  -0.1942 -0.3586 0.0
UNIT 130
COM='DISK OPENING RIGHT BORAL SHEET TUBE - AL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   70  -0.0297 -0.3586 0.0
UNIT 131
COM='DISK OPENING NO BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   71  -0.3586 -0.3586 0.0
UNIT 140
COM='BASKET STRUCTURE IN TRANPORT CASK - WATER DISK'
CYLINDER 3 1 +83.5787 2P1.7145
HOLE 90  -70.3885  +8.7986 0.0
HOLE 83  -52.7914  +8.7986 0.0
HOLE 83  -52.7914 +26.3957 0.0
HOLE 90  -52.7914 +43.9928 0.0
HOLE 83  -35.1942  +8.7986 0.0
HOLE 83  -35.1942 +26.3957 0.0
HOLE 83  -35.1942 +43.9928 0.0
HOLE 90  -35.1942 +61.5899 0.0
HOLE 83  -17.5971  +8.7986 0.0
HOLE 83  -17.5971 +26.3957 0.0
HOLE 83  -17.5971 +43.9928 0.0
HOLE 90  -17.5971 +61.5899 0.0
HOLE 85   0.0      +8.7986 0.0
HOLE 85   0.0     +26.3957 0.0
HOLE 85   0.0     +43.9928 0.0
HOLE 89   0.0     +61.5899 0.0
HOLE 82  +17.5971  +8.7986 0.0
HOLE 82  +17.5971 +26.3957 0.0
HOLE 82  +17.5971 +43.9928 0.0
HOLE 88  +17.5971 +61.5899 0.0
HOLE 82  +35.1942  +8.7986 0.0
HOLE 82  +35.1942 +26.3957 0.0
HOLE 82  +35.1942 +43.9928 0.0
HOLE 91  +35.1942 +61.5899 0.0
HOLE 82  +52.7914  +8.7986 0.0
HOLE 87  +52.7914 +26.3957 0.0
HOLE 91  +52.7914 +43.9928 0.0
HOLE 91  +70.3885  +8.7986 0.0
HOLE 80  -70.3885  -8.7986 0.0
HOLE 80  -52.7914  -8.7986 0.0
HOLE 80  -52.7914 -26.3957 0.0
HOLE 80  -52.7914 -43.9928 0.0
HOLE 80  -35.1942  -8.7986 0.0
HOLE 80  -35.1942 -26.3957 0.0
HOLE 80  -35.1942 -43.9928 0.0
HOLE 80  -35.1942 -61.5899 0.0
HOLE 80  -17.5971  -8.7986 0.0
HOLE 80  -17.5971 -26.3957 0.0
HOLE 80  -17.5971 -43.9928 0.0
HOLE 80  -17.5971 -61.5899 0.0
HOLE 84   0.0      -8.7986 0.0
HOLE 84   0.0     -26.3957 0.0
HOLE 84   0.0     -43.9928 0.0
HOLE 84   0.0     -61.5899 0.0
HOLE 81  +17.5971  -8.7986 0.0
HOLE 81  +17.5971 -26.3957 0.0
HOLE 81  +17.5971 -43.9928 0.0
HOLE 81  +17.5971 -61.5899 0.0
HOLE 81  +35.1942  -8.7986 0.0
HOLE 81  +35.1942 -26.3957 0.0
HOLE 81  +35.1942 -43.9928 0.0
HOLE 86  +35.1942 -61.5899 0.0
HOLE 81  +52.7914  -8.7986 0.0
HOLE 86  +52.7914 -26.3957 0.0
HOLE 86  +52.7914 -43.9928 0.0
HOLE 86  +70.3885  -8.7986 0.0
CYLINDER   5 1  +85.1662 2P1.7145
CYLINDER  10 1  +86.0425 2P1.7145
CYLINDER   7 1  +87.9475 2P1.7145
CYLINDER   8 1  +97.4725 2P1.7145
CYLINDER   9 1 +102.5525 2P1.7145
CYLINDER   7 1 +105.7275 2P1.7145
CUBOID    10 1 4P125.0   2P1.7145
UNIT 141
COM='BASKET STRUCTURE IN TRANPORT CASK - SS DISK'
CYLINDER 7 1  +83.1850 2P0.7938
HOLE 110  -70.3885  +8.7986 0.0
HOLE 103  -52.7914  +8.7986 0.0
```

Figure 6.9-5 (continued)

```
HOLE 103  -52.7914 +26.3957 0.0
HOLE 110  -52.7914 +43.9928 0.0
HOLE 103  -35.1942  +8.7986 0.0
HOLE 103  -35.1942 +26.3957 0.0
HOLE 103  -35.1942 +43.9928 0.0
HOLE 110  -35.1942 +61.5899 0.0
HOLE 103  -17.5971  +8.7986 0.0
HOLE 103  -17.5971 +26.3957 0.0
HOLE 103  -17.5971 +43.9928 0.0
HOLE 110  -17.5971 +61.5899 0.0
HOLE 105   0.0      +8.7986 0.0
HOLE 105   0.0     +26.3957 0.0
HOLE 105   0.0     +43.9928 0.0
HOLE 109   0.0     +61.5899 0.0
HOLE 102  +17.5971  +8.7986 0.0
HOLE 102  +17.5971 +26.3957 0.0
HOLE 102  +17.5971 +43.9928 0.0
HOLE 108  +17.5971 +61.5899 0.0
HOLE 102  +35.1942  +8.7986 0.0
HOLE 102  +35.1942 +26.3957 0.0
HOLE 102  +35.1942 +43.9928 0.0
HOLE 111  +35.1942 +61.5899 0.0
HOLE 102  +52.7914  +8.7986 0.0
HOLE 107  +52.7914 +26.3957 0.0
HOLE 111  +52.7914 +43.9928 0.0
HOLE 111  +70.3885  +8.7986 0.0
HOLE 100  -70.3885  -8.7986 0.0
HOLE 100  -52.7914  -8.7986 0.0
HOLE 100  -52.7914 -26.3957 0.0
HOLE 100  -52.7914 -43.9928 0.0
HOLE 100  -35.1942  -8.7986 0.0
HOLE 100  -35.1942 -26.3957 0.0
HOLE 100  -35.1942 -43.9928 0.0
HOLE 100  -35.1942 -61.5899 0.0
HOLE 100  -17.5971  -8.7986 0.0
HOLE 100  -17.5971 -26.3957 0.0
HOLE 100  -17.5971 -43.9928 0.0
HOLE 100  -17.5971 -61.5899 0.0
HOLE 104   0.0      -8.7986 0.0
HOLE 104   0.0     -26.3957 0.0
HOLE 104   0.0     -43.9928 0.0
HOLE 104   0.0     -61.5899 0.0
HOLE 101  +17.5971  -8.7986 0.0
HOLE 101  +17.5971 -26.3957 0.0
HOLE 101  +17.5971 -43.9928 0.0
HOLE 101  +17.5971 -61.5899 0.0
HOLE 101  +35.1942  -8.7986 0.0
HOLE 101  +35.1942 -26.3957 0.0
HOLE 101  +35.1942 -43.9928 0.0
HOLE 106  +35.1942 -61.5899 0.0
HOLE 101  +52.7914  -8.7986 0.0
HOLE 106  +52.7914 -26.3957 0.0
HOLE 106  +52.7914 -43.9928 0.0
HOLE 106  +70.3885  -8.7986 0.0
CYLINDER   3 1  +83.5787 2P0.7938
CYLINDER   5 1  +85.1662 2P0.7938
CYLINDER  10 1  +86.0425 2P0.7938
CYLINDER   7 1  +87.9475 2P0.7938
CYLINDER   8 1  +97.4725 2P0.7938
CYLINDER   9 1 +102.5525 2P0.7938
CYLINDER   7 1 +105.7275 2P0.7938
CUBOID    10 1 4P125.0   2P0.7938
UNIT 142
COM='BASKET STRUCTURE IN TRANPORT CASK - AL DISK'
CYLINDER 4 1  +82.8675 2P0.6350
HOLE 130  -70.3885  +8.7986 0.0
HOLE 123  -52.7914  +8.7986 0.0
HOLE 123  -52.7914 +26.3957 0.0
HOLE 130  -52.7914 +43.9928 0.0
HOLE 123  -35.1942  +8.7986 0.0
HOLE 123  -35.1942 +26.3957 0.0
HOLE 123  -35.1942 +43.9928 0.0
HOLE 130  -35.1942 +61.5899 0.0
HOLE 123  -17.5971  +8.7986 0.0
HOLE 123  -17.5971 +26.3957 0.0
HOLE 123  -17.5971 +43.9928 0.0
HOLE 130  -17.5971 +61.5899 0.0
HOLE 125   0.0      +8.7986 0.0
HOLE 125   0.0     +26.3957 0.0
HOLE 125   0.0     +43.9928 0.0
HOLE 129   0.0     +61.5899 0.0
HOLE 122  +17.5971  +8.7986 0.0
HOLE 122  +17.5971 +26.3957 0.0
HOLE 122  +17.5971 +43.9928 0.0
HOLE 128  +17.5971 +61.5899 0.0
HOLE 122  +35.1942  +8.7986 0.0
HOLE 122  +35.1942 +26.3957 0.0
HOLE 122  +35.1942 +43.9928 0.0
HOLE 131  +35.1942 +61.5899 0.0
HOLE 122  +52.7914  +8.7986 0.0
HOLE 127  +52.7914 +26.3957 0.0
HOLE 131  +52.7914 +43.9928 0.0
HOLE 131  +70.3885  +8.7986 0.0
HOLE 120  -70.3885  -8.7986 0.0
HOLE 120  -52.7914  -8.7986 0.0
HOLE 120  -52.7914 -26.3957 0.0
HOLE 120  -52.7914 -43.9928 0.0
HOLE 120  -35.1942  -8.7986 0.0
HOLE 120  -35.1942 -26.3957 0.0
```

Figure 6.9-5 (continued)

```
HOLE 120  -35.1942 -43.9928 0.0
HOLE 120  -35.1942 -61.5899 0.0
HOLE 120  -17.5971  -8.7986 0.0
HOLE 120  -17.5971 -26.3957 0.0
HOLE 120  -17.5971 -43.9928 0.0
HOLE 120  -17.5971 -61.5899 0.0
HOLE 124   0.0      -8.7986 0.0
HOLE 124   0.0     -26.3957 0.0
HOLE 124   0.0     -43.9928 0.0
HOLE 124   0.0     -61.5899 0.0
HOLE 121  +17.5971  -8.7986 0.0
HOLE 121  +17.5971 -26.3957 0.0
HOLE 121  +17.5971 -43.9928 0.0
HOLE 121  +17.5971 -61.5899 0.0
HOLE 121  +35.1942  -8.7986 0.0
HOLE 121  +35.1942 -26.3957 0.0
HOLE 121  +35.1942 -43.9928 0.0
HOLE 126  +35.1942 -61.5899 0.0
HOLE 121  +52.7914  -8.7986 0.0
HOLE 126  +52.7914 -26.3957 0.0
HOLE 126  +52.7914 -43.9928 0.0
HOLE 126  +70.3885  -8.7986 0.0
CYLINDER   3 1  +83.5787 2P0.6350
CYLINDER   5 1  +85.1662 2P0.6350
CYLINDER  10 1  +86.0425 2P0.6350
CYLINDER   7 1  +87.9475 2P0.6350
CYLINDER   8 1  +97.4725 2P0.6350
CYLINDER   9 1 +102.5525 2P0.6350
CYLINDER   7 1 +105.7275 2P0.6350
CUBOID    10 1 4P125.0   2P0.6350
GLOBAL UNIT 143
COM='CASK SLICES TOGETHER'
ARRAY  4 -125.00 -125.00 0.0
END GEOM
READ ARRAY
ARA=1   NUX=9 NUY=9 NUZ=1  FILL
    36R1
 4R1  2   4R1
 5R1  2   3R1
    27R1
END FILL
ARA=2   NUX=9 NUY=9 NUZ=1  FILL
    36R3
 4R3  4   4R3
 5R3  4   3R3
    27R3
END FILL
ARA=3   NUX=9 NUY=9 NUZ=1  FILL
    36R5
 4R5  6   4R5
 5R5  6   3R5
    27R5
END FILL
ARA=4 NUX=1 NUY=1 NUZ=4 FILL 140 141 140 142 END FILL
END ARRAY
READ BOUNDS ZFC=PER YXF=PER END BOUNDS
END DATA
END
```

Figure 6.9-6 CSAS Input for Accident Conditions - Transfer Cask Containing BWR Fuel

```
=CSAS25
UMS BWR TFR; ACCIDENT OP; CASK ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 75%B10
27GROUPNDF4 LATTICECELL
UO2   1 0.95 293.0 92235 4.00 92238 96.00 END
ZIRCALLOY  2 1.0  293.0  END
H2O   3 1.0  293.0  END
AL    4 1.0  293.0  END
SS304 5 1.0  293.0  END
AL    6 DEN=2.6849 0.8706 293.O END
B-10  6 DEN=2.6849 0.0137 293.O END
B-11  6 DEN=2.6849 0.0830 293.O END
C     6 DEN=2.6849 0.0281 293.O END
CARBONSTEEL 7 1.0 293.0 END
PB    8 1.0 293.O  END
B-10  9 0.0 8.553-5 END
B-11  9 0.0 3.422-4 END
AL    9 0.0 7.763-3 END
H     9 0.0 5.854-2 END
O     9 0.0 2.609-2 END
C     9 0.0 2.264-2 END
N     9 0.0 1.394-3 END
H2O  10 1.0 293.0 END
H2O  11 1.0 293.0 END
END COMP
SQUAREPITCH  1.4529 0.9055 1 3 1.0770 2 0.9246 11 END
UMS BWR TFR; ACCIDENT OP; CASK ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 75%B10
READ PARAM RUN=YES PLT=NO TME=5000 GEN=803 NPG=1000 END PARAM
READ GEOM
UNIT  1
COM='FUEL PIN CELL - WITH H2O'
CYLINDER  1 1  0.4528   2P1.7145
CYLINDER 11 1  0.4623   2P1.7145
CYLINDER  2 1  0.5385   2P1.7145
CUBOID    3 1  4P0.7264 2P1.7145
UNIT  2
COM='WATER ROD CELL - WITH H2O'
CYLINDER  3 1  0.4623   2P1.7145
CYLINDER  2 1  0.5385   2P1.7145
CUBOID    3 1  4P0.7264 2P1.7145
UNIT  3
COM='FUEL PIN CELL - WITH ST DISK'
CYLINDER  1 1  0.4528   2P0.7938
CYLINDER 11 1  0.4623   2P0.7938
CYLINDER  2 1  0.5385   2P0.7938
CUBOID    3 1  4P0.7264 2P0.7938
UNIT  4
COM='WATER ROD CELL - WITH ST DISK'
CYLINDER  3 1  0.4623   2P0.7938
CYLINDER  2 1  0.5385   2P0.7938
CUBOID    3 1  4P0.7264 2P0.7938
UNIT  5
COM='FUEL PIN CELL - WITH AL DISK'
CYLINDER  1 1  0.4528   2P0.6350
CYLINDER 11 1  0.4623   2P0.6350
CYLINDER  2 1  0.5385   2P0.6350
CUBOID    3 1  4P0.7264 2P0.6350
UNIT  6
COM='WATER ROD CELL - WITH AL DISK'
CYLINDER  3 1  0.4623   2P0.6350
CYLINDER  2 1  0.5385   2P0.6350
CUBOID    3 1  4P0.7264 2P0.6350
UNIT  7
COM='FUEL PIN ARRAY + CHANNEL - BETWEEN DISKS'
ARRAY  1   -6.5376 -6.5376 -1.7145
CUBOID 3 1 4P6.7031 2P1.7145
CUBOID 2 1 4P6.9063 2P1.7145
UNIT  8
COM='FUEL PIN ARRAY + CHANNEL - ST DISKS'
ARRAY  2   -6.5376 -6.5376 -0.7938
CUBOID 3 1 4P6.7031 2P0.7938
CUBOID 2 1 4P6.9063 2P0.7938
UNIT  9
COM='FUEL PIN ARRAY + CHANNEL - AL DISKS'
ARRAY  3   -6.5376 -6.5376 -0.6350
CUBOID 3 1 4P6.7031 2P0.6350
CUBOID 2 1 4P6.9063 2P0.6350
UNIT 10
COM='X-X BORAL + COVER SHEET BETWEEN DISKS'
CUBOID 6 1 2P6.7310 2P0.1124 2P1.7145
CUBOID 4 1 2P6.7310 2P0.1714 2P1.7145
CUBOID 5 1 2P6.7765 +0.2168 -0.1714 2P1.7145
UNIT 11
COM='Y-Y BORAL + COVER SHEET BETWEEN DISKS'
CUBOID 6 1 2P0.1124 2P6.7310 2P1.7145
CUBOID 4 1 2P0.1714 2P6.7310 2P1.7145
CUBOID 5 1 +0.2168 -0.1714 2P6.7765 2P1.7145
UNIT 12
COM='X-X BORAL + COVER SHEET WITH ST DISKS'
CUBOID 6 1 2P6.7310 2P0.1124 2P0.7938
CUBOID 4 1 2P6.7310 2P0.1714 2P0.7938
CUBOID 5 1 2P6.7765 +0.2168 -0.1714 2P0.7938
UNIT 13
COM='Y-Y BORAL + COVER SHEET WITH ST DISKS'
CUBOID 6 1 2P0.1124 2P6.7310 2P0.7938
CUBOID 4 1 2P0.1714 2P6.7310 2P0.7938
CUBOID 5 1 +0.2168 -0.1714 2P6.7765 2P0.7938
```

Figure 6.9-6 (continued)

```
UNIT 14
COM='X-X BORAL + COVER SHEET WITH AL DISKS'
CUBOID 6 1 2P6.7310 2P0.1124 2P0.6350
CUBOID 4 1 2P6.7310 2P0.1714 2P0.6350
CUBOID 5 1 2P6.7765 +0.2168 -0.1714 2P0.6350
UNIT 15
COM='Y-Y BORAL + COVER SHEET WITH AL DISKS'
CUBOID 6 1 2P0.1124 2P6.7310 2P0.6350
CUBOID 4 1 2P0.1714 2P6.7310 2P0.6350
CUBOID 5 1 +0.2168 -0.1714 2P6.7765 2P0.6350
UNIT 20
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (TR)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 +0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 21
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 22
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 23
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 24
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (T)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 0.0 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 25
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 26
COM='FUEL TUBE CELL TOP BORAL SHEETS - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
UNIT 27
COM='FUEL TUBE CELL TOP BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
UNIT 28
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P1.7145
HOLE   11 +7.7859 0.0 0.0
UNIT 29
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P1.7145
HOLE   11 +7.7859 0.0 0.0
UNIT 30
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P1.7145
HOLE   11 +7.7859 0.0 0.0
UNIT 31
COM='FUEL TUBE CELL NO BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
```

Figure 6.9-6 (continued)

```
HOLE   7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
UNIT 40
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (TR)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 +0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 41
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 42
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 43
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 44
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (T)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 0.0 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 45
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 46
COM='FUEL TUBE CELL TOP BORAL SHEETS - STEEL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
UNIT 47
COM='FUEL TUBE CELL TOP BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
UNIT 48
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.7938
HOLE   13 +7.7859 0.0 0.0
UNIT 49
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - STEEL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.7938
HOLE   13 +7.7859 0.0 0.0
UNIT 50
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - STEEL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.7938
HOLE   13 +7.7859 0.0 0.0
UNIT 51
COM='FUEL TUBE CELL NO BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
UNIT 60
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (TR)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 +0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
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Figure 6.9-6 (continued)

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HOLE   15 +7.7859 0.0 0.0
UNIT 61
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 62
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 63
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 64
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (T)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 0.0 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 65
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 66
COM='FUEL TUBE CELL TOP BORAL SHEETS - AL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
UNIT 67
COM='FUEL TUBE CELL TOP BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
UNIT 68
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.6350
HOLE   15 +7.7859 0.0 0.0
UNIT 69
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - AL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.6350
HOLE   15 +7.7859 0.0 0.0
UNIT 70
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - AL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.6350
HOLE   15 +7.7859 0.0 0.0
UNIT 71
COM='FUEL TUBE CELL NO BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
UNIT 80
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (TR)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   20  -0.0297 -0.0297 0.0
UNIT 81
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   21  -0.3586 -0.0297 0.0
UNIT 82
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   22  -0.3586 -0.3586 0.0
UNIT 83
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   23  -0.0297 -0.3586 0.0
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Figure 6.9-6 (continued)

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UNIT 84
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (T)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   24  -0.1942 -0.0297 0.0
UNIT 85
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   25  -0.1942 -0.3586 0.0
UNIT 86
COM='DISK OPENING TOP BORAL SHEET TUBE - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   26  -0.3586 -0.0297 0.0
UNIT 87
COM='DISK OPENING TOP BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   27  -0.3586 -0.3586 0.0
UNIT 88
COM='DISK OPENING RIGHT BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   28  -0.3586 -0.3586 0.0
UNIT 89
COM='DISK OPENING RIGHT BORAL SHEET TUBE - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   29  -0.1942 -0.3586 0.0
UNIT 90
COM='DISK OPENING RIGHT BORAL SHEET TUBE - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   30  -0.0297 -0.3586 0.0
UNIT 91
COM='DISK OPENING NO BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   31  -0.3586 -0.3586 0.0
UNIT 100
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (TR)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   40  -0.0297 -0.0297 0.0
UNIT 101
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   41  -0.3586 -0.0297 0.0
UNIT 102
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   42  -0.3586 -0.3586 0.0
UNIT 103
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   43  -0.0297 -0.3586 0.0
UNIT 104
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (T)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   44  -0.1942 -0.0297 0.0
UNIT 105
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   45  -0.1942 -0.3586 0.0
UNIT 106
COM='DISK OPENING TOP BORAL SHEET TUBE - STEEL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   46  -0.3586 -0.0297 0.0
UNIT 107
COM='DISK OPENING TOP BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   47  -0.3586 -0.3586 0.0
UNIT 108
COM='DISK OPENING RIGHT BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   48  -0.3586 -0.3586 0.0
UNIT 109
COM='DISK OPENING RIGHT BORAL SHEET TUBE - STEEL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   49  -0.1942 -0.3586 0.0
UNIT 110
COM='DISK OPENING RIGHT BORAL SHEET TUBE - STEEL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   50  -0.0297 -0.3586 0.0
UNIT 111
COM='DISK OPENING NO BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   51  -0.3586 -0.3586 0.0
UNIT 120
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (TR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   60  -0.0297 -0.0297 0.0
UNIT 121
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   61  -0.3586 -0.0297 0.0
UNIT 122
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   62  -0.3586 -0.3586 0.0
UNIT 123
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   63  -0.0297 -0.3586 0.0
UNIT 124
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Figure 6.9-6 (continued)

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COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (T)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   64  -0.1942 -0.0297 0.0
UNIT 125
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   65  -0.1942 -0.3586 0.0
UNIT 126
COM='DISK OPENING TOP BORAL SHEET TUBE - AL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   66  -0.3586 -0.0297 0.0
UNIT 127
COM='DISK OPENING TOP BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   67  -0.3586 -0.3586 0.0
UNIT 128
COM='DISK OPENING RIGHT BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   68  -0.3586 -0.3586 0.0
UNIT 129
COM='DISK OPENING RIGHT BORAL SHEET TUBE - AL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   69  -0.1942 -0.3586 0.0
UNIT 130
COM='DISK OPENING RIGHT BORAL SHEET TUBE - AL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   70  -0.0297 -0.3586 0.0
UNIT 131
COM='DISK OPENING NO BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   71  -0.3586 -0.3586 0.0
UNIT 140
COM='BASKET STRUCTURE IN TRANPORT CASK - WATER DISK'
CYLINDER 3 1 +83.5787 2P1.7145
HOLE 90  -70.3885  +8.7986 0.0
HOLE 83  -52.7914  +8.7986 0.0
HOLE 83  -52.7914 +26.3957 0.0
HOLE 90  -52.7914 +43.9928 0.0
HOLE 83  -35.1942  +8.7986 0.0
HOLE 83  -35.1942 +26.3957 0.0
HOLE 83  -35.1942 +43.9928 0.0
HOLE 90  -35.1942 +61.5899 0.0
HOLE 83  -17.5971  +8.7986 0.0
HOLE 83  -17.5971 +26.3957 0.0
HOLE 83  -17.5971 +43.9928 0.0
HOLE 90  -17.5971 +61.5899 0.0
HOLE 85   0.0      +8.7986 0.0
HOLE 85   0.0     +26.3957 0.0
HOLE 85   0.0     +43.9928 0.0
HOLE 89   0.0     +61.5899 0.0
HOLE 82  +17.5971  +8.7986 0.0
HOLE 82  +17.5971 +26.3957 0.0
HOLE 82  +17.5971 +43.9928 0.0
HOLE 88  +17.5971 +61.5899 0.0
HOLE 82  +35.1942  +8.7986 0.0
HOLE 82  +35.1942 +26.3957 0.0
HOLE 82  +35.1942 +43.9928 0.0
HOLE 91  +35.1942 +61.5899 0.0
HOLE 82  +52.7914  +8.7986 0.0
HOLE 87  +52.7914 +26.3957 0.0
HOLE 91  +52.7914 +43.9928 0.0
HOLE 91  +70.3885  +8.7986 0.0
HOLE 80  -70.3885  -8.7986 0.0
HOLE 80  -52.7914  -8.7986 0.0
HOLE 80  -52.7914 -26.3957 0.0
HOLE 80  -52.7914 -43.9928 0.0
HOLE 80  -35.1942  -8.7986 0.0
HOLE 80  -35.1942 -26.3957 0.0
HOLE 80  -35.1942 -43.9928 0.0
HOLE 80  -35.1942 -61.5899 0.0
HOLE 80  -17.5971  -8.7986 0.0
HOLE 80  -17.5971 -26.3957 0.0
HOLE 80  -17.5971 -43.9928 0.0
HOLE 80  -17.5971 -61.5899 0.0
HOLE 84   0.0      -8.7986 0.0
HOLE 84   0.0     -26.3957 0.0
HOLE 84   0.0     -43.9928 0.0
HOLE 84   0.0     -61.5899 0.0
HOLE 81  +17.5971  -8.7986 0.0
HOLE 81  +17.5971 -26.3957 0.0
HOLE 81  +17.5971 -43.9928 0.0
HOLE 81  +17.5971 -61.5899 0.0
HOLE 81  +35.1942  -8.7986 0.0
HOLE 81  +35.1942 -26.3957 0.0
HOLE 81  +35.1942 -43.9928 0.0
HOLE 86  +35.1942 -61.5899 0.0
HOLE 81  +52.7914  -8.7986 0.0
HOLE 86  +52.7914 -26.3957 0.0
HOLE 86  +52.7914 -43.9928 0.0
HOLE 86  +70.3885  -8.7986 0.0
CYLINDER   5 1  +85.1662 2P1.7145
CYLINDER  10 1  +86.0425 2P1.7145
CYLINDER   7 1  +87.9475 2P1.7145
CYLINDER   8 1  +97.4725 2P1.7145
CYLINDER   9 1 +102.5525 2P1.7145
CYLINDER   7 1 +105.7275 2P1.7145
CUBOID    10 1 4P125.0   2P1.7145
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Figure 6.9-6 (continued)

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UNIT 141
COM='BASKET STRUCTURE IN TRANPORT CASK - SS DISK'
CYLINDER 7 1  +83.1850 2P0.7938
HOLE 110  -70.3885  +8.7986 0.0
HOLE 103  -52.7914  +8.7986 0.0
HOLE 103  -52.7914 +26.3957 0.0
HOLE 110  -52.7914 +43.9928 0.0
HOLE 103  -35.1942  +8.7986 0.0
HOLE 103  -35.1942 +26.3957 0.0
HOLE 103  -35.1942 +43.9928 0.0
HOLE 110  -35.1942 +61.5899 0.0
HOLE 103  -17.5971  +8.7986 0.0
HOLE 103  -17.5971 +26.3957 0.0
HOLE 103  -17.5971 +43.9928 0.0
HOLE 110  -17.5971 +61.5899 0.0
HOLE 105   0.0      +8.7986 0.0
HOLE 105   0.0     +26.3957 0.0
HOLE 105   0.0     +43.9928 0.0
HOLE 109   0.0     +61.5899 0.0
HOLE 102  +17.5971  +8.7986 0.0
HOLE 102  +17.5971 +26.3957 0.0
HOLE 102  +17.5971 +43.9928 0.0
HOLE 108  +17.5971 +61.5899 0.0
HOLE 102  +35.1942  +8.7986 0.0
HOLE 102  +35.1942 +26.3957 0.0
HOLE 102  +35.1942 +43.9928 0.0
HOLE 111  +35.1942 +61.5899 0.0
HOLE 102  +52.7914  +8.7986 0.0
HOLE 107  +52.7914 +26.3957 0.0
HOLE 111  +52.7914 +43.9928 0.0
HOLE 111  +70.3885  +8.7986 0.0
HOLE 100  -70.3885  -8.7986 0.0
HOLE 100  -52.7914  -8.7986 0.0
HOLE 100  -52.7914 -26.3957 0.0
HOLE 100  -52.7914 -43.9928 0.0
HOLE 100  -35.1942  -8.7986 0.0
HOLE 100  -35.1942 -26.3957 0.0
HOLE 100  -35.1942 -43.9928 0.0
HOLE 100  -35.1942 -61.5899 0.0
HOLE 100  -17.5971  -8.7986 0.0
HOLE 100  -17.5971 -26.3957 0.0
HOLE 100  -17.5971 -43.9928 0.0
HOLE 100  -17.5971 -61.5899 0.0
HOLE 104   0.0      -8.7986 0.0
HOLE 104   0.0     -26.3957 0.0
HOLE 104   0.0     -43.9928 0.0
HOLE 104   0.0     -61.5899 0.0
HOLE 101  +17.5971  -8.7986 0.0
HOLE 101  +17.5971 -26.3957 0.0
HOLE 101  +17.5971 -43.9928 0.0
HOLE 101  +17.5971 -61.5899 0.0
HOLE 101  +35.1942  -8.7986 0.0
HOLE 101  +35.1942 -26.3957 0.0
HOLE 101  +35.1942 -43.9928 0.0
HOLE 106  +35.1942 -61.5899 0.0
HOLE 101  +52.7914  -8.7986 0.0
HOLE 106  +52.7914 -26.3957 0.0
HOLE 106  +52.7914 -43.9928 0.0
HOLE 106  +70.3885  -8.7986 0.0
CYLINDER   3 1  +83.5787 2P0.7938
CYLINDER   5 1  +85.1662 2P0.7938
CYLINDER  10 1  +86.0425 2P0.7938
CYLINDER   7 1  +87.9475 2P0.7938
CYLINDER   8 1  +97.4725 2P0.7938
CYLINDER   9 1 +102.5525 2P0.7938
CYLINDER   7 1 +105.7275 2P0.7938
CUBOID    10 1 4P125.0   2P0.7938
UNIT 142
COM='BASKET STRUCTURE IN TRANPORT CASK - AL DISK'
CYLINDER 4 1  +82.8675 2P0.6350
HOLE 130  -70.3885  +8.7986 0.0
HOLE 123  -52.7914  +8.7986 0.0
HOLE 123  -52.7914 +26.3957 0.0
HOLE 130  -52.7914 +43.9928 0.0
HOLE 123  -35.1942  +8.7986 0.0
HOLE 123  -35.1942 +26.3957 0.0
HOLE 123  -35.1942 +43.9928 0.0
HOLE 130  -35.1942 +61.5899 0.0
HOLE 123  -17.5971  +8.7986 0.0
HOLE 123  -17.5971 +26.3957 0.0
HOLE 123  -17.5971 +43.9928 0.0
HOLE 130  -17.5971 +61.5899 0.0
HOLE 125   0.0      +8.7986 0.0
HOLE 125   0.0     +26.3957 0.0
HOLE 125   0.0     +43.9928 0.0
HOLE 129   0.0     +61.5899 0.0
HOLE 122  +17.5971  +8.7986 0.0
HOLE 122  +17.5971 +26.3957 0.0
HOLE 122  +17.5971 +43.9928 0.0
HOLE 128  +17.5971 +61.5899 0.0
HOLE 122  +35.1942  +8.7986 0.0
HOLE 122  +35.1942 +26.3957 0.0
HOLE 122  +35.1942 +43.9928 0.0
HOLE 131  +35.1942 +61.5899 0.0
HOLE 122  +52.7914  +8.7986 0.0
HOLE 127  +52.7914 +26.3957 0.0
HOLE 131  +52.7914 +43.9928 0.0
```

Figure 6.9-6 (continued)

```
HOLE 131  +70.3885  +8.7986 0.0
HOLE 120  -70.3885  -8.7986 0.0
HOLE 120  -52.7914  -8.7986 0.0
HOLE 120  -52.7914 -26.3957 0.0
HOLE 120  -52.7914 -43.9928 0.0
HOLE 120  -35.1942  -8.7986 0.0
HOLE 120  -35.1942 -26.3957 0.0
HOLE 120  -35.1942 -43.9928 0.0
HOLE 120  -35.1942 -61.5899 0.0
HOLE 120  -17.5971  -8.7986 0.0
HOLE 120  -17.5971 -26.3957 0.0
HOLE 120  -17.5971 -43.9928 0.0
HOLE 120  -17.5971 -61.5899 0.0
HOLE 124   0.0      -8.7986 0.0
HOLE 124   0.0     -26.3957 0.0
HOLE 124   0.0     -43.9928 0.0
HOLE 124   0.0     -61.5899 0.0
HOLE 121  +17.5971  -8.7986 0.0
HOLE 121  +17.5971 -26.3957 0.0
HOLE 121  +17.5971 -43.9928 0.0
HOLE 121  +17.5971 -61.5899 0.0
HOLE 121  +35.1942  -8.7986 0.0
HOLE 121  +35.1942 -26.3957 0.0
HOLE 121  +35.1942 -43.9928 0.0
HOLE 126  +35.1942 -61.5899 0.0
HOLE 121  +52.7914  -8.7986 0.0
HOLE 126  +52.7914 -26.3957 0.0
HOLE 126  +52.7914 -43.9928 0.0
HOLE 126  +70.3885  -8.7986 0.0
CYLINDER   3 1  +83.5787 2P0.6350
CYLINDER   5 1  +85.1662 2P0.6350
CYLINDER  10 1  +86.0425 2P0.6350
CYLINDER   7 1  +87.9475 2P0.6350
CYLINDER   8 1  +97.4725 2P0.6350
CYLINDER   9 1 +102.5525 2P0.6350
CYLINDER   7 1 +105.7275 2P0.6350
CUBOID    10 1 4P125.0   2P0.6350
GLOBAL UNIT 143
COM='CASK SLICES TOGETHER'
ARRAY  4 -125.00 -125.00 0.0
END GEOM
READ ARRAY
ARA=1   NUX=9 NUY=9 NUZ=1  FILL
    36R1
 4R1  2   4R1
 5R1  2   3R1
    27R1
END FILL
ARA=2   NUX=9 NUY=9 NUZ=1  FILL
    36R3
 4R3  4   4R3
 5R3  4   3R3
    27R3
END FILL
ARA=3   NUX=9 NUY=9 NUZ=1  FILL
    36R5
 4R5  6   4R5
 5R5  6   3R5
    27R5
END FILL
ARA=4 NUX=1 NUY=1 NUZ=4 FILL 140 141 140 142 END FILL
END ARRAY
READ BOUNDS ZFC=PER YXF=PER END BOUNDS
END DATA
END
```

Figure 6.9-7 CSAS Input for Normal Conditions–Vertical Concrete Cask Containing BWR Fuel

```
=CSAS25
UMS BWR VCC; NORMAL OP; CASK ARRAY; 0.0001 GM/CC IN - 0.0001 GM/CC EX; 75%B10
27GROUPNDF4 LATTICECELL
UO2   1 0.95 293.0 92235 4.00 92238 96.00 END
ZIRCALLOY  2 1.0  293.0  END
H2O   3 0.0001  293.0  END
AL    4 1.0  293.0  END
SS304 5 1.0  293.0  END
AL    6 DEN=2.6849 0.8706 293.O END
B-10  6 DEN=2.6849 0.0137 293.O END
B-11  6 DEN=2.6849 0.0830 293.O END
C     6 DEN=2.6849 0.0281 293.O END
CARBONSTEEL 7 1.0 293.0 END
REG-CONCRETE 8 0.9750 293.0 END
H2O   9 0.0001 293.0 END
END COMP
SQUAREPITCH  1.4529 0.9055 1 3 1.0770 2 0.9246 0 END
UMS BWR VCC; NORMAL OP; CASK ARRAY; 0.0001 GM/CC IN - 0.0001 GM/CC EX; 75%B10
READ PARAM RUN=YES PLT=NO TME=5000 GEN=203 NPG=1000 END PARAM
READ GEOM
UNIT  1
COM='FUEL PIN CELL - WITH H2O'
CYLINDER  1 1  0.4528   2P1.7145
CYLINDER  0 1  0.4623   2P1.7145
CYLINDER  2 1  0.5385   2P1.7145
CUBOID    3 1  4P0.7264 2P1.7145
UNIT  2
COM='WATER ROD CELL - WITH H2O'
CYLINDER  3 1  0.4623   2P1.7145
CYLINDER  2 1  0.5385   2P1.7145
CUBOID    3 1  4P0.7264 2P1.7145
UNIT  3
COM='FUEL PIN CELL - WITH ST DISK'
CYLINDER  1 1  0.4528   2P0.7938
CYLINDER  0 1  0.4623   2P0.7938
CYLINDER  2 1  0.5385   2P0.7938
CUBOID    3 1  4P0.7264 2P0.7938
UNIT  4
COM='WATER ROD CELL - WITH ST DISK'
CYLINDER  3 1  0.4623   2P0.7938
CYLINDER  2 1  0.5385   2P0.7938
CUBOID    3 1  4P0.7264 2P0.7938
UNIT  5
COM='FUEL PIN CELL - WITH AL DISK'
CYLINDER  1 1  0.4528   2P0.6350
CYLINDER  0 1  0.4623   2P0.6350
CYLINDER  2 1  0.5385   2P0.6350
CUBOID    3 1  4P0.7264 2P0.6350
UNIT  6
COM='WATER ROD CELL - WITH AL DISK'
CYLINDER  3 1  0.4623   2P0.6350
CYLINDER  2 1  0.5385   2P0.6350
CUBOID    3 1  4P0.7264 2P0.6350
UNIT  7
COM='FUEL PIN ARRAY + CHANNEL - BETWEEN DISKS'
ARRAY  1   -6.5376 -6.5376 -1.7145
CUBOID 3 1 4P6.7031 2P1.7145
CUBOID 2 1 4P6.9063 2P1.7145
UNIT  8
COM='FUEL PIN ARRAY + CHANNEL - ST DISKS'
ARRAY  2   -6.5376 -6.5376 -0.7938
CUBOID 3 1 4P6.7031 2P0.7938
CUBOID 2 1 4P6.9063 2P0.7938
UNIT  9
COM='FUEL PIN ARRAY + CHANNEL - AL DISKS'
ARRAY  3   -6.5376 -6.5376 -0.6350
CUBOID 3 1 4P6.7031 2P0.6350
CUBOID 2 1 4P6.9063 2P0.6350
UNIT 10
COM='X-X BORAL + COVER SHEET BETWEEN DISKS'
CUBOID 6 1 2P6.7310 2P0.1124 2P1.7145
CUBOID 4 1 2P6.7310 2P0.1714 2P1.7145
CUBOID 5 1 2P6.7765 +0.2168 -0.1714 2P1.7145
UNIT 11
COM='Y-Y BORAL + COVER SHEET BETWEEN DISKS'
CUBOID 6 1 2P0.1124 2P6.7310 2P1.7145
CUBOID 4 1 2P0.1714 2P6.7310 2P1.7145
CUBOID 5 1 +0.2168 -0.1714 2P6.7765 2P1.7145
UNIT 12
COM='X-X BORAL + COVER SHEET WITH ST DISKS'
CUBOID 6 1 2P6.7310 2P0.1124 2P0.7938
CUBOID 4 1 2P6.7310 2P0.1714 2P0.7938
CUBOID 5 1 2P6.7765 +0.2168 -0.1714 2P0.7938
UNIT 13
COM='Y-Y BORAL + COVER SHEET WITH ST DISKS'
CUBOID 6 1 2P0.1124 2P6.7310 2P0.7938
CUBOID 4 1 2P0.1714 2P6.7310 2P0.7938
CUBOID 5 1 +0.2168 -0.1714 2P6.7765 2P0.7938
```

Figure 6.9-7 (continued)

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UNIT 14
COM='X-X BORAL + COVER SHEET WITH AL DISKS'
CUBOID 6 1 2P6.7310 2P0.1124 2P0.6350
CUBOID 4 1 2P6.7310 2P0.1714 2P0.6350
CUBOID 5 1 2P6.7765 +0.2168 -0.1714 2P0.6350
UNIT 15
COM='Y-Y BORAL + COVER SHEET WITH AL DISKS'
CUBOID 6 1 2P0.1124 2P6.7310 2P0.6350
CUBOID 4 1 2P0.1714 2P6.7310 2P0.6350
CUBOID 5 1 +0.2168 -0.1714 2P6.7765 2P0.6350
UNIT 20
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (TR)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 +0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 21
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 22
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 23
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 24
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (T)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 0.0 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 25
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 26
COM='FUEL TUBE CELL TOP BORAL SHEETS - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
UNIT 27
COM='FUEL TUBE CELL TOP BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
UNIT 28
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P1.7145
HOLE   11 +7.7859 0.0 0.0
UNIT 29
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P1.7145
HOLE   11 +7.7859 0.0 0.0
UNIT 30
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P1.7145
HOLE   11 +7.7859 0.0 0.0
UNIT 31
COM='FUEL TUBE CELL NO BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
```

Figure 6.9-7 (continued)

```
UNIT 40
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (TR)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 +0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 41
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 42
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 43
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 44
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (T)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 0.0 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 45
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 46
COM='FUEL TUBE CELL TOP BORAL SHEETS - STEEL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
UNIT 47
COM='FUEL TUBE CELL TOP BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
UNIT 48
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.7938
HOLE   13 +7.7859 0.0 0.0
UNIT 49
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - STEEL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.7938
HOLE   13 +7.7859 0.0 0.0
UNIT 50
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - STEEL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.7938
HOLE   13 +7.7859 0.0 0.0
UNIT 51
COM='FUEL TUBE CELL NO BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
UNIT 60
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (TR)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 +0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 61
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (TL)'
```

Figure 6.9-7 (continued)

```
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 62
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 63
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 64
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (T)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 0.0 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 65
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 66
COM='FUEL TUBE CELL TOP BORAL SHEETS - AL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
UNIT 67
COM='FUEL TUBE CELL TOP BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
UNIT 68
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.6350
HOLE   15 +7.7859 0.0 0.0
UNIT 69
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - AL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.6350
HOLE   15 +7.7859 0.0 0.0
UNIT 70
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - AL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.6350
HOLE   15 +7.7859 0.0 0.0
UNIT 71
COM='FUEL TUBE CELL NO BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
UNIT 80
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (TR)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   20  -0.0297 -0.0297 0.0
UNIT 81
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   21  -0.3586 -0.0297 0.0
UNIT 82
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   22  -0.3586 -0.3586 0.0
UNIT 83
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   23  -0.0297 -0.3586 0.0
UNIT 84
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (T)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   24  -0.1942 -0.0297 0.0
```

Figure 6.9-7 (continued)

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UNIT 85
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   25  -0.1942 -0.3586 0.0
UNIT 86
COM='DISK OPENING TOP BORAL SHEET TUBE - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   26  -0.3586 -0.0297 0.0
UNIT 87
COM='DISK OPENING TOP BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   27  -0.3586 -0.3586 0.0
UNIT 88
COM='DISK OPENING RIGHT BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   28  -0.3586 -0.3586 0.0
UNIT 89
COM='DISK OPENING RIGHT BORAL SHEET TUBE - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   29  -0.1942 -0.3586 0.0
UNIT 90
COM='DISK OPENING RIGHT BORAL SHEET TUBE - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   30  -0.0297 -0.3586 0.0
UNIT 91
COM='DISK OPENING NO BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   31  -0.3586 -0.3586 0.0
UNIT 100
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (TR)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   40  -0.0297 -0.0297 0.0
UNIT 101
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   41  -0.3586 -0.0297 0.0
UNIT 102
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   42  -0.3586 -0.3586 0.0
UNIT 103
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   43  -0.0297 -0.3586 0.0
UNIT 104
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (T)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   44  -0.1942 -0.0297 0.0
UNIT 105
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   45  -0.1942 -0.3586 0.0
UNIT 106
COM='DISK OPENING TOP BORAL SHEET TUBE - STEEL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   46  -0.3586 -0.0297 0.0
UNIT 107
COM='DISK OPENING TOP BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   47  -0.3586 -0.3586 0.0
UNIT 108
COM='DISK OPENING RIGHT BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   48  -0.3586 -0.3586 0.0
UNIT 109
COM='DISK OPENING RIGHT BORAL SHEET TUBE - STEEL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   49  -0.1942 -0.3586 0.0
UNIT 110
COM='DISK OPENING RIGHT BORAL SHEET TUBE - STEEL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   50  -0.0297 -0.3586 0.0
UNIT 111
COM='DISK OPENING NO BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   51  -0.3586 -0.3586 0.0
UNIT 120
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (TR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   60  -0.0297 -0.0297 0.0
UNIT 121
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   61  -0.3586 -0.0297 0.0
UNIT 122
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   62  -0.3586 -0.3586 0.0
UNIT 123
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   63  -0.0297 -0.3586 0.0
UNIT 124
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (T)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   64  -0.1942 -0.0297 0.0
UNIT 125
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (B)'
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Figure 6.9-7 (continued)

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CUBOID 3 1 4P7.9731 2P0.6350
HOLE   65  -0.1942 -0.3586 0.0
UNIT 126
COM='DISK OPENING TOP BORAL SHEET TUBE - AL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   66  -0.3586 -0.0297 0.0
UNIT 127
COM='DISK OPENING TOP BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   67  -0.3586 -0.3586 0.0
UNIT 128
COM='DISK OPENING RIGHT BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   68  -0.3586 -0.3586 0.0
UNIT 129
COM='DISK OPENING RIGHT BORAL SHEET TUBE - AL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   69  -0.1942 -0.3586 0.0
UNIT 130
COM='DISK OPENING RIGHT BORAL SHEET TUBE - AL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   70  -0.0297 -0.3586 0.0
UNIT 131
COM='DISK OPENING NO BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   71  -0.3586 -0.3586 0.0
UNIT 140
COM='BASKET STRUCTURE IN TRANPORT CASK - WATER DISK'
CYLINDER 3 1 +83.5787 2P1.7145
HOLE 90  -70.3885  +8.7986 0.0
HOLE 83  -52.7914  +8.7986 0.0
HOLE 83  -52.7914 +26.3957 0.0
HOLE 90  -52.7914 +43.9928 0.0
HOLE 83  -35.1942  +8.7986 0.0
HOLE 83  -35.1942 +26.3957 0.0
HOLE 83  -35.1942 +43.9928 0.0
HOLE 90  -35.1942 +61.5899 0.0
HOLE 83  -17.5971  +8.7986 0.0
HOLE 83  -17.5971 +26.3957 0.0
HOLE 83  -17.5971 +43.9928 0.0
HOLE 90  -17.5971 +61.5899 0.0
HOLE 85   0.0      +8.7986 0.0
HOLE 85   0.0     +26.3957 0.0
HOLE 85   0.0     +43.9928 0.0
HOLE 89   0.0     +61.5899 0.0
HOLE 82  +17.5971  +8.7986 0.0
HOLE 82  +17.5971 +26.3957 0.0
HOLE 82  +17.5971 +43.9928 0.0
HOLE 88  +17.5971 +61.5899 0.0
HOLE 82  +35.1942  +8.7986 0.0
HOLE 82  +35.1942 +26.3957 0.0
HOLE 82  +35.1942 +43.9928 0.0
HOLE 91  +35.1942 +61.5899 0.0
HOLE 82  +52.7914  +8.7986 0.0
HOLE 87  +52.7914 +26.3957 0.0
HOLE 91  +52.7914 +43.9928 0.0
HOLE 91  +70.3885  +8.7986 0.0
HOLE 80  -70.3885  -8.7986 0.0
HOLE 80  -52.7914  -8.7986 0.0
HOLE 80  -52.7914 -26.3957 0.0
HOLE 80  -52.7914 -43.9928 0.0
HOLE 80  -35.1942  -8.7986 0.0
HOLE 80  -35.1942 -26.3957 0.0
HOLE 80  -35.1942 -43.9928 0.0
HOLE 80  -35.1942 -61.5899 0.0
HOLE 80  -17.5971  -8.7986 0.0
HOLE 80  -17.5971 -26.3957 0.0
HOLE 80  -17.5971 -43.9928 0.0
HOLE 80  -17.5971 -61.5899 0.0
HOLE 84   0.0      -8.7986 0.0
HOLE 84   0.0     -26.3957 0.0
HOLE 84   0.0     -43.9928 0.0
HOLE 84   0.0     -61.5899 0.0
HOLE 81  +17.5971  -8.7986 0.0
HOLE 81  +17.5971 -26.3957 0.0
HOLE 81  +17.5971 -43.9928 0.0
HOLE 81  +17.5971 -61.5899 0.0
HOLE 81  +35.1942  -8.7986 0.0
HOLE 81  +35.1942 -26.3957 0.0
HOLE 81  +35.1942 -43.9928 0.0
HOLE 86  +35.1942 -61.5899 0.0
HOLE 81  +52.7914  -8.7986 0.0
HOLE 86  +52.7914 -26.3957 0.0
HOLE 86  +52.7914 -43.9928 0.0
HOLE 86  +70.3885  -8.7986 0.0
CYLINDER  5 1  +85.1662 2P1.7145
CYLINDER  9 1  +94.615 2P1.7145
CYLINDER  7 1 +100.965 2P1.7145
CYLINDER  8 1 +172.72  2P1.7145
CUBOID    9 1 4P230.0  2P1.7145
UNIT 141
COM='BASKET STRUCTURE IN TRANPORT CASK - SS DISK'
CYLINDER 7 1  +83.1850 2P0.7938
HOLE 110  -70.3885  +8.7986 0.0
HOLE 103  -52.7914  +8.7986 0.0
HOLE 103  -52.7914 +26.3957 0.0
HOLE 110  -52.7914 +43.9928 0.0
HOLE 103  -35.1942  +8.7986 0.0
```

Figure 6.9-7 (continued)

```
HOLE 103  -35.1942 +26.3957 0.0
HOLE 103  -35.1942 +43.9928 0.0
HOLE 110  -35.1942 +61.5899 0.0
HOLE 103  -17.5971  +8.7986 0.0
HOLE 103  -17.5971 +26.3957 0.0
HOLE 103  -17.5971 +43.9928 0.0
HOLE 110  -17.5971 +61.5899 0.0
HOLE 105   0.0      +8.7986 0.0
HOLE 105   0.0     +26.3957 0.0
HOLE 105   0.0     +43.9928 0.0
HOLE 109   0.0     +61.5899 0.0
HOLE 102  +17.5971  +8.7986 0.0
HOLE 102  +17.5971 +26.3957 0.0
HOLE 102  +17.5971 +43.9928 0.0
HOLE 108  +17.5971 +61.5899 0.0
HOLE 102  +35.1942  +8.7986 0.0
HOLE 102  +35.1942 +26.3957 0.0
HOLE 102  +35.1942 +43.9928 0.0
HOLE 111  +35.1942 +61.5899 0.0
HOLE 102  +52.7914  +8.7986 0.0
HOLE 107  +52.7914 +26.3957 0.0
HOLE 111  +52.7914 +43.9928 0.0
HOLE 111  +70.3885  +8.7986 0.0
HOLE 100  -70.3885  -8.7986 0.0
HOLE 100  -52.7914  -8.7986 0.0
HOLE 100  -52.7914 -26.3957 0.0
HOLE 100  -52.7914 -43.9928 0.0
HOLE 100  -35.1942  -8.7986 0.0
HOLE 100  -35.1942 -26.3957 0.0
HOLE 100  -35.1942 -43.9928 0.0
HOLE 100  -35.1942 -61.5899 0.0
HOLE 100  -17.5971  -8.7986 0.0
HOLE 100  -17.5971 -26.3957 0.0
HOLE 100  -17.5971 -43.9928 0.0
HOLE 100  -17.5971 -61.5899 0.0
HOLE 104   0.0      -8.7986 0.0
HOLE 104   0.0     -26.3957 0.0
HOLE 104   0.0     -43.9928 0.0
HOLE 104   0.0     -61.5899 0.0
HOLE 101  +17.5971  -8.7986 0.0
HOLE 101  +17.5971 -26.3957 0.0
HOLE 101  +17.5971 -43.9928 0.0
HOLE 101  +17.5971 -61.5899 0.0
HOLE 101  +35.1942  -8.7986 0.0
HOLE 101  +35.1942 -26.3957 0.0
HOLE 101  +35.1942 -43.9928 0.0
HOLE 106  +35.1942 -61.5899 0.0
HOLE 101  +52.7914  -8.7986 0.0
HOLE 106  +52.7914 -26.3957 0.0
HOLE 106  +52.7914 -43.9928 0.0
HOLE 106  +70.3885  -8.7986 0.0
CYLINDER  3 1  +83.5787 2P0.7938
CYLINDER  5 1  +85.1662 2P0.7938
CYLINDER  9 1  +94.615 2P0.7938
CYLINDER  7 1 +100.965 2P0.7938
CYLINDER  8 1 +172.72  2P0.7938
CUBOID    9 1 4P230.0  2P0.7938
UNIT 142
COM='BASKET STRUCTURE IN TRANPORT CASK - AL DISK'
CYLINDER 4 1  +82.8675 2P0.6350
HOLE 130  -70.3885  +8.7986 0.0
HOLE 123  -52.7914  +8.7986 0.0
HOLE 123  -52.7914 +26.3957 0.0
HOLE 130  -52.7914 +43.9928 0.0
HOLE 123  -35.1942  +8.7986 0.0
HOLE 123  -35.1942 +26.3957 0.0
HOLE 123  -35.1942 +43.9928 0.0
HOLE 130  -35.1942 +61.5899 0.0
HOLE 123  -17.5971  +8.7986 0.0
HOLE 123  -17.5971 +26.3957 0.0
HOLE 123  -17.5971 +43.9928 0.0
HOLE 130  -17.5971 +61.5899 0.0
HOLE 125   0.0      +8.7986 0.0
HOLE 125   0.0     +26.3957 0.0
HOLE 125   0.0     +43.9928 0.0
HOLE 129   0.0     +61.5899 0.0
HOLE 122  +17.5971  +8.7986 0.0
HOLE 122  +17.5971 +26.3957 0.0
HOLE 122  +17.5971 +43.9928 0.0
HOLE 128  +17.5971 +61.5899 0.0
HOLE 122  +35.1942  +8.7986 0.0
HOLE 122  +35.1942 +26.3957 0.0
HOLE 122  +35.1942 +43.9928 0.0
HOLE 131  +35.1942 +61.5899 0.0
HOLE 122  +52.7914  +8.7986 0.0
HOLE 127  +52.7914 +26.3957 0.0
HOLE 131  +52.7914 +43.9928 0.0
HOLE 131  +70.3885  +8.7986 0.0
HOLE 120  -70.3885  -8.7986 0.0
HOLE 120  -52.7914  -8.7986 0.0
HOLE 120  -52.7914 -26.3957 0.0
HOLE 120  -52.7914 -43.9928 0.0
HOLE 120  -35.1942  -8.7986 0.0
HOLE 120  -35.1942 -26.3957 0.0
HOLE 120  -35.1942 -43.9928 0.0
HOLE 120  -35.1942 -61.5899 0.0
HOLE 120  -17.5971  -8.7986 0.0
HOLE 120  -17.5971 -26.3957 0.0
```

Figure 6.9-7 (continued)

```
HOLE 120  -17.5971 -43.9928 0.0
HOLE 120  -17.5971 -61.5899 0.0
HOLE 124   0.0      -8.7986 0.0
HOLE 124   0.0     -26.3957 0.0
HOLE 124   0.0     -43.9928 0.0
HOLE 124   0.0     -61.5899 0.0
HOLE 121  +17.5971  -8.7986 0.0
HOLE 121  +17.5971 -26.3957 0.0
HOLE 121  +17.5971 -43.9928 0.0
HOLE 121  +17.5971 -61.5899 0.0
HOLE 121  +35.1942  -8.7986 0.0
HOLE 121  +35.1942 -26.3957 0.0
HOLE 121  +35.1942 -43.9928 0.0
HOLE 126  +35.1942 -61.5899 0.0
HOLE 121  +52.7914  -8.7986 0.0
HOLE 126  +52.7914 -26.3957 0.0
HOLE 126  +52.7914 -43.9928 0.0
HOLE 126  +70.3885  -8.7986 0.0
CYLINDER  3 1  +83.5787 2P0.6350
CYLINDER  5 1  +85.1662 2P0.6350
CYLINDER  9 1  +94.615 2P0.6350
CYLINDER  7 1 +100.965 2P0.6350
CYLINDER  8 1 +172.72  2P0.6350
CUBOID    9 1 4P230.0  2P0.6350
GLOBAL UNIT 143
COM='CASK SLICES TOGETHER'
ARRAY  4 -230.00 -230.00 0.0
END GEOM
READ ARRAY
ARA=1   NUX=9 NUY=9 NUZ=1  FILL
    36R1
 4R1  2   4R1
 5R1  2   3R1
    27R1
END FILL
ARA=2   NUX=9 NUY=9 NUZ=1  FILL
    36R3
 4R3  4   4R3
 5R3  4   3R3
    27R3
END FILL
ARA=3   NUX=9 NUY=9 NUZ=1  FILL
    36R5
 4R5  6   4R5
 5R5  6   3R5
    27R5
END FILL
ARA=4 NUX=1 NUY=1 NUZ=4 FILL 140 141 140 142 END FILL
END ARRAY
READ BOUNDS ZFC=PER YXF=PER END BOUNDS
END DATA
END
```

Figure 6.9-8 CSAS Input for Accident Conditions–Vertical Concrete Cask Containing BWR Fuel

```
=CSAS25
UMS BWR VCC; ACCIDENT; CASK ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 75%B10
27GROUPNDF4 LATTICECELL
UO2   1 0.95 293.0 92235 4.00 92238 96.00 END
ZIRCALLOY  2 1.0  293.0  END
H2O   3 1.0  293.0  END
AL    4 1.0  293.0  END
SS304 5 1.0  293.0  END
AL    6 DEN=2.6849 0.8706 293.O END
B-10  6 DEN=2.6849 0.0137 293.O END
B-11  6 DEN=2.6849 0.0830 293.O END
C     6 DEN=2.6849 0.0281 293.O END
CARBONSTEEL 7 1.0 293.0 END
REG-CONCRETE 8 0.9750 293.0 END
H2O   9 1.0 293.0 END
H2O  10 1.0 293.0 END
END COMP
SQUAREPITCH  1.4529 0.9055 1 3 1.0770 2 0.9246 10 END
UMS BWR VCC; ACCIDENT; CASK ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 75%B10
READ PARAM RUN=YES PLT=NO TME=5000 GEN=803 NPG=1000 END PARAM
READ GEOM
UNIT  1
COM='FUEL PIN CELL - WITH H2O'
CYLINDER  1 1  0.4528   2P1.7145
CYLINDER 10 1  0.4623   2P1.7145
CYLINDER  2 1  0.5385   2P1.7145
CUBOID    3 1  4P0.7264 2P1.7145
UNIT  2
COM='WATER ROD CELL - WITH H2O'
CYLINDER  3 1  0.4623   2P1.7145
CYLINDER  2 1  0.5385   2P1.7145
CUBOID    3 1  4P0.7264 2P1.7145
UNIT  3
COM='FUEL PIN CELL - WITH ST DISK'
CYLINDER  1 1  0.4528   2P0.7938
CYLINDER 10 1  0.4623   2P0.7938
CYLINDER  2 1  0.5385   2P0.7938
CUBOID    3 1  4P0.7264 2P0.7938
UNIT  4
COM='WATER ROD CELL - WITH ST DISK'
CYLINDER  3 1  0.4623   2P0.7938
CYLINDER  2 1  0.5385   2P0.7938
CUBOID    3 1  4P0.7264 2P0.7938
UNIT  5
COM='FUEL PIN CELL - WITH AL DISK'
CYLINDER  1 1  0.4528   2P0.6350
CYLINDER 10 1  0.4623   2P0.6350
CYLINDER  2 1  0.5385   2P0.6350
CUBOID    3 1  4P0.7264 2P0.6350
UNIT  6
COM='WATER ROD CELL - WITH AL DISK'
CYLINDER  3 1  0.4623   2P0.6350
CYLINDER  2 1  0.5385   2P0.6350
CUBOID    3 1  4P0.7264 2P0.6350
UNIT  7
COM='FUEL PIN ARRAY + CHANNEL - BETWEEN DISKS'
ARRAY  1   -6.5376 -6.5376 -1.7145
CUBOID 3 1 4P6.7031 2P1.7145
CUBOID 2 1 4P6.9063 2P1.7145
UNIT  8
COM='FUEL PIN ARRAY + CHANNEL - ST DISKS'
ARRAY  2   -6.5376 -6.5376 -0.7938
CUBOID 3 1 4P6.7031 2P0.7938
CUBOID 2 1 4P6.9063 2P0.7938
UNIT  9
COM='FUEL PIN ARRAY + CHANNEL - AL DISKS'
ARRAY  3   -6.5376 -6.5376 -0.6350
CUBOID 3 1 4P6.7031 2P0.6350
CUBOID 2 1 4P6.9063 2P0.6350
UNIT 10
COM='X-X BORAL + COVER SHEET BETWEEN DISKS'
CUBOID 6 1 2P6.7310 2P0.1124 2P1.7145
CUBOID 4 1 2P6.7310 2P0.1714 2P1.7145
CUBOID 5 1 2P6.7765 +0.2168 -0.1714 2P1.7145
UNIT 11
COM='Y-Y BORAL + COVER SHEET BETWEEN DISKS'
CUBOID 6 1 2P0.1124 2P6.7310 2P1.7145
CUBOID 4 1 2P0.1714 2P6.7310 2P1.7145
CUBOID 5 1 +0.2168 -0.1714 2P6.7765 2P1.7145
UNIT 12
COM='X-X BORAL + COVER SHEET WITH ST DISKS'
CUBOID 6 1 2P6.7310 2P0.1124 2P0.7938
CUBOID 4 1 2P6.7310 2P0.1714 2P0.7938
CUBOID 5 1 2P6.7765 +0.2168 -0.1714 2P0.7938
UNIT 13
COM='Y-Y BORAL + COVER SHEET WITH ST DISKS'
CUBOID 6 1 2P0.1124 2P6.7310 2P0.7938
CUBOID 4 1 2P0.1714 2P6.7310 2P0.7938
CUBOID 5 1 +0.2168 -0.1714 2P6.7765 2P0.7938
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Figure 6.9-8 (continued)

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UNIT 14
COM='X-X BORAL + COVER SHEET WITH AL DISKS'
CUBOID 6 1 2P6.7310 2P0.1124 2P0.6350
CUBOID 4 1 2P6.7310 2P0.1714 2P0.6350
CUBOID 5 1 2P6.7765 +0.2168 -0.1714 2P0.6350
UNIT 15
COM='Y-Y BORAL + COVER SHEET WITH AL DISKS'
CUBOID 6 1 2P0.1124 2P6.7310 2P0.6350
CUBOID 4 1 2P0.1714 2P6.7310 2P0.6350
CUBOID 5 1 +0.2168 -0.1714 2P6.7765 2P0.6350
UNIT 20
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (TR)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 +0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 21
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 22
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 23
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 24
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (T)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 0.0 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 25
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
HOLE   11 +7.7859 0.0 0.0
UNIT 26
COM='FUEL TUBE CELL TOP BORAL SHEETS - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
UNIT 27
COM='FUEL TUBE CELL TOP BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE   10 0.0 +7.7859 0.0
UNIT 28
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P1.7145
HOLE   11 +7.7859 0.0 0.0
UNIT 29
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P1.7145
HOLE   11 +7.7859 0.0 0.0
UNIT 30
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P1.7145
HOLE   11 +7.7859 0.0 0.0
UNIT 31
COM='FUEL TUBE CELL NO BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE   7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
UNIT 40
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Figure 6.9-8 (continued)

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COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (TR)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 +0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 41
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 42
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 43
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 44
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (T)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 0.0 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 45
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
HOLE   13 +7.7859 0.0 0.0
UNIT 46
COM='FUEL TUBE CELL TOP BORAL SHEETS - STEEL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
UNIT 47
COM='FUEL TUBE CELL TOP BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE   12 0.0 +7.7859 0.0
UNIT 48
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.7938
HOLE   13 +7.7859 0.0 0.0
UNIT 49
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - STEEL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.7938
HOLE   13 +7.7859 0.0 0.0
UNIT 50
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - STEEL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.7938
HOLE   13 +7.7859 0.0 0.0
UNIT 51
COM='FUEL TUBE CELL NO BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE   8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
UNIT 60
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (TR)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 +0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 61
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 +0.5867 0.0
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Figure 6.9-8 (continued)

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CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 62
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 63
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 64
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (T)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 0.0 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 65
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
HOLE   15 +7.7859 0.0 0.0
UNIT 66
COM='FUEL TUBE CELL TOP BORAL SHEETS - AL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
UNIT 67
COM='FUEL TUBE CELL TOP BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE   14 0.0 +7.7859 0.0
UNIT 68
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.6350
HOLE   15 +7.7859 0.0 0.0
UNIT 69
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - AL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.6350
HOLE   15 +7.7859 0.0 0.0
UNIT 70
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - AL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.6350
HOLE   15 +7.7859 0.0 0.0
UNIT 71
COM='FUEL TUBE CELL NO BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE   9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
UNIT 80
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (TR)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   20  -0.0297 -0.0297 0.0
UNIT 81
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   21  -0.3586 -0.0297 0.0
UNIT 82
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   22  -0.3586 -0.3586 0.0
UNIT 83
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   23  -0.0297 -0.3586 0.0
UNIT 84
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (T)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   24  -0.1942 -0.0297 0.0
UNIT 85
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.9731 2P1.7145
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Figure 6.9-8 (continued)

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HOLE   25  -0.1942 -0.3586 0.0
UNIT 86
COM='DISK OPENING TOP BORAL SHEET TUBE - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   26  -0.3586 -0.0297 0.0
UNIT 87
COM='DISK OPENING TOP BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   27  -0.3586 -0.3586 0.0
UNIT 88
COM='DISK OPENING RIGHT BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   28  -0.3586 -0.3586 0.0
UNIT 89
COM='DISK OPENING RIGHT BORAL SHEET TUBE - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   29  -0.1942 -0.3586 0.0
UNIT 90
COM='DISK OPENING RIGHT BORAL SHEET TUBE - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   30  -0.0297 -0.3586 0.0
UNIT 91
COM='DISK OPENING NO BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE   31  -0.3586 -0.3586 0.0
UNIT 100
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (TR)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   40  -0.0297 -0.0297 0.0
UNIT 101
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   41  -0.3586 -0.0297 0.0
UNIT 102
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   42  -0.3586 -0.3586 0.0
UNIT 103
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   43  -0.0297 -0.3586 0.0
UNIT 104
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (T)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   44  -0.1942 -0.0297 0.0
UNIT 105
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   45  -0.1942 -0.3586 0.0
UNIT 106
COM='DISK OPENING TOP BORAL SHEET TUBE - STEEL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   46  -0.3586 -0.0297 0.0
UNIT 107
COM='DISK OPENING TOP BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   47  -0.3586 -0.3586 0.0
UNIT 108
COM='DISK OPENING RIGHT BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   48  -0.3586 -0.3586 0.0
UNIT 109
COM='DISK OPENING RIGHT BORAL SHEET TUBE - STEEL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   49  -0.1942 -0.3586 0.0
UNIT 110
COM='DISK OPENING RIGHT BORAL SHEET TUBE - STEEL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   50  -0.0297 -0.3586 0.0
UNIT 111
COM='DISK OPENING NO BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE   51  -0.3586 -0.3586 0.0
UNIT 120
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (TR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   60  -0.0297 -0.0297 0.0
UNIT 121
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   61  -0.3586 -0.0297 0.0
UNIT 122
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   62  -0.3586 -0.3586 0.0
UNIT 123
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   63  -0.0297 -0.3586 0.0
UNIT 124
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (T)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   64  -0.1942 -0.0297 0.0
UNIT 125
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   65  -0.1942 -0.3586 0.0
UNIT 126
COM='DISK OPENING TOP BORAL SHEET TUBE - AL DISKS (TL)'
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Figure 6.9-8 (continued)

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CUBOID 3 1 4P7.9731 2P0.6350
HOLE   66  -0.3586 -0.0297 0.0
UNIT 127
COM='DISK OPENING TOP BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   67  -0.3586 -0.3586 0.0
UNIT 128
COM='DISK OPENING RIGHT BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   68  -0.3586 -0.3586 0.0
UNIT 129
COM='DISK OPENING RIGHT BORAL SHEET TUBE - AL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   69  -0.1942 -0.3586 0.0
UNIT 130
COM='DISK OPENING RIGHT BORAL SHEET TUBE - AL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   70  -0.0297 -0.3586 0.0
UNIT 131
COM='DISK OPENING NO BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE   71  -0.3586 -0.3586 0.0
UNIT 140
COM='BASKET STRUCTURE IN TRANPORT CASK - WATER DISK'
CYLINDER 3 1 +83.5787 2P1.7145
HOLE 90  -70.3885  +8.7986 0.0
HOLE 83  -52.7914  +8.7986 0.0
HOLE 83  -52.7914 +26.3957 0.0
HOLE 90  -52.7914 +43.9928 0.0
HOLE 83  -35.1942  +8.7986 0.0
HOLE 83  -35.1942 +26.3957 0.0
HOLE 83  -35.1942 +43.9928 0.0
HOLE 90  -35.1942 +61.5899 0.0
HOLE 83  -17.5971  +8.7986 0.0
HOLE 83  -17.5971 +26.3957 0.0
HOLE 83  -17.5971 +43.9928 0.0
HOLE 90  -17.5971 +61.5899 0.0
HOLE 85   0.0      +8.7986 0.0
HOLE 85   0.0     +26.3957 0.0
HOLE 85   0.0     +43.9928 0.0
HOLE 89   0.0     +61.5899 0.0
HOLE 82  +17.5971  +8.7986 0.0
HOLE 82  +17.5971 +26.3957 0.0
HOLE 82  +17.5971 +43.9928 0.0
HOLE 88  +17.5971 +61.5899 0.0
HOLE 82  +35.1942  +8.7986 0.0
HOLE 82  +35.1942 +26.3957 0.0
HOLE 82  +35.1942 +43.9928 0.0
HOLE 91  +35.1942 +61.5899 0.0
HOLE 82  +52.7914  +8.7986 0.0
HOLE 87  +52.7914 +26.3957 0.0
HOLE 91  +52.7914 +43.9928 0.0
HOLE 91  +70.3885  +8.7986 0.0
HOLE 80  -70.3885  -8.7986 0.0
HOLE 80  -52.7914  -8.7986 0.0
HOLE 80  -52.7914 -26.3957 0.0
HOLE 80  -52.7914 -43.9928 0.0
HOLE 80  -35.1942  -8.7986 0.0
HOLE 80  -35.1942 -26.3957 0.0
HOLE 80  -35.1942 -43.9928 0.0
HOLE 80  -35.1942 -61.5899 0.0
HOLE 80  -17.5971  -8.7986 0.0
HOLE 80  -17.5971 -26.3957 0.0
HOLE 80  -17.5971 -43.9928 0.0
HOLE 80  -17.5971 -61.5899 0.0
HOLE 84   0.0      -8.7986 0.0
HOLE 84   0.0     -26.3957 0.0
HOLE 84   0.0     -43.9928 0.0
HOLE 84   0.0     -61.5899 0.0
HOLE 81  +17.5971  -8.7986 0.0
HOLE 81  +17.5971 -26.3957 0.0
HOLE 81  +17.5971 -43.9928 0.0
HOLE 81  +17.5971 -61.5899 0.0
HOLE 81  +35.1942  -8.7986 0.0
HOLE 81  +35.1942 -26.3957 0.0
HOLE 81  +35.1942 -43.9928 0.0
HOLE 86  +35.1942 -61.5899 0.0
HOLE 81  +52.7914  -8.7986 0.0
HOLE 86  +52.7914 -26.3957 0.0
HOLE 86  +52.7914 -43.9928 0.0
HOLE 86  +70.3885  -8.7986 0.0
CYLINDER  5 1  +85.1662 2P1.7145
CYLINDER  9 1  +94.615 2P1.7145
CYLINDER  7 1 +100.965 2P1.7145
CYLINDER  8 1 +172.72  2P1.7145
CUBOID    9 1 4P230.0  2P1.7145
UNIT 141
COM='BASKET STRUCTURE IN TRANPORT CASK - SS DISK'
CYLINDER 7 1  +83.1850 2P0.7938
HOLE 110  -70.3885  +8.7986 0.0
HOLE 103  -52.7914  +8.7986 0.0
HOLE 103  -52.7914 +26.3957 0.0
HOLE 110  -52.7914 +43.9928 0.0
HOLE 103  -35.1942  +8.7986 0.0
HOLE 103  -35.1942 +26.3957 0.0
HOLE 103  -35.1942 +43.9928 0.0
HOLE 110  -35.1942 +61.5899 0.0
HOLE 103  -17.5971  +8.7986 0.0
HOLE 103  -17.5971 +26.3957 0.0
```

Figure 6.9-8 (continued)

```
HOLE 103  -17.5971 +43.9928 0.0
HOLE 110  -17.5971 +61.5899 0.0
HOLE 105   0.0      +8.7986 0.0
HOLE 105   0.0     +26.3957 0.0
HOLE 105   0.0     +43.9928 0.0
HOLE 109   0.0     +61.5899 0.0
HOLE 102  +17.5971  +8.7986 0.0
HOLE 102  +17.5971 +26.3957 0.0
HOLE 102  +17.5971 +43.9928 0.0
HOLE 108  +17.5971 +61.5899 0.0
HOLE 102  +35.1942  +8.7986 0.0
HOLE 102  +35.1942 +26.3957 0.0
HOLE 102  +35.1942 +43.9928 0.0
HOLE 111  +35.1942 +61.5899 0.0
HOLE 102  +52.7914  +8.7986 0.0
HOLE 107  +52.7914 +26.3957 0.0
HOLE 111  +52.7914 +43.9928 0.0
HOLE 111  +70.3885  +8.7986 0.0
HOLE 100  -70.3885  -8.7986 0.0
HOLE 100  -52.7914  -8.7986 0.0
HOLE 100  -52.7914 -26.3957 0.0
HOLE 100  -52.7914 -43.9928 0.0
HOLE 100  -35.1942  -8.7986 0.0
HOLE 100  -35.1942 -26.3957 0.0
HOLE 100  -35.1942 -43.9928 0.0
HOLE 100  -35.1942 -61.5899 0.0
HOLE 100  -17.5971  -8.7986 0.0
HOLE 100  -17.5971 -26.3957 0.0
HOLE 100  -17.5971 -43.9928 0.0
HOLE 100  -17.5971 -61.5899 0.0
HOLE 104   0.0      -8.7986 0.0
HOLE 104   0.0     -26.3957 0.0
HOLE 104   0.0     -43.9928 0.0
HOLE 104   0.0     -61.5899 0.0
HOLE 101  +17.5971  -8.7986 0.0
HOLE 101  +17.5971 -26.3957 0.0
HOLE 101  +17.5971 -43.9928 0.0
HOLE 101  +17.5971 -61.5899 0.0
HOLE 101  +35.1942  -8.7986 0.0
HOLE 101  +35.1942 -26.3957 0.0
HOLE 101  +35.1942 -43.9928 0.0
HOLE 106  +35.1942 -61.5899 0.0
HOLE 101  +52.7914  -8.7986 0.0
HOLE 106  +52.7914 -26.3957 0.0
HOLE 106  +52.7914 -43.9928 0.0
HOLE 106  +70.3885  -8.7986 0.0
CYLINDER  3 1  +83.5787 2P0.7938
CYLINDER  5 1  +85.1662 2P0.7938
CYLINDER  9 1  +94.615 2P0.7938
CYLINDER  7 1 +100.965 2P0.7938
CYLINDER  8 1 +172.72  2P0.7938
CUBOID    9 1 4P230.0  2P0.7938
UNIT 142
COM='BASKET STRUCTURE IN TRANPORT CASK - AL DISK'
CYLINDER 4 1  +82.8675 2P0.6350
HOLE 130  -70.3885  +8.7986 0.0
HOLE 123  -52.7914  +8.7986 0.0
HOLE 123  -52.7914 +26.3957 0.0
HOLE 130  -52.7914 +43.9928 0.0
HOLE 123  -35.1942  +8.7986 0.0
HOLE 123  -35.1942 +26.3957 0.0
HOLE 123  -35.1942 +43.9928 0.0
HOLE 130  -35.1942 +61.5899 0.0
HOLE 123  -17.5971  +8.7986 0.0
HOLE 123  -17.5971 +26.3957 0.0
HOLE 123  -17.5971 +43.9928 0.0
HOLE 130  -17.5971 +61.5899 0.0
HOLE 125   0.0      +8.7986 0.0
HOLE 125   0.0     +26.3957 0.0
HOLE 125   0.0     +43.9928 0.0
HOLE 129   0.0     +61.5899 0.0
HOLE 122  +17.5971  +8.7986 0.0
HOLE 122  +17.5971 +26.3957 0.0
HOLE 122  +17.5971 +43.9928 0.0
HOLE 128  +17.5971 +61.5899 0.0
HOLE 122  +35.1942  +8.7986 0.0
HOLE 122  +35.1942 +26.3957 0.0
HOLE 122  +35.1942 +43.9928 0.0
HOLE 131  +35.1942 +61.5899 0.0
HOLE 122  +52.7914  +8.7986 0.0
HOLE 127  +52.7914 +26.3957 0.0
HOLE 131  +52.7914 +43.9928 0.0
HOLE 131  +70.3885  +8.7986 0.0
HOLE 120  -70.3885  -8.7986 0.0
HOLE 120  -52.7914  -8.7986 0.0
HOLE 120  -52.7914 -26.3957 0.0
HOLE 120  -52.7914 -43.9928 0.0
HOLE 120  -35.1942  -8.7986 0.0
HOLE 120  -35.1942 -26.3957 0.0
HOLE 120  -35.1942 -43.9928 0.0
HOLE 120  -35.1942 -61.5899 0.0
HOLE 120  -17.5971  -8.7986 0.0
HOLE 120  -17.5971 -26.3957 0.0
HOLE 120  -17.5971 -43.9928 0.0
HOLE 120  -17.5971 -61.5899 0.0
HOLE 124   0.0      -8.7986 0.0
HOLE 124   0.0     -26.3957 0.0
HOLE 124   0.0     -43.9928 0.0
HOLE 124   0.0     -61.5899 0.0
```


Figure 6.9-8 (continued)

```
HOLE 121  +17.5971  -8.7986 0.0
HOLE 121  +17.5971 -26.3957 0.0
HOLE 121  +17.5971 -43.9928 0.0
HOLE 121  +17.5971 -61.5899 0.0
HOLE 121  +35.1942  -8.7986 0.0
HOLE 121  +35.1942 -26.3957 0.0
HOLE 121  +35.1942 -43.9928 0.0
HOLE 126  +35.1942 -61.5899 0.0
HOLE 121  +52.7914  -8.7986 0.0
HOLE 126  +52.7914 -26.3957 0.0
HOLE 126  +52.7914 -43.9928 0.0
HOLE 126  +70.3885  -8.7986 0.0
CYLINDER  3 1  +83.5787 2P0.6350
CYLINDER  5 1  +85.1662 2P0.6350
CYLINDER  9 1  +94.615 2P0.6350
CYLINDER  7 1 +100.965 2P0.6350
CYLINDER  8 1 +172.72  2P0.6350
CUBOID    9 1 4P230.0  2P0.6350
GLOBAL UNIT 143
COM='CASK SLICES TOGETHER'
ARRAY  4 -230.00 -230.00 0.0
END GEOM
READ ARRAY
ARA=1   NUX=9 NUY=9 NUZ=1  FILL
    36R1
 4R1  2   4R1
 5R1  2   3R1
    27R1
END FILL
ARA=2   NUX=9 NUY=9 NUZ=1  FILL
    36R3
 4R3  4   4R3
 5R3  4   3R3
    27R3
END FILL
ARA=3   NUX=9 NUY=9 NUZ=1  FILL
    36R5
 4R5  6   4R5
 5R5  6   3R5
    27R5
END FILL
ARA=4 NUX=1 NUY=1 NUZ=4 FILL 140 141 140 142 END FILL
END ARRAY
READ BOUNDS ZFC=PER YXF=PER END BOUNDS
END DATA
END
```

Figure 6.9-9 MONK8A Input for PWR Transfer Cask with Soluble Boron

```
columns 1 200
*
*   UMS Transfer Cask - we17b Standard
*
*   Cask Lid Configurations
*           Shield Lid - No Ports
*           Structural Lid - No Weld Shield
*
*   Neutron Poison Loading -  75 %
*   Exterior Water Density 0.0001
*   Cavity Water Density 0.9998
*   Fuel to Clad Gap Water Density 0.9998
*
*   Boron Content in Water - 1000 ppm
*
*   Model Revision v3.0
*
* Parameters
*
@randseed =  12345
*
*
* Unit 1 Control Data
*
begin control data
*READ   ! read and check each independently
*SEEK MULTIPLE DEFINITIONS

SEEDS  @randseed  @randseed
STAGES -15 810 4000 STDV 0.0008

end
*
* Unit 9 Material Specification
*
begin material specification
normalise
nmixtures  7
weight  mixture  1
      u235  4.4072E-02
      u238  8.3737E-01
      o16  1.1856E-01
atoms  mixture  2
      h  6.6667E-01
      o16  3.3333E-01
atoms  mixture  3
      h  6.6667E-01
      o16  3.3333E-01
atoms  mixture  4
      h  4.2857E-01
      b  1.4286E-01
      o16  4.2857E-01
weight  mixture  5
      al  4.6148E-01
      b10  7.5880E-02
      b11  3.4567E-01
      c  1.1697E-01
atoms  mixture  6
      c  2.8571E-01
      h  4.7619E-01
      o16  2.3810E-01
weight  mixture  7
      h  4.2152E-02
      o16  5.4785E-01
      fe  4.7900E-02
      c  9.3500E-02
      si  3.3600E-02
      ca  5.6100E-02
      al  1.7890E-01
*
* Materials List - v1.2 - Class 1 - we17b - WE17 (OFA) Fuel
*
nmaterials  23
volume              ! UO2 at 5%
material  1
  mixture  1  density  10.4120  prop  1.00000
volume              ! Fuel pin cladding
material  2
  zircalloy    density  6.5500  prop  1.00000
volume              ! Water In Lattice and Tube
material  3
  mixture  4  density  1.0015  prop  0.00572  ! mixBoricAcid
  mixture  2  density  1.0015  prop  0.99428  ! mixH2O
volume              ! Water In Fuel Rod Clad Gap
material  4
  mixture  4  density  1.0015  prop  0.00572  ! mixBoricAcid
  mixture  2  density  1.0015  prop  0.99428  ! mixH2O
volume              ! Lower Nozzle Material
material  5
  stainless 304l steel    density  7.9200  prop  0.23669
  mixture  4  density  1.0015  prop  0.00437  ! mixBoricAcid
  mixture  2  density  1.0015  prop  0.75894  ! mixH2O
volume              ! Upper Nozzle Material
material  6
  stainless 304l steel    density  7.9200  prop  0.23180
  mixture  4  density  1.0015  prop  0.00439  ! mixBoricAcid
  mixture  2  density  1.0015  prop  0.76381  ! mixH2O
```

Figure 6.9-9 (continued)

```
*
* Materials List - Common Materials - v2.0
*
volume              ! Tube wall and cover sheet
material  7
  stainless 304l steel    density  7.9300  prop  1.0000
volume              ! BORAL core
material  8
  mixture  5  density  1.9457  prop  1.0000  ! mixBORAL
volume              ! BORAL alumnimum clad
material  9
  aluminium        prop  1.0000
volume              ! Structural Disk Material
material  10
  stainless 304l steel    density  7.9300  prop  1.0000
volume              ! Weldment Material
material  11
  stainless 304l steel    density  7.9300  prop  1.0000
volume              ! Heat Transfer Disk Material
material  12
  aluminium        prop  1.0000
volume              ! Canister Material
material  13
  stainless 304l steel    density  7.9300  prop  1.0000
atoms              ! Transfer steel
material  14    density  0      !  (SCALE carbon steel)
    fe      prop  8.3498E-02
    c      prop  3.9250E-03
volume              ! Lead
material  15
  pb    density  11.0400  prop  1.0000
atoms              ! NS-4-FR
material  16    density  0      ! 0 means atom/b-cm
    b10      prop  8.5500E-05
    b11      prop  3.4200E-04
    al      prop  7.8000E-03
    h      prop  5.8500E-02
    o16      prop  2.6100E-02
    c      prop  2.2600E-02
    n      prop  1.3900E-03
volume              ! Stainless Steel 304
material  17
  stainless 304l steel    density  7.9300  prop  1.0000
volume              ! Vent port middle cylinder
material  18
  stainless 304l steel    density  7.9300  prop  0.5000
  void        prop  0.5000
atoms              ! SCALE Concrete
material  19    density  0
    h      prop  1.3401E-02
    o16      prop  4.4931E-02
    na      prop  1.7036E-03
    al      prop  1.7018E-03
    si      prop  1.6205E-02
    ca      prop  1.4826E-03
    fe      prop  3.3857E-04
volume              ! Heat fins for transport cask
material  20
  cu    density  8.9200  prop  0.4286
  stainless 304l steel    density  7.9300  prop  0.5714
volume              ! Balsa
material  21
  mixture  6  density  0.1250  prop  1.0000
volume              ! Redwood
material  22
  mixture  6  density  0.3870  prop  1.0000
volume              ! NS3
material  23
  mixture  7  density  1.6507  prop  1.0000  ! Weight loss @ 200F of 2.90%
end

*
* Unit 2 Material Geometry
*
begin material geometry
* Fuel Rod - Class 1 - we17b - WE17 (OFA)
PART  1
ZROD  1    0.0000  0.0000  1.7399  0.3922  365.7600    ! Fuel pellet stack
ZROD  2    0.0000  0.0000  1.7399  0.4001  381.6604    ! Annulus + Plenum
ZROD  3    0.0000  0.0000  0.0000  0.4572  385.1402    ! Clad
ZROD  4    0.0000  0.0000  385.1402  0.0000  4.5720    ! Fuel rod to top nozzle
BOX  5    -0.6299  -0.6299  0.0000  1.2597  1.2597  389.7122  ! Pitch box
ZONES
/Fuel/    M1  +1
/Fuel to Clad Gap/    M4  +2  -1
/Clad & End Plugs/    M2  +3  -2
/Rod to Top Nozzle/    M2  +4
/Rod in Pitch/    M3  +5  -4  -3
* PWR Guide Tube - Class 1 - we17b - WE17 (OFA)
PART  2  NEST
ZROD  M3    0.0000  0.0000  0.0000  0.5740  365.7600    ! Guide tube interior
ZROD  M2    0.0000  0.0000  0.0000  0.6121  365.7600    ! Clad
BOX  M3    -0.6299  -0.6299  0.0000  1.2597  1.2597  389.7122  ! Pitch box
* PWR Instrument Tube - Class 1 - we17b - WE17 (OFA)
PART  3  NEST
ZROD  M3    0.0000  0.0000  0.0000  0.5740  365.7600    ! Inst. tube interior
ZROD  M2    0.0000  0.0000  0.0000  0.6121  365.7600    ! Clad
BOX  M3    -0.6299  -0.6299  0.0000  1.2597  1.2597  389.7122  ! Pitch box
* Array_17x17_264
```

Figure 6.9-9 (continued)

```
PART  4  ARRAY
17  17  1
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1  1  1  1  1  2  1  1  2  1  1  2  1  1  1  1  1
1  1  1  2  1  1  1  1  1  1  1  1  1  2  1  1  1
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1  1  2  1  1  2  1  1  2  1  1  2  1  1  2  1  1
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1  1  2  1  1  2  1  1  3  1  1  2  1  1  2  1  1
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1  1  2  1  1  2  1  1  2  1  1  2  1  1  2  1  1
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1  1  1  2  1  1  1  1  1  1  1  1  1  2  1  1  1
1  1  1  1  1  2  1  1  2  1  1  2  1  1  1  1  1
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
* Fuel Assembly Array Inserted Into Assembly - Class 1 - we17b - WE17 (OFA)
PART  5  NEST
BOX  P4  -10.7075  -10.7075  6.8580  21.4149  21.4149  389.7122    ! Array
BOX  M3  -10.7086  -10.7086  6.8580  21.4173  21.4173  389.7122    ! Fuel Width Envelope
BOX  M5  -10.7086  -10.7086  0.0000  21.4173  21.4173  396.5702    ! Lower Nozzle
BOX  M6  -10.7086  -10.7086  0.0000  21.4173  21.4173  405.8920    ! Upper Nozzle - Envelope
* PWR Neutron Poison and Cover Sheet            Configuration  R
PART  6
BOX  1  -9.9009  0.0318  0.0508  20.7467  0.1270  382.2700  ! BORAL Core
BOX  2  -9.9009  0.0000  0.0508  20.7467  0.1905  382.2700  ! BORAL Clad
BOX  3  -10.8458  0.0000  0.0508  21.6916  0.1905  384.2004  ! Space under Cover Sheet
BOX  4  -10.8915  0.0000  0.0051  21.7830  0.2362  384.2918  ! Cover Sheet (top/side)
BOX  5  -10.8966  0.0000  0.0000  21.7932  0.0457  384.3020  ! Remaining Cover Sheet
BOX  6  -10.8966  0.0000  0.0000  21.7932  0.2362  384.3020  ! Container
ZONES
/BORAL Core/    M8  +1
/BORAL Clad/    M9  +2  -1
/Space Under Cover/    H5  +3  -2
/Enclosing Cover/    M7  +4  -3
/Remaining Cover/    M7  +5  -4
/Container/    H5  +6  -5  -4
VOLUMES UNITY
* PWR Neutron Poison and Cover Sheet            Configuration  L
PART  7
BOX  1  -10.8458  0.0318  0.0508  20.7467  0.1270  382.2700  ! BORAL Core
BOX  2  -10.8458  0.0000  0.0508  20.7467  0.1905  382.2700  ! BORAL Clad
BOX  3  -10.8458  0.0000  0.0508  21.6916  0.1905  384.2004  ! Space under Cover Sheet
BOX  4  -10.8915  0.0000  0.0051  21.7830  0.2362  384.2918  ! Cover Sheet (top/side)
BOX  5  -10.8966  0.0000  0.0000  21.7932  0.0457  384.3020  ! Remaining Cover Sheet
BOX  6  -10.8966  0.0000  0.0000  21.7932  0.2362  384.3020  ! Container
ZONES
/BORAL Core/    M8  +1
/BORAL Clad/    M9  +2  -1
/Space Under Cover/    H5  +3  -2
/Enclosing Cover/    M7  +4  -3
/Remaining Cover/    M7  +5  -4
/Container/    H5  +6  -5  -4
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  Q1_4B
PART  8
BOX  1  -11.1684  -11.1684  0.0000  21.4173  21.4173  405.8920    ! Fuel assembly
BOX  2  -11.1684  -11.1684  0.0000  22.3368  22.3368  414.7820    ! Space inside tube from can lid to bottom
BOX  3  -11.2903  -11.2903  5.0800  22.5806  22.5806  388.1120    ! Fuel tube
BOX  4  -10.6807  11.2903  7.1120  21.7932  0.2362  384.3020    ! Boral plus cover sheet - Top (+Y)
BOX  5  11.1125  -11.2903  7.1120  21.7932  0.2362  384.3020  ZROT 180  ! Boral plus cover sheet - Bottom (-Y)
BOX  6  11.2903  11.1125  7.1120  21.7932  0.2362  384.3020  ZROT 90  ! Boral plus cover sheet - Right (+X)
BOX  7  -11.2903  -10.6807  7.1120  21.7932  0.2362  384.3020  ZROT 270  ! Boral plus cover sheet - Left (-X)
BOX  8  -11.5265  -11.5265  0.0000  23.0530  23.0530  414.7820    ! Complete tube with poison
BOX  9  -11.5265  -11.5265  0.0000  23.5890  23.5890  414.7820    ! Disk Opening
ZONES
/Fuel Assembly/  P5  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Boral plus Cover/  P6  +4
/Boral plus Cover/  P7  +5
/Boral plus Cover/  P7  +6
/Boral plus Cover/  P6  +7
/Fuel Tube+Poison/  H5  +8  -3  -2  -4  -6  -5  -7
/Disk Opening/  H5  +9  -8
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  Q2_4B
PART  9
BOX  1  -10.2489  -11.1684  0.0000  21.4173  21.4173  405.8920    ! Fuel assembly
BOX  2  -11.1684  -11.1684  0.0000  22.3368  22.3368  414.7820    ! Space inside tube from can lid to bottom
BOX  3  -11.2903  -11.2903  5.0800  22.5806  22.5806  388.1120    ! Fuel tube
BOX  4  -11.1125  11.2903  7.1120  21.7932  0.2362  384.3020    ! Boral plus cover sheet - Top (+Y)
BOX  5  10.6807  -11.2903  7.1120  21.7932  0.2362  384.3020  ZROT 180  ! Boral plus cover sheet - Bottom (-Y)
BOX  6  11.2903  11.1125  7.1120  21.7932  0.2362  384.3020  ZROT 90  ! Boral plus cover sheet - Right (+X)
BOX  7  -11.2903  -10.6807  7.1120  21.7932  0.2362  384.3020  ZROT 270  ! Boral plus cover sheet - Left (-X)
BOX  8  -11.5265  -11.5265  0.0000  23.0530  23.0530  414.7820    ! Complete tube with poison
BOX  9  -12.0625  -11.5265  0.0000  23.5890  23.5890  414.7820    ! Disk Opening
ZONES
/Fuel Assembly/  P5  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Boral plus Cover/  P7  +4
/Boral plus Cover/  P6  +5
/Boral plus Cover/  P7  +6
/Boral plus Cover/  P6  +7
/Fuel Tube+Poison/  H5  +8  -3  -2  -4  -6  -5  -7
```

Figure 6.9-9 (continued)

```
/Disk Opening/  H5  +9  -8
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  Q3_4B
PART  10
BOX  1  -10.2489  -10.2489  0.0000  21.4173  21.4173  405.8920    ! Fuel assembly
BOX  2  -11.1684  -11.1684  0.0000  22.3368  22.3368  414.7820    ! Space inside tube from can lid to bottom
BOX  3  -11.2903  -11.2903  5.0800  22.5806  22.5806  388.1120    ! Fuel tube
BOX  4  -11.1125  11.2903  7.1120  21.7932  0.2362  384.3020    ! Boral plus cover sheet - Top (+Y)
BOX  5  10.6807  -11.2903  7.1120  21.7932  0.2362  384.3020  ZROT 180  ! Boral plus cover sheet - Bottom (-Y)
BOX  6  11.2903  10.6807  7.1120  21.7932  0.2362  384.3020  ZROT 90  ! Boral plus cover sheet - Right (+X)
BOX  7  -11.2903  -11.1125  7.1120  21.7932  0.2362  384.3020  ZROT 270  ! Boral plus cover sheet - Left (-X)
BOX  8  -11.5265  -11.5265  0.0000  23.0530  23.0530  414.7820    ! Complete tube with poison
BOX  9  -12.0625  -12.0625  0.0000  23.5890  23.5890  414.7820    ! Disk Opening
ZONES
/Fuel Assembly/  P5  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Boral plus Cover/  P7  +4
/Boral plus Cover/  P6  +5
/Boral plus Cover/  P6  +6
/Boral plus Cover/  P7  +7
/Fuel Tube+Poison/  H5  +8  -3  -2  -4  -6  -5  -7
/Disk Opening/  H5  +9  -8
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  Q4_4B
PART  11
BOX  1  -11.1684  -10.2489  0.0000  21.4173  21.4173  405.8920    ! Fuel assembly
BOX  2  -11.1684  -11.1684  0.0000  22.3368  22.3368  414.7820    ! Space inside tube from can lid to bottom
BOX  3  -11.2903  -11.2903  5.0800  22.5806  22.5806  388.1120    ! Fuel tube
BOX  4  -10.6807  11.2903  7.1120  21.7932  0.2362  384.3020    ! Boral plus cover sheet - Top (+Y)
BOX  5  11.1125  -11.2903  7.1120  21.7932  0.2362  384.3020  ZROT 180  ! Boral plus cover sheet - Bottom (-Y)
BOX  6  11.2903  10.6807  7.1120  21.7932  0.2362  384.3020  ZROT 90  ! Boral plus cover sheet - Right (+X)
BOX  7  -11.2903  -11.1125  7.1120  21.7932  0.2362  384.3020  ZROT 270  ! Boral plus cover sheet - Left (-X)
BOX  8  -11.5265  -11.5265  0.0000  23.0530  23.0530  414.7820    ! Complete tube with poison
BOX  9  -11.5265  -12.0625  0.0000  23.5890  23.5890  414.7820    ! Disk Opening
ZONES
/Fuel Assembly/  P5  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Boral plus Cover/  P6  +4
/Boral plus Cover/  P7  +5
/Boral plus Cover/  P6  +6
/Boral plus Cover/  P7  +7
/Fuel Tube+Poison/  H5  +8  -3  -2  -4  -6  -5  -7
/Disk Opening/  H5  +9  -8
VOLUMES UNITY
* PWR Canister Cavity - Basket Radius v2.0
PART  12
BOX  1  -77.3392  -25.4749  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 1
BOX  2  -77.3392  1.8860  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 2
BOX  3  -52.8358  -52.8358  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 3
BOX  4  -51.5658  -25.4749  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 4
BOX  5  -51.5658  1.8860  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 5
BOX  6  -52.8358  29.2468  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 6
BOX  7  -25.4749  -77.3392  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 7
BOX  8  -25.4749  -51.5658  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 8
BOX  9  -25.4749  -25.4749  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 9
BOX  10  -25.4749  1.8860  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 10
BOX  11  -25.4749  27.9768  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 11
BOX  12  -25.4749  53.7502  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 12
BOX  13  1.8860  -77.3392  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 13
BOX  14  1.8860  -51.5658  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 14
BOX  15  1.8860  -25.4749  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 15
BOX  16  1.8860  1.8860  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 16
BOX  17  1.8860  27.9768  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 17
BOX  18  1.8860  53.7502  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 18
BOX  19  29.2468  -52.8358  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 19
BOX  20  27.9768  -25.4749  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 20
BOX  21  27.9768  1.8860  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 21
BOX  22  29.2468  29.2468  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 22
BOX  23  53.7502  -25.4749  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 23
BOX  24  53.7502  1.8860  0.0000  23.5890  23.5890  414.7820  ! Basket Opening 24
CONTAINER
ZROD  25  0.0000  0.0000  0.0000  82.9564  414.7820    ! Basket stack to cavity height
ZONES
/Opening01/  P10  +1
/Opening02/  P9  +2
/Opening03/  P10  +3           ! Corner position
/Opening04/  P10  +4
/Opening05/  P9  +5
/Opening06/  P9  +6           ! Corner position
/Opening07/  P10  +7
/Opening08/  P10  +8
/Opening09/  P10  +9
/Opening10/  P9  +10
/Opening11/  P9  +11
/Opening12/  P9  +12
/Opening13/  P11  +13
/Opening14/  P11  +14
/Opening15/  P11  +15
/Opening16/  P8  +16
/Opening17/  P8  +17
/Opening18/  P8  +18
/Opening19/  P11  +19           ! Corner position
/Opening20/  P11  +20
/Opening21/  P8  +21
/Opening22/  P8  +22           ! Corner position
/Opening23/  P11  +23
/Opening24/  P8  +24
```

Figure 6.9-9 (continued)

```
/Basket/  H1  +25  -1  -2  -3  -4  -5
    -6  -7  -8  -9  -10  -11
    -12  -13  -14  -15  -16  -17
    -18  -19  -20  -21  -22  -23
    -24

VOLUMES  UNITY
* Basket in Canister Cavity v2.0
PART  13  NEST
ZROD  P12  0.0000  0.0000  0.0000  82.9564  414.7820    ! Basket inserted - Includes gap to lid
ZROD  H5  0.0000  0.0000  0.0000  83.5787  414.7820    ! Inserts flood matl to canister shell
* Canister - Structural Lid - No Weld Shield v2.0
PART  14
ZROD  1  0.0000  0.0000  0.0000  83.5787  414.7820    ! Canister cavity contents
ZROD  2  0.0000  0.0000  -4.4450  85.1662  4.4450    ! Canister Bottom Plate
ZROD  3  0.0000  0.0000  414.7820  83.5787  17.7800    ! Shield Lid
ZROD  4  0.0000  0.0000  432.5620  83.5787  7.6200    ! Structural Lid
ZROD  5  0.0000  0.0000  0.0000  83.5787  440.1820    ! Canister Shell Inner
ZROD  6  0.0000  0.0000  0.0000  85.1662  440.1820    ! Canister Shell Outer
ZROD  7  0.0000  0.0000  -4.4450  85.1662  444.6270    ! Inner Detector Surface
ZONES
/Cavity/  P13  +1
/BottomPlate/  M13  +2
/ShieldLid/  P15  +3
/StructLid/  M13  +4
/Shell/  M13  +6  -5
/Canister/  M0  +7  -6  -4  -2
VOLUMES  UNITY
* Shield Lid - With Ports v2.0
PART  15  CLUSTER
ZROD  P16  -41.8271  59.7354  0.0000  7.6200  17.7800    ! Vent port
ZROD  P16  41.8271  -59.7354  0.0000  7.6200  17.7800    ! Drain port
ZROD  M13  0.0000  0.0000  0.0000  83.5787  17.7800    ! Shield Lid
* Vent Port Model - No Port v2.0
PART  16  CLUSTER
ZROD  M13  0.0000  0.0000  0.0000  1.3843  8.4328    ! Bottom Cylinder
ZROD  M13  0.0000  0.0000  8.4328  5.0800  7.9248    ! Middle Cyclinder
ZROD  M13  0.0000  0.0000  16.3576  7.6200  1.4224    ! Top Cylinder
ZROD  M13  0.0000  0.0000  0.0000  7.6200  17.7800    ! Shield lid material
* Transfer Cask Geometry - No Weld Shield - v2.0
PART  17
ZROD  1  0.0000  0.0000  0.0000  85.1662  444.6270    ! TSC
ZROD  2  0.0000  0.0000  0.0000  86.0425  450.3420    ! Cask cavity
ZROD  3  0.0000  0.0000  0.0000  108.2675  2.5400    ! Bottom plate
ZROD  4  0.0000  0.0000  2.5400  87.9475  442.7220    ! Inner shell
ZROD  5  0.0000  0.0000  2.5400  97.8535  436.6260    ! Lead shell
ZROD  6  0.0000  0.0000  2.5400  105.0925  442.7220    ! NS-4-FR shell
ZROD  7  0.0000  0.0000  2.5400  108.2675  442.7220    ! Outer shell
ZROD  8  0.0000  0.0000  445.2620  108.2675  5.0800    ! Top plate
ZROD  9  0.0000  0.0000  450.3420  82.2325  1.9050    ! Area inside retaining ring
ZROD  10  0.0000  0.0000  450.3420  97.8535  1.9050    ! Retaining ring
ZROD  11  0.0000  0.0000  -22.8600  108.2675  22.8600    ! Shield doors and rails
YP  12  102.5525            ! Y plane for shield door rail cutoff
YP  13  -102.5525            ! Y plane for shield door rail cutoff
XROD  14  -118.2675  0.0000  412.2420  12.7000  236.5350    ! Trunions (extended in x)
YROD  15  0.0000  -118.2675  412.2420  12.7000  236.5350    ! Trunions (extended in y)
ZROD  16  0.0000  0.0000  439.1660  97.8535  6.0960    ! Shielding ring
BOX  17  -2.5400  -86.8045  -5.0800  64.9732  173.6090  3.8100  ! Shield door B NS box
YXPRISM  18  62.4332  -86.8045  -5.0800        ! Shield door B NS trapezoid
    173.6090  39.4984  3.8100  36.9157  36.9157
BOX  19  -62.4332  -86.8045  -5.0800  54.8132  173.6090  3.8100  ! Shield door A NS box
YXPRISM  20  -101.9316  -34.2265  -5.0800        ! Shield door A NS trapezoid
    68.4530  39.4984  3.8100  143.0843  143.0843
YXPRISM  21  64.2620  -90.6780  -22.8600        ! Shield door B cut prism
    181.3560  41.4020  22.8600  36.9157  36.9157
XP  22  64.2620            ! Cut plane for NS boundary B
YXPRISM  23  -105.6640  -35.5600  -22.8600        ! Shield door A cut prism
    71.1200  41.4020  22.8600  143.0843  143.0843
XP  24  -64.2620            ! Cut plane for NS boundary A
ZROD  25  0.0000  0.0000  -22.8600  108.2675  475.1070    ! Container
ZONES
/TSC/  P14  +1            ! TSC
/CaskCavity/  M0  +2  -1          ! Cask cavity
/BottomPlate/  M14  +3  -2          ! Bottom plate
/InnerShell/  M14  +4  -2  -14  -15      ! Inner shell
/LeadShell/  M15  +5  -4  -14  -15      ! Lead shell
/NS-4-FRShell/  M16  +6  -5  -14  -15  -16    ! NS-4-FR shell
/ShieldRing/  M14  +16  -4  -14  -15      ! Shielding ring
/OuterShell/  M14  +7  -6  -14  -15      ! Outer shell
/TopPlate/  M14  +8  -2          ! Top plate
/RetRingInner/  M0  +9            ! Area inside retaining ring (null)
/RetRing/  M0  +10  -9          ! Retaining ring
/ShieldDoor1/  M14  +11  +13  -12  -17  -19    ! Shield doors and rails
    -18  -20  -22  +24
/ShieldDoor2/  M14  +11  +13  -12  -17  -19    ! Shield doors and rails
    -18  -20  +22  +21
/ShieldDoor3/  M14  +11  +13  -12  -17  -19    ! Shield doors and rails
    -18  -20  -24  +23
/ShieldDoorOuter1/  M0  +11  +12          ! Space outside of shield door
/ShieldDoorOuter2/  M0  +11  -13          ! Space outside of shield door
/ShieldDoorOuter3/  M0  +11  +22  -21        ! Space outside of shield door B
/ShieldDoorOuter4/  M0  +11  -24  -23        ! Space outside of shield door A
/XTrunions/  M14  +14  +7  -2        ! X Trunions
/YTrunions/  M14  +15  +7  -2        ! Y Trunions
/ShldDrBNSBox/  M16  +17            ! Shield door B NS box
/ShldDrANSBox/  M16  +19            ! Shield door A NS box
/ShldDrBNSTrap/  M16  +18            ! Shield door B NS trapezoid
/ShldDrANSTrap/  M16  +20            ! Shield door A NS trapezoid
/Container/  M0  +25  -11  -3  -7  -8  -10  ! Container
```

Figure 6.9-9 (continued)

```
VOLUMES UNITY
end

*
* Unit 5 - Source Geometry for
*
begin source geometry
ZONEMAT
ALL / MATERIAL    1
end

*
* Unit 3 Hole Data
*
begin hole data
* PWR Canister Hole Description v2.0
* Hole  1  General Basket Structure
PLATE
0  0  1
5
413.0040  0      ! Top of Basket
379.9840  -2      ! Top of Highest Support Disk
16.3068  -4      ! Bottom of Lowest Support Disk
0.0000  -3      ! Bottom of Basket
0.0000  3      ! Basket Offset
3

* Hole  2  Top Weldment Disk - no structure above the weldment disk
RZMESH
2        ! number of radial points
82.2198
83.1850
5        ! number of axial intervals
379.9840        ! Top of diskstack
394.4620        ! Bottom of weldment
397.6370        ! Top of weldment plate
406.1241        ! Ullage
411.7340        ! Flange
413.0040        ! Void to top of basket
3  3      ! Material below weldment
11  11      ! Plate Material
3  11      ! Ullage
3  11      ! Flange
3  3      ! Void to top of basket
3        ! Outside material

* Hole  3  Bottom Weldment Disk - no structure in the weldment disk support
RZMESH
1        ! number of radial points
83.1850
1        ! number of axial intervals
2.5400
5.0800        ! Coordinates inherited from PLATE Hole
11        ! Plate Material
3        ! Outside material

* Hole  4  Support disk and heat transfer disk stack
PLATE
origin  0  0  16.3068  ! Origin
0  0  1
4
cell  12.4968      ! Sets up a repeating lattice of cells
12.4968  3      ! flood matl
7.5184  3      ! water gap
6.2484  12      ! aluminium disk
1.2700  3      ! water gap
10        ! steel disk

* Hole  5  Flood material model
PLATE
0  0  1
1
406.1241  3      ! Above flooded region
3        ! Flooded region

end
```

Figure 6.9-10 MONK8A Input for BWR Transfer Cask

```
columns 1 200
*
*   UMS Transfer Cask - ex09c Standard
*
*   Cask Lid Configurations
*           Shield Lid - No Ports
*           Structural Lid - No Weld Shield
*
*   Neutron Poison Loading -  75 %
*   Exterior Water Density 0.0001
*   Cavity Water Density 0.9998
*   Fuel to Clad Gap Water Density 0.9998
*
*   Boron Content in Water - 0 ppm
*
*   Model Revision v3.0
*
* Parameters
*
@randseed =  12345
*
*
* Unit 1 Control Data
*
begin control data
*READ   ! read and check each independently
*SEEK MULTIPLE DEFINITIONS

SEEDS  @randseed  @randseed
STAGES -15 810 4000 STDV 0.0008

end
*
* Unit 9 Material Specification
*
begin material specification
normalise
nmixtures  7
weight  mixture  1
      u235  3.8784E-02
      u238  8.4267E-01
      o16  1.1855E-01
atoms  mixture  2
      h  6.6667E-01
      o16  3.3333E-01
atoms  mixture  3
      h  6.6667E-01
      o16  3.3333E-01
atoms  mixture  4
      h  4.2857E-01
      b  1.4286E-01
      o16  4.2857E-01
weight  mixture  5
      al  7.6834E-01
      b10  3.2642E-02
      b11  1.4870E-01
      c  5.0317E-02
atoms  mixture  6
      c  2.8571E-01
      h  4.7619E-01
      o16  2.3810E-01
weight  mixture  7
      h  4.2152E-02
      o16  5.4785E-01
      fe  4.7900E-02
      c  9.3500E-02
      si  3.3600E-02
      ca  5.6100E-02
      al  1.7890E-01
*
* Materials List - v1.2 - Class 5 - ex09c - Ex/ANF9 (JP-4,5) Fuel
*
nmaterials  23
volume              ! UO2 at 4.4%
material  1
  mixture  1  density  10.4120  prop  1.00000
volume              ! Fuel pin cladding
material  2
  zircalloy    density  6.5500  prop  1.00000
volume              ! Water In Lattice and Tube
material  3
  mixture  2  density  0.9998  prop  1.00000  ! mixH2O
volume              ! Water In Fuel Rod Clad Gap
material  4
  mixture  2  density  0.9998  prop  1.00000  ! mixH2O
volume              ! Lower Nozzle Material
material  5
  stainless 304l steel    density  7.9200  prop  0.17007
  mixture  2  density  0.9998  prop  0.82993  ! mixH2O
volume              ! Upper Nozzle Material
material  6
  stainless 304l steel    density  7.9200  prop  0.06774
  mixture  2  density  0.9998  prop  0.93226  ! mixH2O
```

Figure 6.9-10 (continued)

```
*
* Materials List - Common Materials - v2.0
*
volume              ! Tube wall and cover sheet
material  7
  stainless 304l steel    density  7.9300  prop  1.0000
volume              ! BORAL core
material  8
  mixture  5  density  1.9901  prop  1.0000  ! mixBORAL
volume              ! BORAL alumnimum clad
material  9
  aluminium        prop  1.0000
volume              ! Structural Disk Material
material  10
  stainless 304l steel    density  7.9300  prop  1.0000
volume              ! Weldment Material
material  11
  stainless 304l steel    density  7.9300  prop  1.0000
volume              ! Heat Transfer Disk Material
material  12
  aluminium        prop  1.0000
volume              ! Canister Material
material  13
  stainless 304l steel    density  7.9300  prop  1.0000
atoms              ! Transfer steel
material  14    density  0      !  (SCALE carbon steel)
    fe      prop  8.3498E-02
    c      prop  3.9250E-03
volume              ! Lead
material  15
  pb    density  11.0400  prop  1.0000
atoms              ! NS-4-FR
material  16    density  0      ! 0 means atom/b-cm
    b10      prop  8.5500E-05
    b11      prop  3.4200E-04
    al      prop  7.8000E-03
    h      prop  5.8500E-02
    o16      prop  2.6100E-02
    c      prop  2.2600E-02
    n      prop  1.3900E-03
volume              ! Stainless Steel 304
material  17
  stainless 304l steel    density  7.9300  prop  1.0000
volume              ! Vent port middle cylinder
material  18
  stainless 304l steel    density  7.9300  prop  0.5000
  void        prop  0.5000
atoms              ! SCALE Concrete
material  19    density  0
    h      prop  1.3401E-02
    o16      prop  4.4931E-02
    na      prop  1.7036E-03
    al      prop  1.7018E-03
    si      prop  1.6205E-02
    ca      prop  1.4826E-03
    fe      prop  3.3857E-04
volume              ! Heat fins for transport cask
material  20
  cu    density  8.9200  prop  0.4286
  stainless 304l steel    density  7.9300  prop  0.5714
volume              ! Balsa
material  21
  mixture  6  density  0.1250  prop  1.0000
volume              ! Redwood
material  22
  mixture  6  density  0.3870  prop  1.0000
volume              ! NS3
material  23
  mixture  7  density  1.6507  prop  1.0000  ! Weight loss @ 200F of 2.90%
end

*
* Unit 2 Material Geometry
*
begin material geometry
* Fuel Rod - Class 5 - ex09c - Ex/ANF9 (JP-4,5)
PART  1
ZROD  1    0.0000  0.0000  0.9017  0.4528  381.0000    ! Fuel pellet stack
ZROD  2    0.0000  0.0000  0.9017  0.4623  405.3281    ! Annulus + Plenum
ZROD  3    0.0000  0.0000  0.0000  0.5385  407.1315    ! Clad
ZROD  4    0.0000  0.0000  407.1315  0.2692  3.3782    ! Fuel rod to top nozzle
BOX  5    -0.7264  -0.7264  0.0000  1.4528  1.4528  410.5097  ! Pitch box
ZONES
/Fuel/    M1  +1
/Fuel to Clad Gap/    M4  +2  -1
/Clad & End Plugs/    M2  +3  -2
/Rod to Top Nozzle/    M2  +4
/Rod in Pitch/    M3  +5  -4  -3
* BWR Water Rod - Class 5 - ex09c - Ex/ANF9 (JP-4,5)
PART  2  NEST
ZROD  M3    0.0000  0.0000  0.0000  0.4623  381.0000    ! Water Rod Interior
ZROD  M2    0.0000  0.0000  0.0000  0.5385  381.0000    ! Clad
BOX  M3    -0.7264  -0.7264  0.0000  1.4528  1.4528  410.5097  ! Pitch box
* Array_9x9_79
PART  3  ARRAY
9  9  1
1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1
```

Figure 6.9-10 (continued)

```
1  1  1  1  1  1  1  1  1
1  1  1  1  2  1  1  1  1
1  1  1  1  1  2  1  1  1
1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1
* Fuel Assembly Array Inserted Into Assembly - Class 5 - ex09c - Ex/ANF9 (JP-4,5)
PART  4  NEST
BOX  P3  -6.5376  -6.5376  17.6276  13.0752  13.0752  410.5097    ! Array
BOX  M3  -6.7031  -6.7031  17.6276  13.4061  13.4061  410.5097    ! BWR Channel Interior
BOX  M2  -6.9063  -6.9063  17.6276  13.8125  13.8125  410.5097    ! BWR Channel
BOX  M3  -6.9063  -6.9063  17.6276  13.8125  13.8125  410.5097    ! Fuel Width Envelope
BOX  M5  -6.9063  -6.9063  0.0000  13.8125  13.8125  428.1373    ! Lower Nozzle
BOX  M6  -6.9063  -6.9063  0.0000  13.8125  13.8125  447.1873    ! Upper Nozzle - Envelope
* BWR Neutron Poison and Cover Sheet            Configuration  C
PART  5
BOX  1  -6.7031  0.1080  0.0508  13.4061  0.1270  396.4940  ! BORAL Core
BOX  2  -6.7031  0.0000  0.0508  13.4061  0.3429  396.4940  ! BORAL Clad
BOX  3  -7.1755  0.0000  0.0508  14.3510  0.3429  398.4244  ! Space under Cover Sheet
BOX  4  -7.2212  0.0000  0.0051  14.4424  0.3886  398.5158  ! Cover Sheet (top/side)
BOX  5  -7.2263  0.0000  0.0000  14.4526  0.0457  398.5260  ! Remaining Cover Sheet
BOX  6  -7.2263  0.0000  0.0000  14.4526  0.3886  398.5260  ! Container
ZONES
/BORAL Core/    M8  +1
/BORAL Clad/    M9  +2  -1
/Space Under Cover/    H5  +3  -2
/Enclosing Cover/    M7  +4  -3
/Remaining Cover/    M7  +5  -4
/Container/    H5  +6  -5  -4
VOLUMES UNITY
* BWR Neutron Poison and Cover Sheet            Configuration  R
PART  6
BOX  1  -6.2306  0.1080  0.0508  13.4061  0.1270  396.4940  ! BORAL Core
BOX  2  -6.2306  0.0000  0.0508  13.4061  0.3429  396.4940  ! BORAL Clad
BOX  3  -7.1755  0.0000  0.0508  14.3510  0.3429  398.4244  ! Space under Cover Sheet
BOX  4  -7.2212  0.0000  0.0051  14.4424  0.3886  398.5158  ! Cover Sheet (top/side)
BOX  5  -7.2263  0.0000  0.0000  14.4526  0.0457  398.5260  ! Remaining Cover Sheet
BOX  6  -7.2263  0.0000  0.0000  14.4526  0.3886  398.5260  ! Container
ZONES
/BORAL Core/    M8  +1
/BORAL Clad/    M9  +2  -1
/Space Under Cover/    H5  +3  -2
/Enclosing Cover/    M7  +4  -3
/Remaining Cover/    M7  +5  -4
/Container/    H5  +6  -5  -4
VOLUMES UNITY
* BWR Neutron Poison and Cover Sheet            Configuration  L
PART  7
BOX  1  -7.1755  0.1080  0.0508  13.4061  0.1270  396.4940  ! BORAL Core
BOX  2  -7.1755  0.0000  0.0508  13.4061  0.3429  396.4940  ! BORAL Clad
BOX  3  -7.1755  0.0000  0.0508  14.3510  0.3429  398.4244  ! Space under Cover Sheet
BOX  4  -7.2212  0.0000  0.0051  14.4424  0.3886  398.5158  ! Cover Sheet (top/side)
BOX  5  -7.2263  0.0000  0.0000  14.4526  0.0457  398.5260  ! Remaining Cover Sheet
BOX  6  -7.2263  0.0000  0.0000  14.4526  0.3886  398.5260  ! Container
ZONES
/BORAL Core/    M8  +1
/BORAL Clad/    M9  +2  -1
/Space Under Cover/    H5  +3  -2
/Enclosing Cover/    M7  +4  -3
/Remaining Cover/    M7  +5  -4
/Container/    H5  +6  -5  -4
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  Q1_2B
PART  8
BOX  1  -7.4981  -7.4981  0.0000  13.8125  13.8125  447.1873    ! Fuel assembly
BOX  2  -7.4981  -7.4981  0.0000  14.9962  14.9962  453.6440    ! Space inside tube from can lid to bottom
BOX  3  -7.6200  -7.6200  12.7000  15.2400  15.2400  409.4480    ! Fuel tube
BOX  4  -7.1120  7.6200  14.7320  14.4526  0.3886  398.5260    ! Boral plus cover sheet - Top (+Y)
BOX  5  7.6200  7.3406  14.7320  14.4526  0.3886  398.5260  ZROT 90  ! Boral plus cover sheet - Right (+X)
BOX  6  -7.6200  -7.6200  0.0000  15.6286  15.6286  453.6440    ! Complete tube with poison
BOX  7  -7.6200  -7.6200  0.0000  15.9461  15.9461  453.6440    ! Disk Opening
ZONES
/Fuel Assembly/  P4  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Boral plus Cover/  P6  +4
/Boral plus Cover/  P7  +5
/Fuel Tube+Poison/  H5  +6  -3  -2  -4  -5
/Disk Opening/  H5  +7  -6
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  Q2_2B
PART  9
BOX  1  -6.3144  -7.4981  0.0000  13.8125  13.8125  447.1873    ! Fuel assembly
BOX  2  -7.4981  -7.4981  0.0000  14.9962  14.9962  453.6440    ! Space inside tube from can lid to bottom
BOX  3  -7.6200  -7.6200  12.7000  15.2400  15.2400  409.4480    ! Fuel tube
BOX  4  -7.3406  7.6200  14.7320  14.4526  0.3886  398.5260    ! Boral plus cover sheet - Top (+Y)
BOX  5  7.6200  7.3406  14.7320  14.4526  0.3886  398.5260  ZROT 90  ! Boral plus cover sheet - Right (+X)
BOX  6  -7.6200  -7.6200  0.0000  15.6286  15.6286  453.6440    ! Complete tube with poison
BOX  7  -7.9375  -7.6200  0.0000  15.9461  15.9461  453.6440    ! Disk Opening
ZONES
/Fuel Assembly/  P4  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Boral plus Cover/  P7  +4
/Boral plus Cover/  P7  +5
/Fuel Tube+Poison/  H5  +6  -3  -2  -4  -5
/Disk Opening/  H5  +7  -6
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  Q3_2B
```

Figure 6.9-10 (continued)

```
PART  10
BOX  1  -6.3144  -6.3144  0.0000  13.8125  13.8125  447.1873    ! Fuel assembly
BOX  2  -7.4981  -7.4981  0.0000  14.9962  14.9962  453.6440    ! Space inside tube from can lid to bottom
BOX  3  -7.6200  -7.6200  12.7000  15.2400  15.2400  409.4480    ! Fuel tube
BOX  4  -7.3406  7.6200  14.7320  14.4526  0.3886  398.5260    ! Boral plus cover sheet - Top (+Y)
BOX  5  7.6200  7.1120  14.7320  14.4526  0.3886  398.5260  ZROT 90  ! Boral plus cover sheet - Right (+X)
BOX  6  -7.6200  -7.6200  0.0000  15.6286  15.6286  453.6440    ! Complete tube with poison
BOX  7  -7.9375  -7.9375  0.0000  15.9461  15.9461  453.6440    ! Disk Opening
ZONES
/Fuel Assembly/  P4  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Boral plus Cover/  P7  +4
/Boral plus Cover/  P6  +5
/Fuel Tube+Poison/  H5  +6  -3  -2  -4  -5
/Disk Opening/  H5  +7  -6
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  Q4_2B
PART  11
BOX  1  -7.4981  -6.3144  0.0000  13.8125  13.8125  447.1873    ! Fuel assembly
BOX  2  -7.4981  -7.4981  0.0000  14.9962  14.9962  453.6440    ! Space inside tube from can lid to bottom
BOX  3  -7.6200  -7.6200  12.7000  15.2400  15.2400  409.4480    ! Fuel tube
BOX  4  -7.1120  7.6200  14.7320  14.4526  0.3886  398.5260    ! Boral plus cover sheet - Top (+Y)
BOX  5  7.6200  7.1120  14.7320  14.4526  0.3886  398.5260  ZROT 90  ! Boral plus cover sheet - Right (+X)
BOX  6  -7.6200  -7.6200  0.0000  15.6286  15.6286  453.6440    ! Complete tube with poison
BOX  7  -7.6200  -7.9375  0.0000  15.9461  15.9461  453.6440    ! Disk Opening
ZONES
/Fuel Assembly/  P4  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Boral plus Cover/  P6  +4
/Boral plus Cover/  P6  +5
/Fuel Tube+Poison/  H5  +6  -3  -2  -4  -5
/Disk Opening/  H5  +7  -6
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  CT_2B
PART  12
BOX  1  -6.9063  -7.4981  0.0000  13.8125  13.8125  447.1873    ! Fuel assembly
BOX  2  -7.4981  -7.4981  0.0000  14.9962  14.9962  453.6440    ! Space inside tube from can lid to bottom
BOX  3  -7.6200  -7.6200  12.7000  15.2400  15.2400  409.4480    ! Fuel tube
BOX  4  -7.2263  7.6200  14.7320  14.4526  0.3886  398.5260    ! Boral plus cover sheet - Top (+Y)
BOX  5  7.6200  7.3406  14.7320  14.4526  0.3886  398.5260  ZROT 90  ! Boral plus cover sheet - Right (+X)
BOX  6  -7.6200  -7.6200  0.0000  15.6286  15.6286  453.6440    ! Complete tube with poison
BOX  7  -7.7788  -7.6200  0.0000  15.9461  15.9461  453.6440    ! Disk Opening
ZONES
/Fuel Assembly/  P4  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Boral plus Cover/  P5  +4
/Boral plus Cover/  P7  +5
/Fuel Tube+Poison/  H5  +6  -3  -2  -4  -5
/Disk Opening/  H5  +7  -6
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  CB_2B
PART  13
BOX  1  -6.9063  -6.3144  0.0000  13.8125  13.8125  447.1873    ! Fuel assembly
BOX  2  -7.4981  -7.4981  0.0000  14.9962  14.9962  453.6440    ! Space inside tube from can lid to bottom
BOX  3  -7.6200  -7.6200  12.7000  15.2400  15.2400  409.4480    ! Fuel tube
BOX  4  -7.2263  7.6200  14.7320  14.4526  0.3886  398.5260    ! Boral plus cover sheet - Top (+Y)
BOX  5  7.6200  7.1120  14.7320  14.4526  0.3886  398.5260  ZROT 90  ! Boral plus cover sheet - Right (+X)
BOX  6  -7.6200  -7.6200  0.0000  15.6286  15.6286  453.6440    ! Complete tube with poison
BOX  7  -7.7788  -7.9375  0.0000  15.9461  15.9461  453.6440    ! Disk Opening
ZONES
/Fuel Assembly/  P4  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Boral plus Cover/  P5  +4
/Boral plus Cover/  P6  +5
/Fuel Tube+Poison/  H5  +6  -3  -2  -4  -5
/Disk Opening/  H5  +7  -6
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  Q1_RB
PART  14
BOX  1  -7.4981  -7.4981  0.0000  13.8125  13.8125  447.1873    ! Fuel assembly
BOX  2  -7.4981  -7.4981  0.0000  14.9962  14.9962  453.6440    ! Space inside tube from can lid to bottom
BOX  3  -7.6200  -7.6200  12.7000  15.2400  15.2400  409.4480    ! Fuel tube
BOX  4  7.6200  7.3406  14.7320  14.4526  0.3886  398.5260  ZROT 90  ! Boral plus cover sheet - Right (+X)
BOX  5  -7.6200  -7.6200  0.0000  15.6286  15.2400  453.6440    ! Complete tube with poison
BOX  6  -7.6200  -7.6200  0.0000  15.9461  15.9461  453.6440    ! Disk Opening
ZONES
/Fuel Assembly/  P4  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Boral plus Cover/  P7  +4
/Fuel Tube+Poison/  H5  +5  -3  -2    -4
/Disk Opening/  H5  +6  -5
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  Q2_RB
PART  15
BOX  1  -6.3144  -7.4981  0.0000  13.8125  13.8125  447.1873    ! Fuel assembly
BOX  2  -7.4981  -7.4981  0.0000  14.9962  14.9962  453.6440    ! Space inside tube from can lid to bottom
BOX  3  -7.6200  -7.6200  12.7000  15.2400  15.2400  409.4480    ! Fuel tube
BOX  4  7.6200  7.3406  14.7320  14.4526  0.3886  398.5260  ZROT 90  ! Boral plus cover sheet - Right (+X)
BOX  5  -7.6200  -7.6200  0.0000  15.6286  15.2400  453.6440    ! Complete tube with poison
BOX  6  -7.9375  -7.6200  0.0000  15.9461  15.9461  453.6440    ! Disk Opening
ZONES
/Fuel Assembly/  P4  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
```

Figure 6.9-10 (continued)

```
/Boral plus Cover/  P7  +4
/Fuel Tube+Poison/  H5  +5  -3  -2    -4
/Disk Opening/  H5  +6  -5
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  CT_RB
PART  16
BOX  1  -6.9063  -7.4981  0.0000  13.8125  13.8125  447.1873    ! Fuel assembly
BOX  2  -7.4981  -7.4981  0.0000  14.9962  14.9962  453.6440    ! Space inside tube from can lid to bottom
BOX  3  -7.6200  -7.6200  12.7000  15.2400  15.2400  409.4480    ! Fuel tube
BOX  4  7.6200  7.3406  14.7320  14.4526  0.3886  398.5260  ZROT 90  ! Boral plus cover sheet - Right (+X)
BOX  5  -7.6200  -7.6200  0.0000  15.6286  15.2400  453.6440    ! Complete tube with poison
BOX  6  -7.7788  -7.6200  0.0000  15.9461  15.9461  453.6440    ! Disk Opening
ZONES
/Fuel Assembly/  P4  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Boral plus Cover/  P7  +4
/Fuel Tube+Poison/  H5  +5  -3  -2    -4
/Disk Opening/  H5  +6  -5
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  Q1_TB
PART  17
BOX  1  -7.4981  -7.4981  0.0000  13.8125  13.8125  447.1873    ! Fuel assembly
BOX  2  -7.4981  -7.4981  0.0000  14.9962  14.9962  453.6440    ! Space inside tube from can lid to bottom
BOX  3  -7.6200  -7.6200  12.7000  15.2400  15.2400  409.4480    ! Fuel tube
BOX  4  -7.1120  7.6200  14.7320  14.4526  0.3886  398.5260    ! Boral plus cover sheet - Top (+Y)
BOX  5  -7.6200  -7.6200  0.0000  15.2400  15.6286  453.6440    ! Complete tube with poison
BOX  6  -7.6200  -7.6200  0.0000  15.9461  15.9461  453.6440    ! Disk Opening
ZONES
/Fuel Assembly/  P4  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Boral plus Cover/  P6  +4
/Fuel Tube+Poison/  H5  +5  -3  -2  -4
/Disk Opening/  H5  +6  -5
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  Q4_TB
PART  18
BOX  1  -7.4981  -6.3144  0.0000  13.8125  13.8125  447.1873    ! Fuel assembly
BOX  2  -7.4981  -7.4981  0.0000  14.9962  14.9962  453.6440    ! Space inside tube from can lid to bottom
BOX  3  -7.6200  -7.6200  12.7000  15.2400  15.2400  409.4480    ! Fuel tube
BOX  4  -7.1120  7.6200  14.7320  14.4526  0.3886  398.5260    ! Boral plus cover sheet - Top (+Y)
BOX  5  -7.6200  -7.6200  0.0000  15.2400  15.6286  453.6440    ! Complete tube with poison
BOX  6  -7.6200  -7.9375  0.0000  15.9461  15.9461  453.6440    ! Disk Opening
ZONES
/Fuel Assembly/  P4  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Boral plus Cover/  P6  +4
/Fuel Tube+Poison/  H5  +5  -3  -2  -4
/Disk Opening/  H5  +6  -5
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  Q1_NB
PART  19
BOX  1  -7.4981  -7.4981  0.0000  13.8125  13.8125  447.1873    ! Fuel assembly
BOX  2  -7.4981  -7.4981  0.0000  14.9962  14.9962  453.6440    ! Space inside tube from can lid to bottom
BOX  3  -7.6200  -7.6200  12.7000  15.2400  15.2400  409.4480    ! Fuel tube
BOX  4  -7.6200  -7.6200  0.0000  15.2400  15.2400  453.6440    ! Complete tube with poison
BOX  5  -7.6200  -7.6200  0.0000  15.9461  15.9461  453.6440    ! Disk Opening
ZONES
/Fuel Assembly/  P4  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Fuel Tube+Poison/  H5  +4  -3  -2
/Disk Opening/  H5  +5  -4
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  Q1O_NB
PART  20
BOX  1  -7.6759  -7.6759  0.0000  13.8125  13.8125  447.1873    ! Fuel assembly
BOX  2  -7.6759  -7.6759  0.0000  15.3518  15.3518  453.6440    ! Space inside tube from can lid to bottom
BOX  3  -7.7978  -7.7978  12.7000  15.5956  15.5956  409.4480    ! Fuel tube
BOX  4  -7.7978  -7.7978  0.0000  15.5956  15.5956  453.6440    ! Complete tube with poison
BOX  5  -7.7978  -7.7978  0.0000  16.3271  16.3271  453.6440    ! Disk Opening
ZONES
/Fuel Assembly/  P4  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Fuel Tube+Poison/  H5  +4  -3  -2
/Disk Opening/  H5  +5  -4
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  Q2O_RB
PART  21
BOX  1  -6.1366  -7.6759  0.0000  13.8125  13.8125  447.1873    ! Fuel assembly
BOX  2  -7.6759  -7.6759  0.0000  15.3518  15.3518  453.6440    ! Space inside tube from can lid to bottom
BOX  3  -7.7978  -7.7978  12.7000  15.5956  15.5956  409.4480    ! Fuel tube
BOX  4  7.7978  7.5184  14.7320  14.4526  0.3886  398.5260  ZROT 90  ! Boral plus cover sheet - Right (+X)
BOX  5  -7.7978  -7.7978  0.0000  15.9842  15.5956  453.6440    ! Complete tube with poison
BOX  6  -8.1407  -7.7978  0.0000  16.3271  16.3271  453.6440    ! Disk Opening
ZONES
/Fuel Assembly/  P4  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Boral plus Cover/  P7  +4
/Fuel Tube+Poison/  H5  +5  -3  -2    -4
/Disk Opening/  H5  +6  -5
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  Q3O_2B
PART  22
BOX  1  -6.1366  -6.1366  0.0000  13.8125  13.8125  447.1873    ! Fuel assembly
```

Figure 6.9-10 (continued)

```
BOX  2  -7.6759  -7.6759  0.0000  15.3518  15.3518  453.6440    ! Space inside tube from can lid to bottom
BOX  3  -7.7978  -7.7978  12.7000  15.5956  15.5956  409.4480    ! Fuel tube
BOX  4  -7.5184  7.7978  14.7320  14.4526  0.3886  398.5260    ! Boral plus cover sheet - Top (+Y)
BOX  5  7.7978  6.9342  14.7320  14.4526  0.3886  398.5260  ZROT 90  ! Boral plus cover sheet - Right (+X)
BOX  6  -7.7978  -7.7978  0.0000  15.9842  15.9842  453.6440    ! Complete tube with poison
BOX  7  -8.1407  -8.1407  0.0000  16.3271  16.3271  453.6440    ! Disk Opening
ZONES
/Fuel Assembly/  P4  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Boral plus Cover/  P7  +4
/Boral plus Cover/  P6  +5
/Fuel Tube+Poison/  H5  +6  -3  -2  -4  -5
/Disk Opening/  H5  +7  -6
VOLUMES UNITY
* Fuel Assembly in Tube v2.0          Configuration  Q4O_TB
PART  23
BOX  1  -7.6759  -6.1366  0.0000  13.8125  13.8125  447.1873    ! Fuel assembly
BOX  2  -7.6759  -7.6759  0.0000  15.3518  15.3518  453.6440    ! Space inside tube from can lid to bottom
BOX  3  -7.7978  -7.7978  12.7000  15.5956  15.5956  409.4480    ! Fuel tube
BOX  4  -6.9342  7.7978  14.7320  14.4526  0.3886  398.5260    ! Boral plus cover sheet - Top (+Y)
BOX  5  -7.7978  -7.7978  0.0000  15.5956  15.9842  453.6440    ! Complete tube with poison
BOX  6  -7.7978  -8.1407  0.0000  16.3271  16.3271  453.6440    ! Disk Opening
ZONES
/Fuel Assembly/  P4  +1
/Space in Tube/  H5  +2  -1
/Fuel Tube/  M7  +3  -2
/Boral plus Cover/  P6  +4
/Fuel Tube+Poison/  H5  +5  -3  -2  -4
/Disk Opening/  H5  +6  -5
VOLUMES UNITY
* BWR Canister Cavity - Basket Radius v2.0
PART  24
BOX  1  -78.3615  -16.7716  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 1
BOX  2  -78.3615  0.8255  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 2
BOX  3  -60.9549  -52.1564  0.0000  16.3271  16.3271  453.6440  ! Basket Opening 3 - Oversize
BOX  4  -60.7644  -34.3687  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 4
BOX  5  -60.7644  -16.7716  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 5
BOX  6  -60.7644  0.8255  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 6
BOX  7  -60.7644  18.4226  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 7
BOX  8  -60.9549  35.8292  0.0000  16.3271  16.3271  453.6440  ! Basket Opening 8 - Oversize
BOX  9  -43.1673  -69.5630  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 9
BOX  10  -43.1673  -51.9659  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 10
BOX  11  -43.1673  -34.3687  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 11
BOX  12  -43.1673  -16.7716  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 12
BOX  13  -43.1673  0.8255  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 13
BOX  14  -43.1673  18.4226  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 14
BOX  15  -43.1673  36.0197  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 15
BOX  16  -43.1673  53.6169  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 16
BOX  17  -25.5702  -69.5630  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 17
BOX  18  -25.5702  -51.9659  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 18
BOX  19  -25.5702  -34.3687  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 19
BOX  20  -25.5702  -16.7716  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 20
BOX  21  -25.5702  0.8255  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 21
BOX  22  -25.5702  18.4226  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 22
BOX  23  -25.5702  36.0197  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 23
BOX  24  -25.5702  53.6169  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 24
BOX  25  -7.9731  -69.5630  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 25
BOX  26  -7.9731  -51.9659  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 26
BOX  27  -7.9731  -34.3687  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 27
BOX  28  -7.9731  -16.7716  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 28
BOX  29  -7.9731  0.8255  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 29
BOX  30  -7.9731  18.4226  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 30
BOX  31  -7.9731  36.0197  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 31
BOX  32  -7.9731  53.6169  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 32
BOX  33  9.6241  -69.5630  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 33
BOX  34  9.6241  -51.9659  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 34
BOX  35  9.6241  -34.3687  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 35
BOX  36  9.6241  -16.7716  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 36
BOX  37  9.6241  0.8255  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 37
BOX  38  9.6241  18.4226  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 38
BOX  39  9.6241  36.0197  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 39
BOX  40  9.6241  53.6169  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 40
BOX  41  27.2212  -69.5630  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 41
BOX  42  27.2212  -51.9659  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 42
BOX  43  27.2212  -34.3687  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 43
BOX  44  27.2212  -16.7716  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 44
BOX  45  27.2212  0.8255  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 45
BOX  46  27.2212  18.4226  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 46
BOX  47  27.2212  36.0197  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 47
BOX  48  27.2212  53.6169  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 48
BOX  49  44.6278  -52.1564  0.0000  16.3271  16.3271  453.6440  ! Basket Opening 49 - Oversize
BOX  50  44.8183  -34.3687  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 50
BOX  51  44.8183  -16.7716  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 51
BOX  52  44.8183  0.8255  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 52
BOX  53  44.8183  18.4226  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 53
BOX  54  44.6278  35.8292  0.0000  16.3271  16.3271  453.6440  ! Basket Opening 54 - Oversize
BOX  55  62.4154  -16.7716  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 55
BOX  56  62.4154  0.8255  0.0000  15.9461  15.9461  453.6440  ! Basket Opening 56
CONTAINER
ZROD  57  0.0000  0.0000  0.0000  82.8675  453.6440    ! Basket stack to cavity height
ZONES
/Opening1/  P10  +1
/Opening2/  P15  +2
/Opening3/  P22  +3           ! Oversized opening
/Opening4/  P10  +4
/Opening5/  P10  +5
/Opening6/  P9  +6
/Opening7/  P9  +7
```

Figure 6.9-10 (continued)

```
/Opening8/  P21  +8            ! Oversized opening
/Opening9/  P10  +9
/Opening10/  P10  +10
/Opening11/  P10  +11
/Opening12/  P10  +12
/Opening13/  P9  +13
/Opening14/  P9  +14
/Opening15/  P9  +15
/Opening16/  P15  +16
/Opening17/  P10  +17
/Opening18/  P10  +18
/Opening19/  P10  +19
/Opening20/  P10  +20
/Opening21/  P9  +21
/Opening22/  P9  +22
/Opening23/  P9  +23
/Opening24/  P15  +24
/Opening25/  P13  +25
/Opening26/  P13  +26
/Opening27/  P13  +27
/Opening28/  P13  +28
/Opening29/  P12  +29
/Opening30/  P12  +30
/Opening31/  P12  +31
/Opening32/  P16  +32
/Opening33/  P11  +33
/Opening34/  P11  +34
/Opening35/  P11  +35
/Opening36/  P11  +36
/Opening37/  P8  +37
/Opening38/  P8  +38
/Opening39/  P8  +39
/Opening40/  P14  +40
/Opening41/  P18  +41
/Opening42/  P11  +42
/Opening43/  P11  +43
/Opening44/  P11  +44
/Opening45/  P8  +45
/Opening46/  P8  +46
/Opening47/  P8  +47
/Opening48/  P19  +48
/Opening49/  P23  +49            ! Oversized opening
/Opening50/  P18  +50
/Opening51/  P11  +51
/Opening52/  P8  +52
/Opening53/  P17  +53
/Opening54/  P20  +54            ! Oversized opening
/Opening55/  P18  +55
/Opening56/  P19  +56
/Basket/  H1  +57  -1  -2  -3  -4  -5
    -6  -7  -8  -9  -10  -11
    -12  -13  -14  -15  -16  -17
    -18  -19  -20  -21  -22  -23
    -24  -25  -26  -27  -28  -29
    -30  -31  -32  -33  -34  -35
    -36  -37  -38  -39  -40  -41
    -42  -43  -44  -45  -46  -47
    -48  -49  -50  -51  -52  -53
    -54  -55  -56

VOLUMES  UNITY
* Basket in Canister Cavity v2.0
PART  25  NEST
ZROD  P24  0.0000  0.0000  0.0000  82.8675  453.6440    ! Basket inserted - Includes gap to lid
ZROD  H5  0.0000  0.0000  0.0000  83.5787  453.6440    ! Inserts flood matl to canister shell
* Canister - Structural Lid - No Weld Shield v2.0
PART  26
ZROD  1  0.0000  0.0000  0.0000  83.5787  453.6440    ! Canister cavity contents
ZROD  2  0.0000  0.0000  -4.4450  85.1662  4.4450    ! Canister Bottom Plate
ZROD  3  0.0000  0.0000  453.6440  83.5787  17.7800    ! Shield Lid
ZROD  4  0.0000  0.0000  471.4240  83.5787  7.6200    ! Structural Lid
ZROD  5  0.0000  0.0000  0.0000  83.5787  479.0440    ! Canister Shell Inner
ZROD  6  0.0000  0.0000  0.0000  85.1662  479.0440    ! Canister Shell Outer
ZROD  7  0.0000  0.0000  -4.4450  85.1662  483.4890    ! Inner Detector Surface
ZONES
/Cavity/  P25  +1
/BottomPlate/  M13  +2
/ShieldLid/  P27  +3
/StructLid/  M13  +4
/Shell/  M13  +6  -5
/Canister/  M0  +7  -6  -4  -2
VOLUMES  UNITY
* Shield Lid - With Ports v2.0
PART  27  CLUSTER
ZROD  P28  -46.8743  55.8626  0.0000  7.6200  17.7800    ! Vent port
ZROD  P28  46.8743  -55.8626  0.0000  7.6200  17.7800    ! Drain port
ZROD  M13  0.0000  0.0000  0.0000  83.5787  17.7800    ! Shield Lid
* Vent Port Model - No Port v2.0
PART  28  CLUSTER
ZROD  M13  0.0000  0.0000  0.0000  1.3843  8.4328    ! Bottom Cylinder
ZROD  M13  0.0000  0.0000  8.4328  5.0800  7.9248    ! Middle Cyclinder
ZROD  M13  0.0000  0.0000  16.3576  7.6200  1.4224    ! Top Cylinder
ZROD  M13  0.0000  0.0000  0.0000  7.6200  17.7800    ! Shield lid material
* Transfer Cask Geometry - No Weld Shield - v2.0
PART  29
ZROD  1  0.0000  0.0000  0.0000  85.1662  483.4890    ! TSC
ZROD  2  0.0000  0.0000  0.0000  86.0425  489.2040    ! Cask cavity
ZROD  3  0.0000  0.0000  0.0000  108.2675  2.5400    ! Bottom plate
ZROD  4  0.0000  0.0000  2.5400  87.9475  481.5840    ! Inner shell
```

Figure 6.9-10 (continued)

```
ZROD  5  0.0000  0.0000  2.5400  97.8535  475.4880    ! Lead shell
ZROD  6  0.0000  0.0000  2.5400  105.0925  481.5840    ! NS-4-FR shell
ZROD  7  0.0000  0.0000  2.5400  108.2675  481.5840    ! Outer shell
ZROD  8  0.0000  0.0000  484.1240  108.2675  5.0800    ! Top plate
ZROD  9  0.0000  0.0000  489.2040  82.2325  1.9050    ! Area inside retaining ring
ZROD  10  0.0000  0.0000  489.2040  97.8535  1.9050    ! Retaining ring
ZROD  11  0.0000  0.0000  -22.8600  108.2675  22.8600    ! Shield doors and rails
YP  12  102.5525            ! Y plane for shield door rail cutoff
YP  13  -102.5525            ! Y plane for shield door rail cutoff
XROD  14  -118.2675  0.0000  451.1040  12.7000  236.5350    ! Trunions (extended in x)
YROD  15  0.0000  -118.2675  451.1040  12.7000  236.5350    ! Trunions (extended in y)
ZROD  16  0.0000  0.0000  478.0280  97.8535  6.0960    ! Shielding ring
BOX  17  -2.5400  -86.8045  -5.0800  64.9732  173.6090  3.8100  ! Shield door B NS box
YXPRISM  18  62.4332  -86.8045  -5.0800        ! Shield door B NS trapezoid
    173.6090  39.4984  3.8100  36.9157  36.9157
BOX  19  -62.4332  -86.8045  -5.0800  54.8132  173.6090  3.8100  ! Shield door A NS box
YXPRISM  20  -101.9316  -34.2265  -5.0800        ! Shield door A NS trapezoid
    68.4530  39.4984  3.8100  143.0843  143.0843
YXPRISM  21  64.2620  -90.6780  -22.8600        ! Shield door B cut prism
    181.3560  41.4020  22.8600  36.9157  36.9157
XP  22  64.2620            ! Cut plane for NS boundary B
YXPRISM  23  -105.6640  -35.5600  -22.8600        ! Shield door A cut prism
    71.1200  41.4020  22.8600  143.0843  143.0843
XP  24  -64.2620            ! Cut plane for NS boundary A
ZROD  25  0.0000  0.0000  -22.8600  108.2675  513.9690    ! Container
ZONES
/TSC/  P26  +1            ! TSC
/CaskCavity/  M0  +2  -1          ! Cask cavity
/BottomPlate/  M14  +3  -2          ! Bottom plate
/InnerShell/  M14  +4  -2  -14  -15      ! Inner shell
/LeadShell/  M15  +5  -4  -14  -15      ! Lead shell
/NS-4-FRShell/  M16  +6  -5  -14  -15  -16    ! NS-4-FR shell
/ShieldRing/  M14  +16  -4  -14  -15      ! Shielding ring
/OuterShell/  M14  +7  -6  -14  -15      ! Outer shell
/TopPlate/  M14  +8  -2          ! Top plate
/RetRingInner/  M0  +9            ! Area inside retaining ring (null)
/RetRing/  M0  +10  -9          ! Retaining ring
/ShieldDoor1/  M14  +11  +13  -12  -17  -19    ! Shield doors and rails
    -18  -20  -22  +24
/ShieldDoor2/  M14  +11  +13  -12  -17  -19    ! Shield doors and rails
    -18  -20  +22  +21
/ShieldDoor3/  M14  +11  +13  -12  -17  -19    ! Shield doors and rails
    -18  -20  -24  +23
/ShieldDoorOuter1/  M0  +11  +12          ! Space outside of shield door
/ShieldDoorOuter2/  M0  +11  -13          ! Space outside of shield door
/ShieldDoorOuter3/  M0  +11  +22  -21        ! Space outside of shield door B
/ShieldDoorOuter4/  M0  +11  -24  -23        ! Space outside of shield door A
/XTrunions/  M14  +14  +7  -2        ! X Trunions
/YTrunions/  M14  +15  +7  -2        ! Y Trunions
/ShldDrBNSBox/  M16  +17            ! Shield door B NS box
/ShldDrANSBox/  M16  +19            ! Shield door A NS box
/ShldDrBNSTrap/  M16  +18            ! Shield door B NS trapezoid
/ShldDrANSTrap/  M16  +20            ! Shield door A NS trapezoid
/Container/  M0  +25  -11  -3  -7  -8  -10  ! Container
VOLUMES UNITY
end

*
* Unit 5 - Source Geometry for
*
begin source geometry
ZONEMAT
ALL / MATERIAL    1
end

*
* Unit 3 Hole Data
*
begin hole data
* BWR Canister Hole Description v2.0
* Hole  1  General Basket Structure
PLATE
0  0  1
7
451.8660  0      ! Top of Basket
413.1056  -2      ! Top of Highest Support Disk
275.3233  -7      ! Resume support disk only
110.1598  -4      ! Start of support+heat disk region
22.6060  -6      ! Bottom of Lowest Support Disk
0.0000  -3      ! Bottom of Basket
0.0000  3      ! Basket Offset
3

* Hole  2  Top Weldment Disk - no structure above the weldment disk
RZMESH
2        ! number of radial points
82.2198
83.1850
5        ! number of axial intervals
413.1056        ! Top of diskstack
423.1640        ! Bottom of weldment
425.7040        ! Top of weldment plate
444.9861        ! Ullage
450.4690        ! Flange
451.8660        ! Void to top of basket
3  3      ! Material below weldment
11  11      ! Plate Material
3  11      ! Ullage
3  11      ! Flange
```

Figure 6.9-10 (continued)

```
3  3      ! Void to top of basket
3        ! Outside material

* Hole  3  Bottom Weldment Disk - no structure in the weldment disk support
RZMESH
1        ! number of radial points
83.1850
1        ! number of axial intervals
10.1600
12.7000        ! Coordinates inherited from PLATE Hole
11        ! Plate Material
3        ! Outside material

* Hole  4  Support disk and heat transfer disk stack
PLATE
origin  0  0  110.1598  ! Origin
0  0  1
4
cell  9.7155      ! Sets up a repeating lattice of cells
9.7155  3      ! flood matl
6.2865  3      ! water gap
5.0165  12      ! aluminium disk
1.5875  3      ! water gap
10        ! steel disk

* Hole  5  Flood material model
PLATE
0  0  1
1
444.9861  3      ! Above flooded region
3        ! Flooded region

* Hole  6  Support disk stack lower
PLATE
origin  0  0  22.6060  ! Origin
0  0  1
2
cell  9.7282      ! Sets up a repeating lattice of cells
9.7282  3      ! flood matl
1.5875  3      ! water gap
10        ! steel disk

* Hole  7  Support disk stack upper
PLATE
origin  0  0  275.3233  ! Origin
0  0  1
2
cell  9.7282      ! Sets up a repeating lattice of cells
9.7282  3      ! flood matl
1.5875  3      ! water gap
10        ! steel disk

end
```

Table of Contents

List of Tables

(helium) of ANSI N14.5[9] is applied. The leak test is performed at a sensitivity of 1.0×10^{-7} cm^3/sec (helium). Any indication of a leak of 2.0×10^{-7} cm^3/sec (helium) or greater is unacceptable and repair is required as appropriate.

9.1.4 Component Tests

The components of the Universal Storage System do not require any special tests in addition to the material receipt, dimensional, and form and fit tests described in this chapter.

9.1.4.1 Valves, Rupture Disks and Fluid Transport Devices

The transportable storage canister and the vertical concrete cask do not contain rupture disks or fluid transport devices. There are no valves that are part of the confinement boundary for transport or storage. Quick-disconnect valves are installed in the vent and drain ports of the shield lid. These valves are convenience items for the operator, as they provide a means of quickly connecting ancillary drain and vent lines to the canister. During storage and transport, these fittings are not accessible, as they are covered by port covers that are welded in place when the canister is closed. As presented for storage and transport, the canister has no accessible valves or fittings.

9.1.4.2 Gaskets

The transportable storage canister and the vertical concrete cask have no mechanical seals or gaskets that form an integral part of the system, and there are no mechanical seals or gaskets in the confinement boundary.

9.1.5 Shielding Tests

Based on the conservative design of the Universal Storage System for shielding criteria and the detailed construction requirements, no shielding tests of the vertical concrete cask are required.

9.1.6 Neutron Absorber Tests

A neutron absorbing material is used for criticality control in the PWR, BWR and oversize BWR fuel tubes. The placement and dimensions of the neutron absorber are as shown on the License Drawings for these components. The neutron absorbing material is an aluminum matrix material formed from aluminum and boron-carbide. The mixing of the aluminum and boron-carbide powder forming the neutron absorber material is controlled to assure the required ^{10}B areal density, as specified on the component License Drawings. The constituents of the neutron absorber material shall be verified by chemical testing and/or spectroscopy and by physical

property measurement to ensure the quality of the finished plate or sheet. The results of all neutron absorber material tests and inspections, including the results of wet chemistry coupon testing, are documented and become part of the quality records documentation package for the fuel tube and basket assembly.

Aluminum/boron carbide neutron absorbing material is available under the trade name BORAL®. BORAL is procured and qualified under a Quality Assurance/Quality Control program in conformance with the requirements of 10 CFR 72, Subpart G.

The manufacturing process of BORAL consists of several steps. The initial step is the mixing of the aluminum and boron carbide powders that form the core of the finished material. The amount of each powder is a function of the desired 10B areal density. The methods used to control the weight and blend the powders are patented and proprietary processes of the manufacturer.

After manufacturing, test samples from each batch of neutron absorber sheets shall be tested using wet chemistry techniques to verify the presence and minimum weight percent of 10B. The tests shall be performed in accordance with approved written procedures.

9.1.6.1 Neutron Absorber Material Sampling Plan

The neutron absorber sampling plan is selected to demonstrate a 95/95 statistical confidence level in the neutron absorber sheet material in compliance with the specification. In addition to the specified sampling plan, each sheet of material is visually and dimensionally inspected using at least 6 measurements on each sheet. No rejected neutron absorber sheet is used. The sampling plan is supported by written and approved procedures.

The sampling plan requires that a coupon sample be taken from each of the first 100 sheets of absorber material. Thereafter, coupon samples are taken from 20 randomly selected sheets from each set of 100 sheets. This 1 in 5 sampling plan continues until there is a change in lot or batch of constituent materials of the sheet (i.e., boron carbide powder, aluminum powder, or aluminum extrusion) or a process change. The sheet samples are indelibly marked and recorded for identification. This identification is used to document neutron absorber test results, which become part of the quality record documentation package.

9.1.6.2 Neutron Absorber Wet Chemistry Testing

Wet chemistry testing of the test coupons obtained from the sampling plan is used to verify the ^{10}B content of the neutron absorber material. Wet chemistry testing is applied because it is considered to be the most accurate and practical direct measurement method for determining ^{10}B, boron and B_4C content of metal materials and is considered by the Electric Power Research Institute (EPRI) to be the method of choice for this determination.

An approved facility with chemical analysis capability, which could include the neutron absorber vendor's facility, shall be selected to perform the wet chemistry tests. Personnel performing the testing shall be trained and qualified in the process and in the test procedure.

Wet chemistry testing is performed by dissolving the aluminum in the matrix, including the powder and cladding, in a strong acid, leaving the B_4C material. A comparison of the amount of B_4C material remaining to the amount required to meet the ^{10}B content specification is made using a mass-balance calculation based on sample size.

A statistical conclusion about the neutron absorber sheet from which the sample was taken and that batch of neutron absorber sheets may then be drawn based on the test results and the controlled manufacturing processes.

The adequacy of the wet chemistry method is based on its use to qualify the standards employed in neutron blackness testing. The neutron absorption performance of a test material is validated based on its performance compared to a standard. The material properties of the standard are demonstrated by wet chemistry testing. Consequently, the specified test regimen provides adequate assurance that the neutron absorber sheet thus qualified is acceptable.

9.1.6.3 Acceptance Criteria

The wet chemistry test results shall be considered acceptable if the ^{10}B areal density is determined to be equal to, or greater than, that specified on the fuel tube License Drawings. Failure of any coupon wet chemistry test shall result in 100% sampling, as described in the sampling plan, until compliance with the acceptance criteria is demonstrated.

9.1.6.4 Alternative Neutron Absorber/Poison Tests for BWR Baskets

Neutron absorber materials are included in the design and fabrication of the BWR fuel baskets assemblies to assist in the control of reactivity, as described in Chapter 6. The basket assemblies support the spent fuel contents. Criticality safety is dependent upon the neutron absorber material remaining fixed in position on the fuel tubes and containing the required amount of uniformly distributed boron. A neutron absorber material can be a composite of fine particles in a metal matrix or an alloy of boron compounds with aluminum. Fine particles of boron or boron-carbide that are uniformly distributed are required to obtain the best neutron absorption. Three types of neutron absorber materials are commonly used in spent fuel baskets: BORAL (registered trademark), borated metal matrix composites (MMC), and borated aluminum alloy. The fabrication of the neutron absorber material is controlled to provide a uniform boron carbide distribution and the specified ^{10}B areal density.

BORAL specific test information is included in Sections 9.1.6.1 thru 9.1.6.3.

9.1.6.4.1 Design/Performance Requirements

The BWR fuel basket assemblies utilize sheets of neutron absorber material that are attached to the sides of the spent fuel storage locations in the fuel baskets. The material is called out as a metallic composite (includes borated aluminum alloy, borated MMC, and Boral, which are available under various commercial trade names). Incorporating optional neutron absorber materials in the design provides fabrication flexibility for the use of the most economical and available neutron absorber material that meets the critical characteristics necessary to assure criticality safety. The critical design characteristics of the neutron absorber material are:

- A baseline, 100% credit, areal density of 0.011, g/cm^2 ^{10}B
- A uniform distribution of boron carbide

The required minimum actual ^{10}B loading in a neutron absorber sheet is determined based on the effectiveness of the material, i.e., 90% for borated aluminum alloys and for borated metal matrix composites. Testing will be used to verify the areal density and the uniform distribution of ^{10}B in the neutron absorber materials. Table 9.1.6.4-1 presents a tabulation of the alternative types of neutron absorber materials, the required minimum effective areal density of ^{10}B, and the required minimum as-fabricated areal density of ^{10}B.

Stainless Steel cover sheets welded over each neutron absorber ensure that the neutron absorber remains in place for all loading conditions for the lifetime of the system.

9.1.6.4.2 Terminology

Applicable terminology definitions for the neutron absorber materials:

acceptance –	tests conducted to determine whether a specific production lot meets selected material properties and characteristics, or both, so that the lot can be accepted for commercial use.
areal density –	for sheets with flat parallel surfaces, the density of the neutron absorber times the thickness of the material.
designer –	the organization responsible for the design or the license holder for the dry cask storage system or transport packaging. The designer is usually the purchaser of the neutron absorber material, either directly or indirectly (through a fabrication subcontractor).
lot –	a quantity of a product or material accumulated under conditions that are considered uniform for sampling purposes.
neutron absorber –	a nuclide that has a large thermal or epithermal neutron absorption cross-section, or both.
neutron absorber material –	a compound, alloy, composite or other material that contains a neutron absorber.
neutron attenuation test –	a process in which a material is placed in a thermal neutron beam, and the number of neutrons transmitted through the material in a specified period of time is counted. The observed neutron counting rate may be converted to areal density by performing the same test on a series of calibration standards.
neutron cross-section –	a measure of the probability that a neutron will interact with a nucleus; a function of the neutron energy and the structure of the interacting nucleus.

packaging –	in transport of radioactive material, the assembly of components necessary to enclose the radioactive contents completely.
qualification –	the process of evaluating and testing, or both, a material produced by a specific manufacturing process to demonstrate uniformity and durability for a specific application.

9.1.6.4.3 Inspections

After manufacturing, each sheet of neutron absorber material will be visually and dimensionally inspected for damage, embedded foreign material, and dimensional compliance. The neutron absorber sheets are intended to be defect/damage free, but limited defects/damages are acceptable. Allowed defects are discussed in each material specification section that follows. Standard industrial inspections will be performed on the neutron absorber sheets to verify the acceptability of physical characteristics such as dimensions, flatness, straightness, tensile properties (if structural considerations are applicable) or other mechanical properties as appropriate, surface quality and finish. Inspection and testing of the neutron absorber materials will be performed in accordance with written procedures, by appropriately certified personnel, and the inspection and test results will be documented.

9.1.6.4.4 Specification

Three types of neutron absorber materials are permitted to augment criticality control in the NAC-BWR fuel baskets – (1) Boral, a clad composite of aluminum and boron carbide, as specified in in previous section; (2) borated metal matrix composites (MMC) and (3) borated aluminum alloy, as specified in this section. Environmental conditions encountered by the neutron absorber material may include:

- Immersion in water with the associated chemical, temperature and pressure concerns
- Dissimilar materials
- Gamma and neutron radiation fluence
- Dry heat-up rates
- Maximum temperatures

Except for materials for which validation has been completed, the durability of the neutron absorber materials is validated to demonstrate the following results:

- Neutron absorber materials will not incur significant damage due to the pressure, temperature, radiation, or corrosion environments that may be present in the loading and transport of spent fuel;
- Aluminum and boron carbide do not react with each other in the range of the maximum temperatures present in the fuel baskets;
- There are no significant changes in mechanical properties of the neutron absorber materials due to the fast neutron fluences experienced in spent fuel storage;
- General corrosion does not have time to affect the integrity of the neutron absorber material due to the very short time of immersion in spent fuel pool water.

Individual material types and process lots are tested to verify the presence, uniform distribution and minimum areal density (effectiveness) of ^{10}B specific to each type of neutron absorber material.

All neutron absorber materials are procured and qualified under a Quality Assurance/Quality Control program in conformance with the requirements of 10 CFR 72, Subpart G.

9.1.6.4.5 Metal Matrix Composites

Borated metal matrix composite (MMC) material can be produced by powder metallurgy, casting or thermal spray methods and consists of fine boron carbide particles in a matrix of aluminum. Borated MMC material is a metallurgically bonded matrix, low porosity product. Borated metal matrix composites rely on a fine (average 10-40 micron) boron carbide particle size to achieve a uniform boron distribution. Specifications on the boron carbide particle size in MMCs are included in Section 9.1.6.4.9. MMCs are credited with an effectiveness up to 90% of ^{10}B based on acceptance and qualification testing of the material as described in Sections 9.1.6.4.7 and 9.1.6.4.8. Visual inspections of the sheets of borated MMC material will be based on Aluminum Association recommendations, as applicable—i.e., blisters and/or widespread rough surface conditions such as die chatter or porosity shall be identified as nonconforming. Nonconforming items are segregated and evaluated within the NAC International Quality Assurance Program, and assigned one of the following dispositions: "Use-As-Is," "Rework/Repair" or "Reject." Only material that is determined to meet all applicable conditions of the license will be accepted. Local or cosmetic conditions such as scratches, nicks, die lines, inclusions, abrasion, isolated pores or discoloration are acceptable based on material neutron attenuation and thermal performance not being impacted by minor fabrication anomalies. Metal matrix composites may be encased by aluminum.

9.1.6.4.6 Borated Aluminum

Borated aluminum material is a direct chill cast metallurgy product with a uniform fine dispersion of discrete boron particles in a matrix of aluminum. Borated aluminum material is a metallurgically bonded matrix, low porosity product. Borated aluminum is credited with an effectiveness up to 90% based on acceptance and qualification testing of the material as described in Section 9.1.6.4.7 and Section 9.1.6.4.8. Visual inspections of the sheets of borated aluminum material will be based on Aluminum Association recommendations, as applicable—i.e., blisters and/or widespread rough surface conditions such as die chatter or porosity shall be identified as nonconforming. Nonconforming items are segregated and evaluated within the NAC International Quality Assurance Program, and assigned one of the following dispositions: "Use-As-Is," "Rework/Repair" or "Reject." Only material that is determined to meet all applicable conditions of the license will be accepted. Local or cosmetic conditions such as scratches, nicks, die lines, inclusions, abrasion, isolated pores or discoloration are acceptable based on material neutron attenuation and thermal performance not being impacted by minor fabrication anomalies.

9.1.6.4.7 Metal Matrix and Borated Aluminum Neutron Absorber Tests

Testing by Neutron Attenuation (90% Credit)

Acceptance testing shall be performed to ensure that neutron absorber material properties for sheets in a given production run are in compliance with the materials requirements and that the process is operating in a satisfactory manner.

Statistical tests will be run to augment findings relating to isotopic content, impurity content or uniformity of the ^{10}B distribution.

- Determination of neutron absorber material acceptance shall be performed by neutron attenuation testing. Neutron attenuation testing of the final product, or the coupons, shall compare the results with those for calibrated standards, which may be composed of homogeneous or heterogeneous materials. The heterogeneous standard will be calibrated to a recognized standard (e.g., homogeneous material such as ZrB_2 plate material or a NIST-produced standard) or by attenuation of a thermal neutron beam correlated to the known cross-section of ^{10}B at the beam energies. These tests shall include a statistical sample of finished product or test coupons taken from each lot of material to verify the presence, uniform distribution and the minimum areal density of ^{10}B.

- The ^{10}B areal density is measured using a collimated thermal neutron beam of up to 2.54 cm in diameter, with a tolerance of 10 percent.
- Based on the required 90% credit a minimum effective areal density of ^{10}B is 0.0099 g/cm^2 (0.011x0.9).
- Test locations/coupons shall be well distributed throughout the lot of material, particularly in the areas most likely to contain variances in thickness, and shall not contain unacceptable defects that could inhibit accurate physical and test measurements.
- The sampling plan shall require that each of the first 50 sheets of neutron absorber material from a lot, or a coupon taken therefrom, be tested. Thereafter, coupons shall be taken from 10 randomly selected sheets from each set of 50 sheets. All coupons (100%) taken shall be tested by neutron attenuation. This 1 in 5 sampling plan shall continue until there is a change in lot or batch of constituent materials of the sheet (i.e., boron carbide powder or aluminum powder) or a process change. A measured value less than the required minimum areal density of ^{10}B during the reduced inspection (neutron attenuation testing) is defined as nonconforming, along with other contiguous sheets, and mandates a return to 100% inspection (neutron attenuation testing) for the next 50 sheets. The coupons are indelibly marked and recorded for identification. This identification will be used to document the neutron absorber material test results, which become part of the quality record documentation package.
- The minimum areal density specified shall be verified for each lot at the 95% probability, 95% confidence level (also expressed as 95/95 level) or better. The following illustrates one acceptable method:
  - The acceptance criterion for individual plates is determined from a statistical analysis of the test results for that lot. The minimum ^{10}B areal densities determined by neutron attenuation are converted to volume density (g/cm^3), i.e., the neutron attenuation measurement divided by the maximum thickness of the coupon. The lower tolerance limit of ^{10}B volume density is then determined - defined as the mean value of ^{10}B volume density for the sample, less K times the standard deviation, where K is the one-sided tolerance limit factor for a normal distribution with 95% probability and 95% confidence.
  - Finally, the minimum specified value of ^{10}B areal density is divided by the lower tolerance limit of ^{10}B volume density to arrive at the minimum plate thickness that provides the specified ^{10}B areal density.
  - Any plate that is thinner than this minimum or the minimum design thickness, whichever is greater, shall be treated as nonconforming, with the following exception. Local depressions are acceptable, as long as they total no more than 0.5% of the area

on any given plate and the thickness at their location is not less than 90% of the minimum design thickness.

- All neutron absorber material acceptance verification will be conducted in accordance with the NAC International Quality Assurance Program. The neutron absorber material supplier shall control manufacturing in accordance with the key process controls via a documented quality assurance system (approved by NAC or NAC's approved fabricator), and the designer shall verify conformance by reviewing the manufacturing records.
- Nonconforming material shall be evaluated within the NAC International Quality Assurance Program and shall be assigned one of the following dispositions: "Use-As-Is," "Rework/Repair" or "Reject." Only material that is determined to meet all applicable conditions of the license will be accepted.

Wet Chemistry Testing (75% Credit)

Wet Chemistry testing and acceptance is described in Section 9.1.6.2 and Section 9.1.6.3

9.1.6.4.8 Qualification Testing of Metal Matrix and Borated Aluminum Neutron Absorber Material

Qualification tests for each neutron absorber material and its set of manufacturing processes shall be performed at least once to demonstrate acceptability and durability based on the critical design characteristics, previously defined in this section.

The licensed service life will include a range of environmental conditions associated with short-term transfer operations, normal transport conditions, as well as accident storage events. Additional qualification testing is not required for a neutron absorber material previously qualified, i.e., reference can be provided to prior testing with the same, or similar, materials for similar design functions and service conditions.

- Qualification testing is required for: (1) neutron absorber material specifications not previously qualified; (2) neutron absorber material specifications previously qualified but manufactured by a new supplier; and (3) neutron absorber material specifications previously qualified, but with changes in key process controls. Key process controls for producing the neutron absorber material used for qualification testing shall be the same as those to be used for commercial production.
- Qualification testing shall demonstrate consistency between lots (2 minimum).
- Environmental conditions qualification will be verified by direct testing or by validation by data on the same, or similar, material, i.e., the neutron absorber material is shown to

not undergo physical changes that would preclude the performance of its design functions. Conditions encountered by the neutron absorber material may include short-term immersion in water, exposure to chemical, temperature, pressure, and gamma and neutron radiation environments. Suppliers' testing will document the durability of neutron absorber materials that may be used in the system by demonstrating that the neutron absorber materials will not incur significant damage due to the pressure, temperature, radiation, or corrosion environments or the short-term water immersion that may occur in the loading and storage of spent fuel.

- The uniformity of the boron carbide distribution in the material shall be verified by neutron attenuation testing of a statistically significant number of measurements of the areal density at locations distributed throughout the test material production run, i.e., at a minimum from the ends and the middle of the run. The sampling plan must be designed to demonstrate 95/95 compliance with the absorber content requirements. Details on acceptable neutron attenuation testing are previously provided in this section for Acceptance Testing. Alternate test methods may be employed provided they are validated (benchmarked) to neutron attenuation tests.
- One standard deviation of the neutron attenuation test sampling results shall be less than 10% of the sample mean. This requirement provides additional assurance that a consistent product is achieved by the manufacturing process.
- A material qualification report verifying that all design requirements are satisfied shall be prepared.
- Key manufacturing process controls in the form of a complete specification for materials and process controls shall be developed for the neutron absorber material by the supplier and approved by NAC to ensure that the product delivered for use is consistent with the qualified material in all respects that are important to the material's design function.
- Major changes in key manufacturing processes for neutron absorber material shall be controlled by mutually agreed-upon process controls established by the certificate holder/purchaser and the neutron absorber supplier. These process controls will ensure that the neutron absorber delivered will always be consistent with the qualification test material in any and all respects that are important to the neutron absorber's safety characteristics. Changes in the agreed-upon process controls may require requalification of those parts of the qualification that could be affected by the process changes. Typical changes covered by the agreed-upon process controls include:
  - Changes that could adversely affect mechanical properties (e.g., change in thermal conductivity, porosity, material strength, change of matrix alloy, boron carbide content, increase in the B_4C content above that used in previously qualified material, etc.);

  - Changes that could affect the uniformity of boron (e.g., change to mixing process for aluminum and boron carbide powders, change in stirring of melt, change in boron precipitate phase, etc.).

- Minor neutron absorber material processing changes, i.e., roller machine hardware or final sheet cutting methods, water jet, shear cut, etc., may be determined to be acceptable on the basis of engineering review without additional qualification testing, if such changes do not adversely affect the particle bonding microstructure, i.e., the durability or the uniformity of the boron carbide particle distribution, which is the neutron absorber effectiveness.
- Nonconforming material shall be evaluated within the NAC International Quality Assurance Program and shall be assigned one of the following dispositions: "Use-As-Is," "Rework/Repair" or "Reject." Only material that is determined to meet all applicable conditions of the license will be accepted.

9.1.6.4.9 Additional Material Specifications

Boron carbide particles for MMCs shall have an average size in the range of 10-40 microns and no more than 10% of the particles shall be over 60 microns. The material shall have negligible interconnected porosity exposed at the surface or edges.

Open porosity for borated aluminum and borated MMC neutron absorber material must be no greater than 0.5% unless qualification tests are performed to ensure that blisters are not produced under submerging and subsequent vacuum drying conditions.

Chemical composition of the boron carbide powder must meet the requirements of Table 1 of ASTM C 750-03, Type 3. Additional chemical requirements, applicable to a particular absorber material, may be placed on the boron carbide powder as a result of the "key manufacturing process controls" invoked by Section 9.1.6.4.8. Additional requirements may include, but are not limited to, upper limits on fluorine and chlorine content.

Table 9.1.6.4-1 Neutron Absorber Material Minimum ^{10}B Loading

Neutron Absorber Type	Required Minimum Effective Areal Density (^{10}B g/cm^2)	% Credit Used in Criticality Analyses	Required Minimum Actual Areal Density (^{10}B g/cm^2)
Borated Aluminum Alloy	0.0099	90	0.011
Borated MMC	0.0099	90	0.011
Borated Aluminum Alloy	0.00825	75	0.011
Borated MMC	0.00825	75	0.011

9.1.7 Thermal Tests

No thermal acceptance testing of the Universal Storage System is required during construction. Thermal performance of the system was confirmed in accordance with the procedure specified in Section 9.2.3 and documented in a report. In addition, initial temperature measurements are taken of the concrete cask(s) placed in service, in accordance with LCO A 3.1.6 to verify the operability of the cask.

9.1.8 Cask Identification

A stainless steel nameplate is permanently attached at eye level on the outer surface of the concrete cask as shown on Drawing No. 790-562.

Drawing No. 790-565 shows the information included on the nameplate.

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10.2 Radiation Protection Design Features

The radiation shielding design description is provided in Section 5.3.1. The design criteria radiation exposure rates are summarized in Table 2-1. The principal radiation protection design features are the shielding necessary to meet the design objectives, the placement of penetrations near the edge of the canister shield lid to reduce operator exposure and handling time, and the use of shaped supplemental shielding for work on and around the shield lid, as necessary. This supplemental shielding reduces operator dose rates during the welding, inspection, draining, drying and backfilling operations that seal the canister. An optional supplemental shielding fixture, shown in Drawing 790-613, may be installed in the air inlets to reduce the radiation dose rate at the base of the vertical concrete cask.

Radiation exposure rates at various work locations are determined for the principal Universal Storage System operational steps using a combination of the SAS4 [3] and SKYSHINE III [4] computer codes or MCNP. The use of SAS4 is described in Section 5.1.2. The SKYSHINE-III code is discussed in Section 10.4. Dose/exposures for loading, maintenance, and public for the additional BWR contents evaluated using MCNP are discussed in Section 10.6. The calculated dose rates decrease with time.

10.2.1 Design Basis for Normal Storage Conditions

The radiation protection design basis for the Universal Storage System vertical concrete cask is derived from 10 CFR 72 and the applicable ALARA guidelines. The design basis surface dose rates, and the calculated surface and 1-foot dose rates are:

Vertical Concrete Cask	Design Basis Surface Dose Rate (mrem/hr)	Surface Dose Rate (mrem/hr)		1-Foot Maximum Dose Rate (mrem/hr)	
		PWR	BWR(3)	PWR	BWR(3)
Side wall	50.0 (avg.)	37.3	22.7	42.3	24.5
Air inlet(1)	100.0(2)	136	129	47.8	44.9
Air outlet	100.0(2)	63	55	15.7	12.8
Top lid	50.0 (avg.)	26.1	19.7	22.6	15.7

(1) Air inlet dose rates are based on the use of the air inlet shields. Design basis source terms require the use of the inlet shields to remain below the technical specification limits outlined in Appendix A.

(2) An air inlet and outlet average dose rate of 100 mrem/hr.

(3) BWR dose rates for additional BWR contents (10x10 Assembly Array, High Burnup Fuel and Damaged Fuel) are shown in Section 5.8.1 through 5.8.2

With the exception of the additional BWR contents the calculated dose rates at these, and at other dose points, are reported in Sections 5.1.3 and 5.4.3. The dose rates presented are for the design basis 40,000 MWd/MTU, 5-year cooled fuel. These dose rates bound those of the higher burnup, but longer cooled, fuel described in Section 2.1.

Activities associated with closing the canister, including welding of the shield and structural lids, draining, drying, backfilling and testing, may employ temporary shielding to minimize personnel dose in the performance of those tasks.

10.2.2 Design Basis for Accident Conditions

Damage to the vertical concrete cask after a design basis accident does not result in a radiation exposure at the controlled area boundary in excess of 5 rem to the whole body or any organ. The high energy missile impact is estimated to reduce the concrete shielding thickness, locally at the point of impact, by approximately 6 inches. Localized cask surface dose rates for the removal of 6 inches of concrete are estimated to be less than 250 mrem/hr for the PWR and BWR configurations.

A hypothetical accident event, tip-over of the vertical concrete cask, is considered in Section 11.2.12. There is no design basis event that would result in the tip-over of the vertical concrete cask.

10.3 Estimated On-Site Collective Dose Assessment

Estimated collective dose for contents except MY site specific and the additional BWR contents are discussed in Section 10.3. MY site specific contents are discussed in Section 10.5 with the additional BWR contents discussed in Section 10.6.

Occupational radiation exposures (person-mrem) resulting from the use of the Universal Storage System are calculated using the estimated exposure rates presented in Sections 5.1.3, 5.4.3 and 10.2.1. Exposure is evaluated by identifying the tasks and estimating the duration and number of personnel performing those tasks based on industry experience. The tasks identified are based on the design basis operating procedures, as presented in Chapter 8.

Dose rates for the standard transfer cask and the concrete storage cask are calculated using the shielding analysis design basis fuel assemblies. The shielding design basis PWR assembly is the Westinghouse 17×17 Standard fuel assembly, with an initial enrichment of 3.7 wt % ^{235}U. The design basis BWR assembly is the GE 9×9, with 79 fuel rods and an initial enrichment of 3.25 wt % ^{235}U. Both design basis fuel assemblies have an assumed burnup of 40,000 MWD/MTU, and a cool time of 5 years. The selection of these assemblies for the shielding design basis is described in Section 5.1. The principal parameters of these assemblies are presented in Table 2.1.1-1.

10.3.1 Estimated Collective Dose for Loading a Single Universal Storage System

This section estimates the collective dose due to the loading, sealing, transfer and placement on the independent spent fuel storage installation (ISFSI) pad, of the Universal Storage System. The analysis assumes that the exposure incurred by the operators is independent of background radiation, as background radiation varies from site to site. The number of persons allocated to task completion is a typical number required for the task. Working area exposure rates are assigned based on the orientation of the worker with respect to the source and take into account the use of temporary shielding.

Table 10.3-1 summarizes the estimated total exposure by task, attributable to the loading, transfer, sealing and placement of a design basis Universal Storage System based on the use of the standard transfer cask. As documented in Section 5.1, exposures from the advanced transfer cask are not going to differ substantially from exposures documented for the standard transfer cask.

Exposures associated with shield lid operations are based on the presence of a temporary 5-inch thick steel shield.

This estimated dose is considered to be conservative as it assumes the loading of a cask with design basis fuel, and does not account for efficiencies in the loading process that occur with experience.

10.3.2 Estimated Annual Dose Due to Routine Operations

Once in place, the ISFSI requires limited ongoing inspection and surveillance throughout its service life. The annual dose evaluations presented in Tables 10.3-4 through 10.3-7 estimate the exposure due to a combination of inspection and surveillance activities and other tasks that are anticipated to be representative of an operational facility. The visual inspection exposure, based on a daily inspection of the storage cask or storage cask array, is provided for information only since a daily inspection is not required as long as the temperature monitoring system is operational. Other than an inspection of the Vertical Concrete Cask surface, no annual maintenance of the storage system is required. Collective dose due to design basis off-normal conditions and accident events, such as clearing the blockage of air vents, is accounted for in Chapter 11.0, and is not included in this evaluation.

Routine operations are expected to include:

- The optional daily electronic measurement of ambient air and air outlet temperatures for each cask in service. The outlet temperature-monitoring station may be located away from the cask array. Remote temperature measurement is not assumed to contribute to operator dose.

- An optional daily inspection of the concrete cask inlet and outlet screens to verify they are intact and unobstructed. The time required to perform the inspection, and the expected dose, will be site specific due to ISFSI pad dimensions and configurations, concrete cask array, distance of the inspector from the cask, etc.

- A daily security inspection of the fence and equipment surrounding the storage area. The security inspection is assumed to make no significant additional contribution to operator dose.

- Grounds maintenance performed every other week by 1 maintenance technician. Grounds maintenance is assumed to require 0.5 hour.

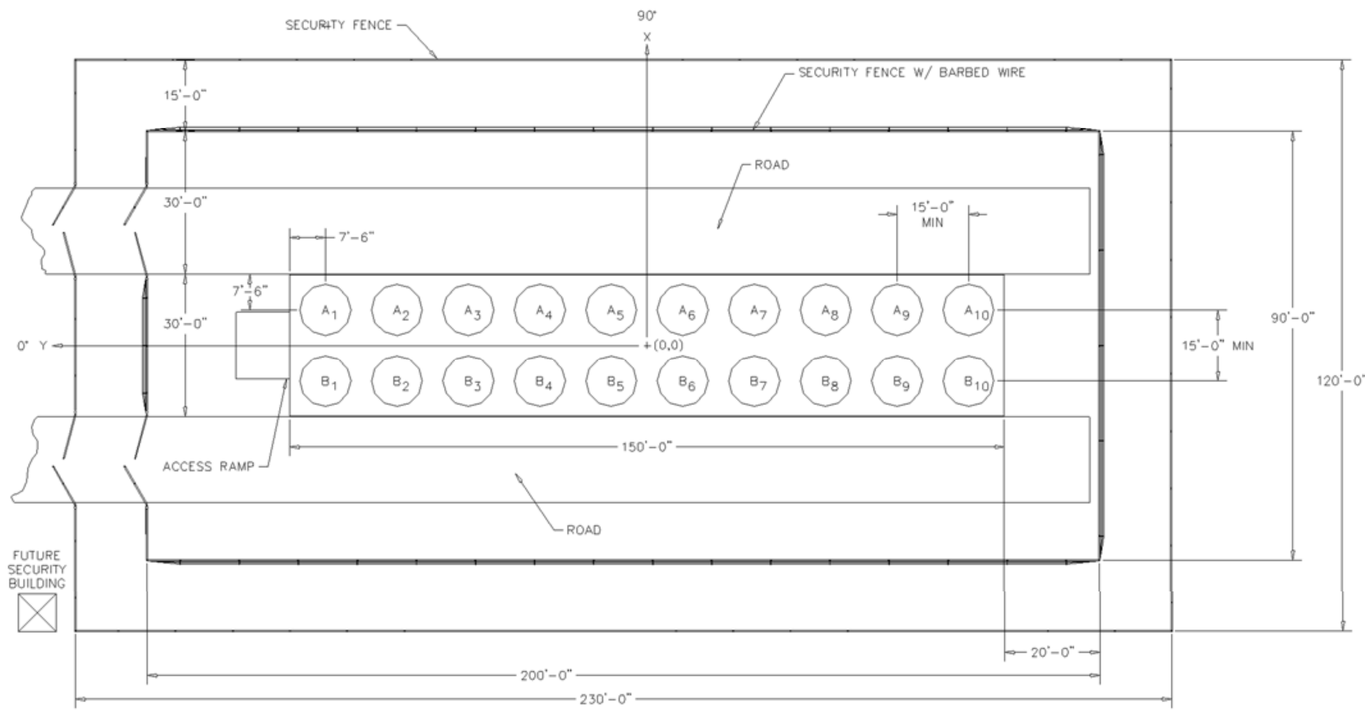
- Quarterly radiological surveillance. The surveillance consists of a radiological survey comprised of a surface radiation measurement on each cask, the determination and/or verification of general area exposure rates and radiological postings. This surveillance is assumed to require 1 hour and 1 person.

- Annual inspection of the general condition of the casks. This inspection is estimated to require 15 minutes per cask and require 2 technicians.

Calculation of the dose due to annual operation and surveillance requirements is estimated based on a single cask containing design basis fuel, and on an ISFSI array of 20 casks that are assumed to be loaded at the rate of 2 casks per year over a ten-year period. Consequently, the casks in the array are assumed to have the cool times as shown in Table 10.3-2. To account for the reduction in source term with cool time, weighting factors are applied to the neutron and gamma radiation spectra as shown in Table 10.3-3.

The annual operation and surveillance requirements result in an estimated annual collective exposure of 26.4 person-mrem for a single PWR cask containing design basis fuel and 17.0 person-mrem for a single design basis BWR cask. The annual operation and surveillance requirements for the assumed single cask and total estimated dose are shown in Table 10.3-4 for the single PWR cask and in Table 10.3-6 for the BWR cask. The annual operation and surveillance requirements for the assumed 20-cask ISFSI are shown in Tables 10.3-5 and 10.3-7 for PWR and BWR configurations, respectively. These tables show an estimated annual collective exposure of 377.6 person-mrem for the PWR cask configuration and 239.4 person-mrem for the BWR cask configuration for operation and maintenance of a 20-cask array.

Figure 10.3-1 Typical ISFSI 20 Cask Array Layout



10.4 Exposure to the Public

Exposures to the public for contents except for MY site specific and the additional BWR contents are discussed in Section 10.4. MY site specific contents are discussed in Section 10.5 with the additional BWR contents discussed in Section 10.6.

The NAC Version 5.0.1 of the SKYSHINE-III code is used to evaluate the placement of the controlled area boundary for a single storage cask containing design basis fuel, and for a 20-cask array. For the 20-cask array, the storage casks are assumed to be loaded with design basis fuel at the rate of two casks per year. SKYSHINE III calculates dose rates for user defined detector locations for up to 100 point sources.

Version 5.0.1 of SKYSHINE-III explicitly calculates cask self-shielding based on the storage cask geometry and arrangement of the cask array. A ray tracing technique is utilized. Given the source position on the cask surface and the direction cosines for the source emission, geometric tests are made to see if any adjacent casks are in the path of the emission. If so, the emission history does not contribute to the air scatter dose. Also, given the source position on the cask surface and the direction cosines for the source to detector location, geometric tests are made to see if any adjacent casks are in the source path. If so, the emission position does not contribute to the uncollided dose at the detector location.

The code is benchmarked by modeling a set of Kansas State University ^{60}Co skyshine experiments and by modeling two Kansas State University neutron computational benchmarks. The code compares well with these benchmarks for both neutron and gamma doses versus distance.

The storage cask array is explicitly modeled in the code, with the source term from each cask represented as top and side surface sources. Surface source emission fluxes are provided from one-dimensional SAS1 shielding evaluations. The top and side source energy distributions for both neutron and gamma radiation are taken from the design basis cask shielding evaluation. As stated in Section 10.3, the array cask source strengths are multiplied by weighting factors to correct for the differences in cooling times resulting from the assumption of a loading rate of 2 casks per year. The SKYSHINE cask surface fluxes (sources) are adjusted to reflect the higher cask surface fluxes calculated by the SAS4 three-dimensional shielding evaluation. Surface gamma-ray fluxes are also adjusted for dose peaks associated with fuel assembly end-fitting hardware and radiation streaming through the cask vents and canister-to-cask annulus. Air inlet and outlet dose rates have been recalculated in Section 5.4 based on the use of the MCBEND Monte Carlo code. The MCBEND generated air inlet dose rate results are significantly higher

than those obtained from the SAS4 evaluation. Since the air inlets represent less than 0.6% of the total radial surface of the cask, and considering that the 100 mrem/hr air inlet and outlet dose rate limit is retained in the technical specification, an increase in the calculated air inlet dose rate (surface flux) will not significantly impact SKYSHINE results based on the SAS4 evaluation. The 2×10 ISFSI storage cask array layout is presented in Figure 10.3-1. For this analysis, the cask-to-cask pitch is conservatively taken at 16 feet, as opposed to the minimum 15 feet, to minimize cask-to-cask shadowing. These results are conservative for the minimum 15-foot cask center-to-center-spacing specified in Section 6.3.2.

Exposures are determined at distances ranging from 50 to 500 meters surrounding a single PWR and BWR storage cask containing design basis fuel. The results are presented graphically in Figures 10.4-1 and 10.4-2, for the PWR or BWR single cask, respectively. The storage casks in the 2×10 array are assumed to be loaded at the rate of 2 per year with design basis PWR and BWR spent fuel, with credit taken for the cool time that occurs during the 10-year period that the ISFSI array is completed. For both the single cask and 2×10 array calculations, the controlled area boundary is based on the 25 mrem/year limit. Occupancy at the controlled area boundary is assumed at 2,080 hours per year. While higher occupancy may be required at certain sites, the increased exposure time will likely be offset by increased cool time or decreased burnup.

Table 10.4-1 presents a summary of the dose rates versus distance for a single PWR and BWR storage cask containing design basis fuel. Linear interpolation of these results shows that minimum distances from a single cask to the site boundary of 93 meters and 84 meters for the design basis PWR and BWR fuels, respectively, are required for compliance with the requirements of 10 CFR 72.104(a), i.e., a dose rate of 25 mrem/year. Table 10.4-2 results show that a minimum site boundary of ≈195 meters is required for a 2×10 PWR cask array to meet the 10 CFR 72.104(a) 25 mrem/year requirement. The 2×10 BWR cask array requires a minimum site boundary of ≈186 meters to meet 10 CFR 72.104(a).

The distances used in Tables 10.4-1 and 10.4-2 are measured from the center of the 2×10 cask array along a line perpendicular to the center of the 10-cask face of the array.

10.6 Radiation Protection Evaluation for Additional BWR Contents (10x10 Assembly Array, High Burnup Fuel and Damaged Fuel)

10.6.1 Estimated On-Site Collective Dose Assessment

Evaluations for the additional BWR payloads are like those discussed in Section 10.3 with input from the MCNP evaluations discussed in Section 5.8 (cask near field dose rates) and 10.6.2 (skyshine dose rates). Exposure time and number of personnel for loading and maintenance steps are those listed in Section 10.3.1. Primary differences are the use of the high burnup dose evaluation results performed using MCNP and all casks in the array being assigned design basis sources versus the assumed decayed casks listed in Table 10.3-2.

Table 10.6-1 summarizes the estimated total exposure by task, attributable to the loading, transfer, sealing, and placement of a design basis Universal Storage System.

Once in place, the ISFSI requires limited ongoing inspection and surveillance throughout its service life. The annual dose evaluations presented in Tables 10.6-2 and 10.6-3 estimate the exposure due to a combination of inspection and surveillance activities and other tasks that are anticipated to be representative of an operational facility.

10.6.2 Exposure to the Public

MCNP is used to evaluate the placement of the controlled area boundary for a single storage cask containing design basis fuel, and for a 20-cask array. For the 20-cask array, the storage casks are assumed to be loaded with design basis fuel (i.e., source producing maximum surface dose rates) per Section 5.8.2 and evaluated at full time (8760 hours) exposure.

The storage cask array is explicitly modeled in the code, with the source term from each cask generated using the MCNP surface source write option. The surface source file is then imposed on each of the casks in the array.

Exposures are determined at distances out to 600 meters surrounding a single BWR storage cask containing design basis fuel. The results are presented in Table 10.6-4. Results for the 20-cask array are listed in Table 10.6-5.

Table 10.6-1 Estimated Exposure for Operations Using the Standard Transfer Cask

Fuel Handling Activity	# Personnel	Time [hr]	Exposure [person-mrem]	Average Dose Rate [mrem/hr]
Load Canister	2	21.9	95	2.2
Move to Decon Area	2	0.6	35	29.2
Setup Shield Lid Weld	2	0.5	40	40
Shield Lid Welding (Automatic)	1	0.3	0	0
Shield Lid Weld Inspections	1	7.5	84	11.2
Drain, Dry, and Backfill Canister	2	0.4	38	47.5
Weld and Inspect Port Covers	2	2.2	320	72.8
Setup Structural Lid Weld	2	0.3	26	43.4
Structural Lid Welding (Automatic)	1	0.3	0	0
Structural Lid Weld Inspections	1	7.7	90	11.7
Transfer to Vertical Concrete Cask	4	2.8	791	70.7
Position on ISFSI Pad	2	0.8	15	9.4
Total			1534	

Table 10.6-2 Estimate of Annual Exposure for the Operation and Surveillance of a Single BWR Cask

Activity	Location	No. of Casks	Frequency	Time (min)	Dose Rate (mrem/hr)	Number Personel	Total Dose (person-mrem)
Visual Inspection	4 m	1	365	1	2.4	1	14.6
Radiological Surveillance	4 m	1	4	15	2.4	1	2.4
Annual Inspection	1 m	1	1	15	6.3	1	1.6
Radiological Support	1 m	1	1	3	6.3	1	0.4
Corrective Maintenance	30 cm	0.25	1	30	9.7	2	2.5
Radiological Support	1 m	0.25	1	10	6.3	1	0.3
Ground Maintenance	10 m	1	26	15	0.6	1	3.9
Total Person-mrem Per Design Basis Cask							25.7

Table 10.6-3 Estimate of Annual Exposure for the Operation and Surveillance of a 20-Cask Array of BWR Casks

Activity	Location	No. of Casks	Frequency	Time (min)	Dose Rate (mrem/hr)	Number Personel	Total Dose (person-mrem)
Visual Inspection	4 m	20	365	1	11.0	1	66.7
Radiological Surveillance	4 m	1	4	15	11.0	1	11
Annual Inspection	1 m	20	1	15	19.0	1	4.8
Radiological Support	1 m	20	1	3	19.0	1	1
Corrective Maintenance	30 cm	5	1	30	29.2	2	145.8
Radiological Support	1 m	5	1	10	19.0	1	15.9
Ground Maintenance	10 m	1	26	15	5.3	1	34.8
Total Person-mrem Per Design Basis Cask							279.6
Total Person-mrem - Average Dose Per Cask for Each Cask in the Array							14.0

Table 10.6-4 Dose Versus Distance for a Single Cask Containing Design Basis High Burnup Fuel(1)

Distance	y=1 m		x=1 m	
meters	mrem/yr	FSD	mrem/yr	FSD
99	69.1	0.8%	68.9	1.1%
197.5	11.1	2.4%	10.8	1.1%
295	2.88	1.9%	2.79	1.0%
395	0.89	1.8%	0.87	1.2%
495	0.32	1.2%	0.32	1.4%
595	0.12	1.1%	0.12	1.3%

Table 10.6-5 Annual Exposures from a 2×10 Cask Array Containing Design Basis BWR High Burnup Fuel(1)

Distance	y=1m		x=1m	
meters	mrem/yr	FSD	mrem/yr	FSD
99	898	0.8%	638	0.9%
197.5	144	1.0%	99.0	0.8%
295	36.4	1.0%	24.5	0.8%
395	11.4	1.2%	7.29	1.7%
495	3.95	1.2%	2.35	1.0%
595	1.53	1.1%	0.86	1.6%

1 Point detectors are placed along the long side (y=1 m) and short side (x=1 m) of the array instead of along the central axis, with its locations consistent with the mesh tally locations for the ISFSI dose rates.

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10.7 References

1. Title 10 of the Code of Federal Regulations, Part 72 (10 CFR 72), "Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation," April 1996.

2. Title 10 of the Code of Federal Regulations, Part 20 (10 CFR 20), "Standards for Protection Against Radiation," April 1996.

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4. SKYSHINE III, "Calculation of the Effects of Structure Design on Neutron, Primary Gamma-Ray and Secondary Gamma-Ray Dose Rates in Air," RISC Code Package CCC-289, NAC International, Version 4.0.1, February 1997.

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11.2.16 Fuel Rods Structural Evaluation for Burnup to 60,000 MWd/MTU

This section presents a structural evaluation of PWR and BWR fuel rods with a maximum burnup of 60,000 MWd/MTU for normal and accident conditions of storage.

During normal and off-normal conditions for the fuel in the canister, the loads applied to the fuel assembly are minimal and do not require further evaluation. The only significant axial loading the fuel assembly will experience is the 24-inch drop of the vertical concrete cask. The bounding lateral loading on the fuel assembly occurs during the tip-over accident condition. As presented in Section 11.2.16.1, the lateral loading and axial loading conditions are evaluated for PWR fuel rods considering a bounding configuration of a grid spacer missing for an unsupported fuel rod length up to 60 inches. Based on results of the drop analysis presented in the following sections, PWR fuel assemblies with one or more grid spacers missing or damaged for an unsupported fuel rod length up to 60 inches are, therefore, considered to be undamaged assemblies for loading within the UMS® Universal Storage System. Section 11.2.16.2 presents the evaluation for the BWR fuel rods for the end drop and side drop accident events.

11.2.16.1 PWR Fuel Rod Evaluation

End Drop Evaluation

This section presents the buckling evaluation for the UMS® Universal Storage System high burnup PWR fuel rods (peak rod average burnup of 62.5 GWd/MTU). In order to account for the cladding oxide layer, a conservative 120-micron thick layer is assumed to be removed from the reference clad in the rod structural evaluation. The 120-micron clad removal is conservative, as this value represents double the maximum oxide layer thickness listed for end-of-life PWR fuel rods in PNL-4835[62]. Applying a time-dependent oxide layer growth approximation to the PNL-4835-reported maximum thickness of 60 microns to account for an increase in burnup from standard (45 GWd/MTU) to high (62.5 GWd/MTU) yields a maximum end-of-life oxide layer in the range of 90 microns. As high burnup claddings are designed to reduce oxidation, actual layers are expected to be significantly lower (reported as low as 20 microns for >70 GWd/MTU M5 zircaloy clad). Therefore, a significant margin exists to the evaluated oxide layer levels.

These analyses show that the maximum stresses in the high burnup PWR fuel remain below the yield strength in the design basis accident events and confirm that the fuel rods will return to their original configuration prior to the end drop event. An end drop orientation is considered with an acceleration of 48g, which subjects the fuel rods to axial loading. This 48g acceleration bounds the maximum end drop acceleration calculated for the 24-inch concrete cask end drop.

In the end drop orientation, the fuel rods are laterally restrained by the grids and come into contact with the fuel assembly base. The only vertical constraint for the fuel rod is the base of the assembly. As opposed to employing a straight fuel assembly in the evaluation with all the grids present, the fuel assembly is considered to be bowed, and a fuel assembly grid may be missing and still meet the acceptable configuration for undamaged fuel. The evaluation of the PWR fuel rods is based on the following representative samples.

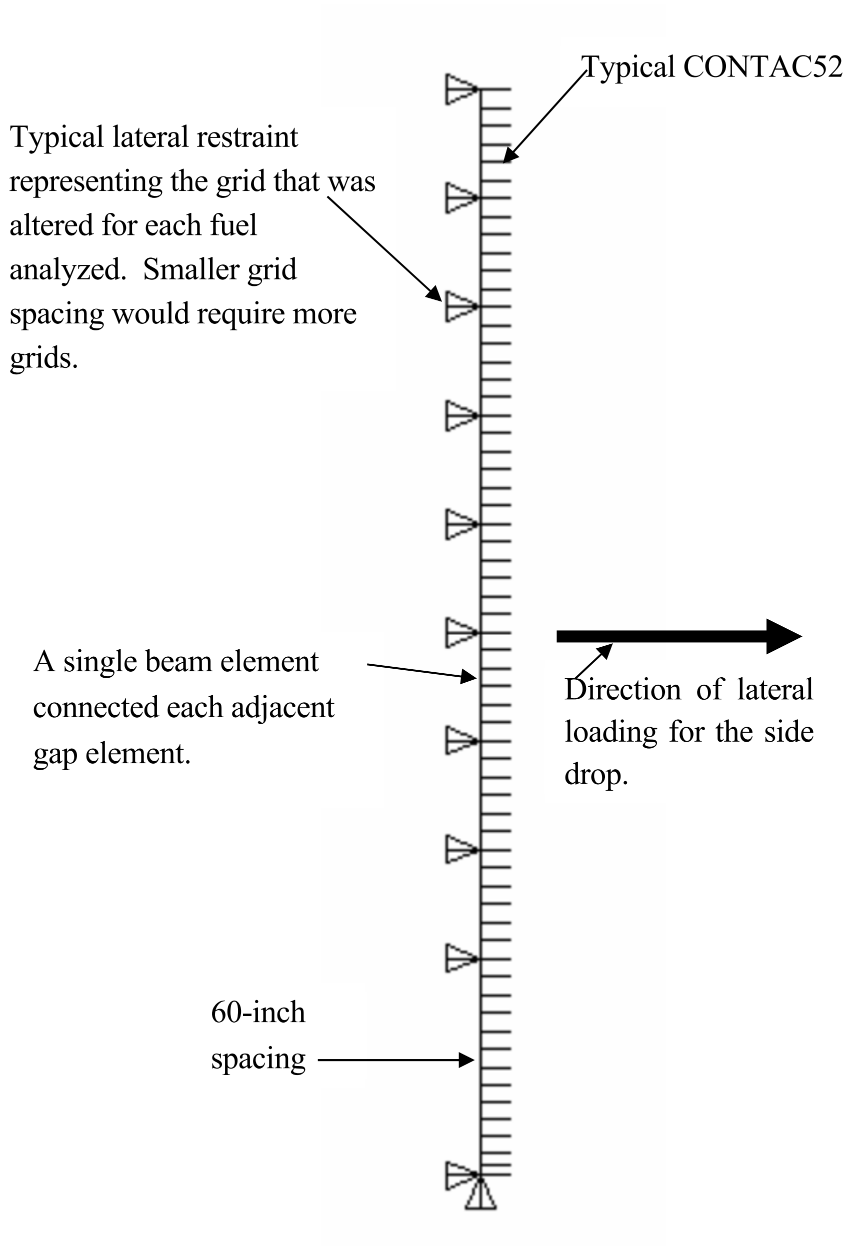
Fuel Assembly	Cladding Diameter (in)	Cladding Thickness (in)	Fuel Rod Pitch (in)	Gap Between Fuel Assembly and Fuel Tube Wall (in)
We 17x17	0.360	0.021	0.496	0.504
We 15x15	0.417	0.024	0.563	0.501
We 14x14	0.400	0.022	0.556	1.172
CE16x16	0.382	0.025	0.506	0.828
CE14x14	0.440	0.031	0.580	0.820
BW17x17	0.377	0.022	0.502	0.391
BW15x15	0.414	0.022	0.568	0.434

Review of the design basis fuel inventory indicates that the largest gap between a straight fuel assembly and the basket fuel tube inner wall could be 1.17 inches, corresponding to a 14 ×14 rod array having a minimum rod pitch of 0.556 inch and a minimum rod diameter of 0.40 inch inside a basket fuel cell, with a maximum inside dimension of 8.8 inches. It is physically possible for a fuel rod to have a bow of 1.17 inches and still be able to fit into the larger basket cell. Actual fuel assembly bow is expected to be much less than this maximum value and on the order of 0.125 to 0.25 inch. A missing grid implies that the axial distance between two adjacent grids could be as large as 60 inches. The bounding axial loading is the 24-inch bottom end drop, which identifies the bounding condition to be the 60-inch distance from the end of the fuel rod to the first grid. To implement a conservative bow of 1.23 inches (an increase of 0.06 inch over 1.17 inches) into the fuel assembly, the half-symmetry ANSYS model shown in Figure 11.2.16-1 is used. This model contains 0.5-inch long individual fuel pellets modeled with brick elements, with a 0.002-inch gap between the fuel pellet and the clad. The clad is modeled with shell elements. Elastic properties are used for the fuel pellet and the clad as shown in the following table.

	Modulus of Elasticity (10^6 psi)	Density (lb/in^3)
Rod Clad	10.47 [61]	0.237
Fuel Pellet	13 [48]*	0.396

* To further reduce the strength of the pellet, this is 50% of the value reported in Reference 48.

Figure 11.2.16-3 ANSYS Model for the PWR Fuel Rod High Burnup Condition



11.2.16.2 BWR Fuel Rod Evaluation

This section presents the structural evaluations of the BWR high burnup fuel assemblies for the 24-inch end drop condition of the storage cask and a bounding 60-g side drop condition for the cask tip-over accident. The high burnup BWR fuel is considered to have a cladding oxide layer of 125 microns thick. A reduced cladding thickness is assumed due to the cladding oxide layer.

End Drop Evaluation

In the end drop orientation, the fuel rods are laterally restrained by the grids and come into contact with the fuel assembly base. The fuel assembly is considered to have an initial of bow of 0.157 inch [64]. The evaluation of the BWR fuel rod is based on the following representative samples of BWR fuel assemblies:

BWR Fuel Assembly	Cladding Diameter (in)	Cladding Thickness (in)	Fuel Rod Pitch (in)	Gap between fuel assembly and fuel tube wall (in)
8X8	0.483	0.032	0.64	0.937
9X9	0.433	0.026	0.572	0.891
10X10	0.396	0.024	0.51	0.914

Review of the design basis fuel inventory indicates that the largest gap between the envelop of the fuel rods of a straight fuel assembly and the basket fuel tube inner wall could be 0.937 inch. In this evaluation, an assembly with an initial bow of 0.157 inch is permitted to displace an additional 0.78 inch to the full gap displacement of 0.937 inch. To implement a bow of 0.157 inch into the fuel assembly, the half symmetry ANSYS model corresponding to a row of fuel rods (Figure 11.2.16-4) is used. The clad is modeled with shell elements (see Figure 11.2.16-5). Each grid is modeled using brick elements to maintain the spacing between the fuel rods at the grid. The fuel tube is modeled using brick elements to restrict the lateral motion of the fuel assembly. Each of the fuel rods in the ANSYS model is simply supported at each end. A static force is applied to the ANSYS model at the grid nearest the axial center to develop a 0.157 inch lateral displacement. The purpose of the ANSYS model and solution is to provide the coordinates of the fuel clad for the LS-DYNA model. This is accomplished by obtaining a static solution with the ANSYS model, and then using the option to update the coordinates of the nodes based on the displacements from the solution.

Three (3) LS-DYNA models are considered for the 24-inch cask end drop conditions. All models incorporate a bow of 0.157 inch. These cases envelope the range of the cross-sectional moment of inertia for the BWR fuel rods and the largest grid spacing of the fuel assembly are summarized in the following Table.

Case	Fuel Assembly	Largest grid spacing (inch)
1	8×8	23.61
2	9×9	22.28
3	10×10	22.57

In each case the thickness of the clad was reduced by 125 microns (0.0049inch). Each case requires a separate ANSYS model and a LS-DYNA model to represent unique coordinates or boundary conditions. The LS-DYNA model employs the same nodes and elements as the ANSYS model (with the incorporation of the 0.157 inch bow). Elastic properties are used in the ANSYS model and the bilinear properties are employed in the LS-DYNA model. An initial downward velocity of 136 in/sec (corresponding to a 24-inch end drop of the storage cask) is assigned to all nodes in the model. The deceleration time history is applied to the nodes of the brick elements representing the fuel tube. The acceleration time history is obtained from the analysis for the 24-inch drop of the VCC in Section 11.2.4. The side walls of the fuel tube are restrained in the lateral direction to maximize the effect of the fuel rods impacting the fuel tube side wall.

The LS-DYNA analyses for Cases 1 through 3 were performed for the duration of 0.08 second to capture the response of the fuel after the 0.02 second loading duration. Post-processing each analysis result identifies the maximum shear stress occurring at the shell surface. The maximum shear stress result from LS-DYNA is factored by two to determine the maximum stress intensity. The following table contains the maximum stress intensity and the margin of safety (M.S.) for the three cases.

Case	Fuel Assembly	Maximum Stress Intensity (ksi)	M.S. Against Yield Strength
1	8×8	19.71	+2.53
2	9×9	18.98	+2.67
3	10×10	20.60	+2.38

All stresses are shown to be well below the yield strength. The results confirm that high burnup BWR fuel will remain structurally adequate for the storage design basis cask end drop load condition.

Side Drop Evaluation

A structural evaluation is performed for the BWR fuel rod for a 60g side drop condition, which bounds the cask tip-over accident condition. Static analyses using ANSYS are performed to evaluate the response in the side drop for the BWR fuel rod. During a side drop, the maximum deflection of a fuel rod is based on the fuel rod spacing of the fuel assembly. Assuming a 10×10 array (fuel assembly with the maximum number of rods), the maximum fuel rod deflection, including the 125-micron oxide layer, is:

$$(10\text{-}1) \times (0.51\text{-}0.3957+2\times125\cdot10^{-6}\times39.37) = 1.12 \text{ in.}$$

The side drop loading is evaluated for three fuel rods, which corresponds to the limits of the stress modulus Z (ratio of the cross-sectional moment of inertia to the maximum radius to relate the maximum fiber stress (S) to the bending moment (M), S=M/Z) as shown in the following table.

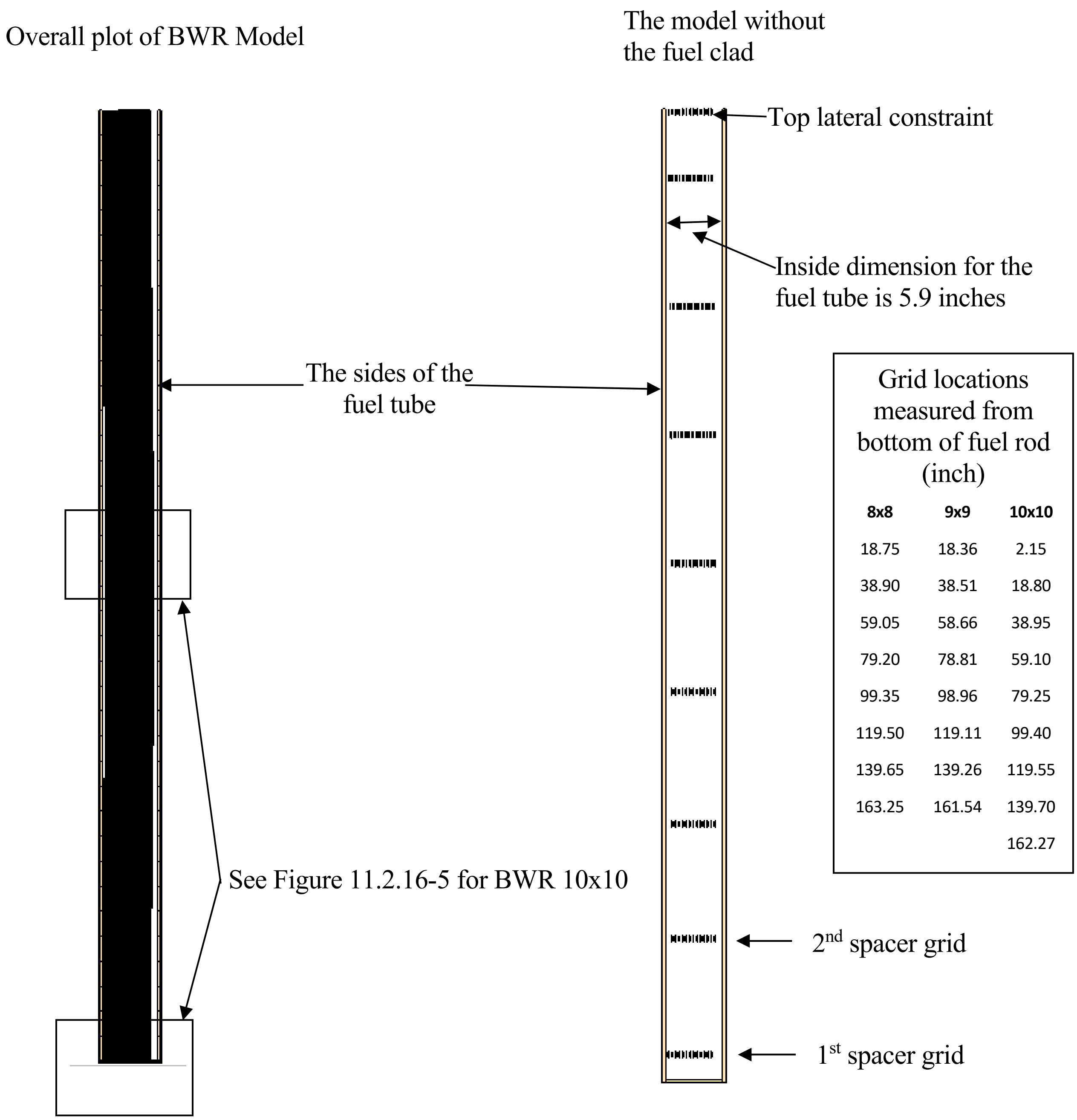
Case	Rod diameter (inches)	Clad thickness (inches)	Cross sectional Area (A) (in^2)	Cross sectional moment (I) (in^4) 10^{-4}	Z (in^3) 10^{-3}
8×8	0.483	0.032	0.03795	9.47	4.00
9×9	0.433	0.026	0.026628	5.40	2.55
10×10	0.3957	0.0239	0.021876	3.69	1.91

ANSYS is used to perform a static analysis with a lateral loading of 60g. The model is shown in Figure 11.2.16-6. The fuel rod is modeled with beam elements having the properties for the fuel clad taking into account the reduction of the outer radius by 0.00492 inch (125 microns). The density of the beam element material was based on the zircaloy clad (0.237 lb/in3) and the pellet density (0.396 lb/in3). The lateral constraints shown in Figure 11.2.16-4 indicate the location of the grids used in the model. To represent the maximum gap of 1.12 inches, which the fuel rod can displace in the side drop, CONTAC52 elements are modeled at each node. The gap for each CONTAC52 was set to 1.12 inches to limit the lateral displacement of the fuel rod to 1.12 inches. The maximum stresses and the margins of safety (M.S.) for each case are shown in the following table.

Case	Maximum Stress (ksi)	M.S. Against Yield Strength
8×8	26.0	+1.68
9×9	30.1	+1.32
10×10	34.0	+1.05

This confirms that the BWR high burnup fuel rod subject to high burnup is structurally adequate for a 60g side drop condition, which bounds the tip-over accident condition.

Figure 11.2.16-4 Overall Model Plot for a Typical BWR Fuel Assembly



8x8	9x9	10x10
18.75	18.36	2.15
38.90	38.51	18.80
59.05	58.66	38.95
79.20	78.81	59.10
99.35	98.96	79.25
119.50	119.11	99.40
139.65	139.26	119.55
163.25	161.54	139.70
		162.27

Figure 11.2.16-5 Detailed View of the BWR 10×10 Fuel Assembly Model

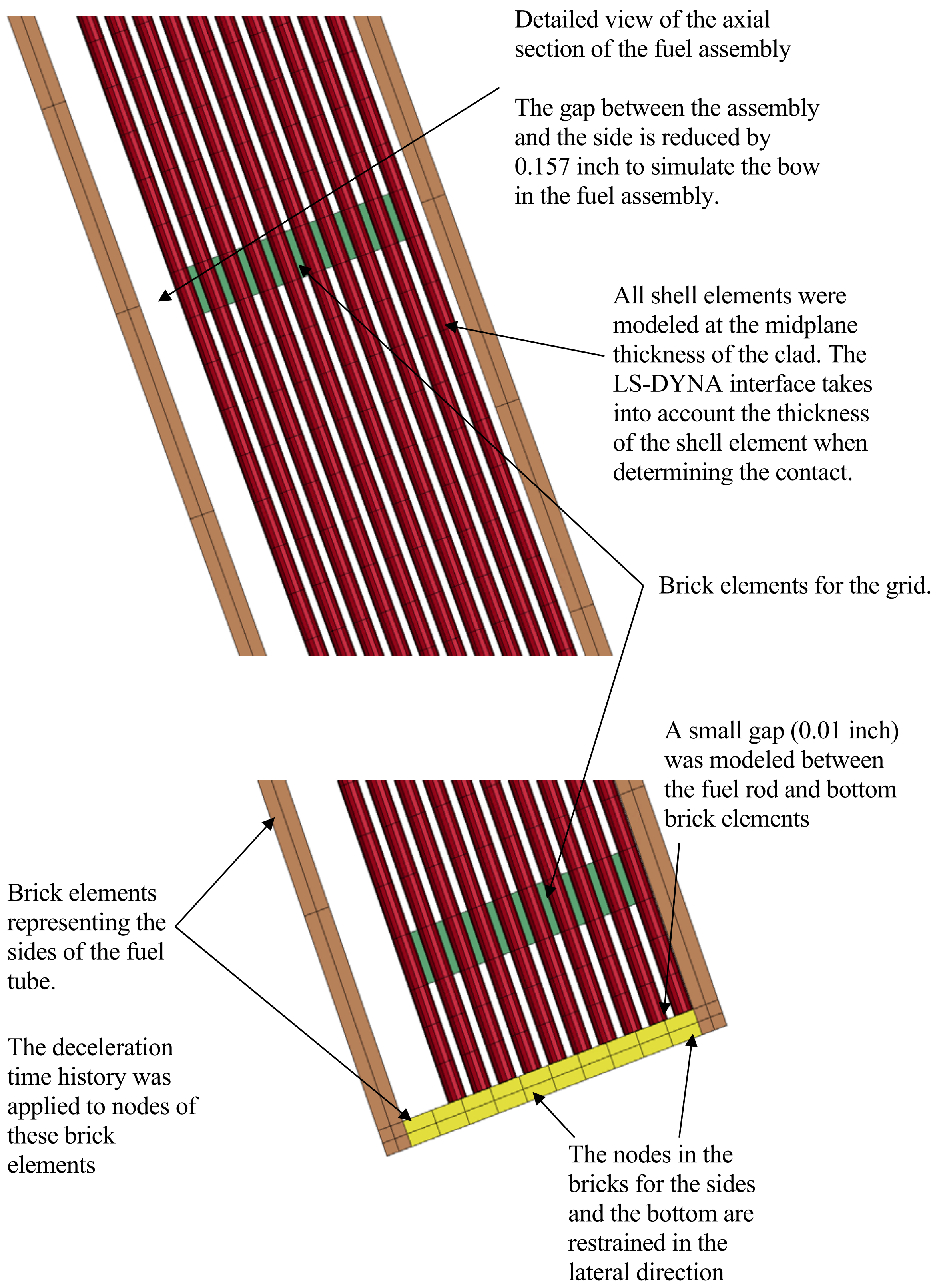
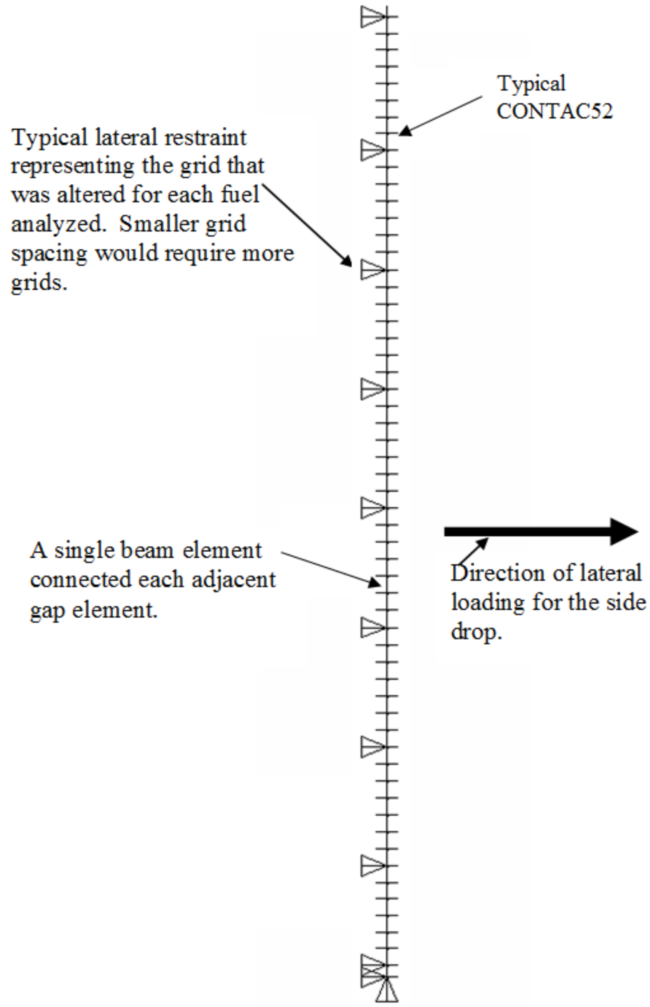


Figure 11.2.16-6 ANSYS Model for the BWR Fuel Rod Side Drop Evaluation



11.2.16.3 Thermal Evaluation of Fuel Rods

The UMS® system limits normal storage condition fuel cladding temperatures to levels below zirconium alloy or stainless steel cladding temperature limits; therefore, degradation is not expected to occur below this temperature in an inert gas environment.

As shown in Chapter 4, fuel cladding temperature limits for PWR and BWR fuel rods have been established at 400°C (752°F) for normal and off-normal conditions of storage, including transfer operations, and 570°C (1,058ºF) for accident conditions. Chapter 4 demonstrates that the maximum fuel cladding temperatures are well below the temperature limits for all design conditions of storage.

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Spent fuel having a burnup from 45,000 to 50,000 MWd/MTU is assigned to peripheral locations, and may require loading in a Maine Yankee fuel can. The interior locations must be loaded with fuel that has lower burnup and/or longer cool times in order to maintain the design basis heat load and component temperature limits for the basket and canister.

The Fuel Assembly Limits for the Maine Yankee SITE SPECIFIC FUEL are shown in Table B2-7 of Appendix B of the CoC Number 1015 Technical Specifications. Part A of the table lists the STANDARD, UNDAMAGED FUEL ASSEMBLY and SITE SPECIFIC FUEL that does not require preferential loading.

Part B of the table lists the SITE SPECIFIC FUEL configurations that require preferential loading due to the criticality, shielding or thermal evaluation. The loading pattern for Maine Yankee SITE SPECIFIC FUEL that must be preferentially loaded is presented in Section B 2.1.2. The preferential loading controls take advantage of design features of the UMS® Storage System to allow the loading of fuel configurations that may have higher burnup or additional hardware or fuel source material that is not specifically considered in the design basis fuel evaluation.

Fuel assemblies with a Control Element Assembly (CEA) or a CEA plug inserted are loaded in a Class 2 canister and basket due to the increased length of the assembly with either of these components installed. However, these assemblies are not restricted as to loading position within the basket.

The Transportable Storage Canister loading procedures for Maine Yankee SITE SPECIFIC FUEL are administratively controlled in accordance with the requirements of Section B 2.1.2 for the loading of: (1) a fuel configuration with removed fuel or poison rods, (2) a MAINE YANKEE FUEL CAN, or (3) fuel with burnup between 45,000 MWd/MTU and 50,000 MWd/MTU.

Table 12-1 NAC-UMS® System Controls and Limits

Control or Limit	Applicable Technical Specification	Condition or Item Controlled
1. Fuel Characteristics	Table B2-1 Table B2-2 Table B2-3 Table B2-4 Table B2-5 and B2-10 thru B2-12 Table B2-13 thru B2-15 Table B2-7 Table B2-8 Table B2-9	Type and Condition Class, Dimensions and Weight for PWR Class, Dimensions and Weight for BWR Minimum Cooling Time for PWR Fuel Minimum Cooling Time for BWR Fuel BGWR Enrichment Limits not specified in Table B2-3 Maine Yankee Site Specific Fuel Limits Minimum Cooling Time for Maine Yankee Fuel – No CEA Minimum Cooling Time for Maine Yankee Fuel – With CEA
2. Canister Fuel Loading Drying Backfilling Sealing Vacuum External Surface Unloading	LCO 3.1.4 Table B2-1 Table B2-7 Table B2-4 Table B2-5 and B2-10 thru B2-12 LCO 3.1.2 LCO 3.1.3 LCO 3.1.5 LCO 3.1.1 LCO 3.2.1 Note 1	Time in Transfer Cask (fuel loading) Weight and Number of Assemblies Maine Yankee Site Specific Fuel Limits Minimum Cooling Time for PWR Fuel Minimum Cooling Time for BWR Fuel Vacuum Drying Pressure Helium Backfill Pressure Helium Leak Rate Time in Vacuum Drying Level of Contamination Fuel Cooldown Requirement
3. Concrete Cask	LCO 3.2.2 Note 1 Note 2	Surface Dose Rates Cask Spacing Cask Handling Height
4. Surveillance	LCO 3.1.6	Heat Removal System
5. Transfer Cask	B 3.4(8)	Minimum Temperature
6. ISFSI Concrete Pad	B3.4.1(6) B3.4.2(7)	Seismic Event Performance

1. Procedure and/or limits are presented in the Operating Procedures of Chapter 8.
2. Lifting height and handling restrictions are provided in Section A5.6 of Appendix A.