RENEWED CERTIFICATE OF COMPLIANCE NO. 1008

APPENDIX B

APPROVED CONTENTS AND DESIGN FEATURES

FOR THE HI-STAR 100 CASK SYSTEM

AMENDMENT 0

APPENDIX B DESIGN FEATURES

1.0 Definitions

NOTE

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

| Term | Definition |
|---|---|
| DAMAGED FUEL ASSEMBLY | DAMAGED FUEL ASSEMBLIES are fuel assemblies with known or suspected cladding defects greater than pinhole leaks or hairline cracks, missing fuel rods that are not replaced with dummy fuel rods, or those that cannot be handled by normal means. A DAMAGED FUEL ASSEMBLY's inability to be handled by normal means must be due to mechanical damage and must not be due to fuel rod cladding damage. |
| DAMAGED FUEL CONTAINER (DFC) | DFCs are specially designed enclosures for DAMAGED FUEL ASSEMBLIES or FUEL DEBRIS which permit gaseous and liquid media to escape while minimizing dispersal of gross particulates. |
| FUEL DEBRIS | FUEL DEBRIS is ruptured fuel rods, severed rods, loose fuel pellets or fuel assemblies with known or suspected defects which cannot be handled by normal means due to fuel cladding damage. |
| INTACT FUEL ASSEMBLY | INTACT FUEL ASSEMBLIES are fuel assemblies without known or suspected cladding defects greater than pinhole leaks or hairline cracks and which can be handled by normal means. Partial fuel assemblies, that is fuel assemblies from which fuel rods are missing, shall not be classified as INTACT FUEL ASSEMBLIES unless dummy fuel rods are used to displace an amount of water greater than or equal to that displaced by the original fuel rod(s) |
| PLANAR-AVERAGE INITIAL ENRICHMENT | PLANAR-AVERAGE INITIAL ENRICHMENT is the simple average of the distributed fuel rod enrichments within a given axial plane of the assembly lattice. |

## 1.1 Fuel Specifications

### 1.1.1 Fuel To Be Stored In The HI-STAR 100 SFSC System

a. INTACT FUEL ASSEMBLIES, DAMAGED FUEL ASSEMBLIES, and FUEL DEBRIS meeting the limits specified in Table 1.1-1 (which refers to Tables 1.1-2 through 1.1-5) may be stored in the HI-STAR 100 SFSC System.

b. For MPCs partially loaded with stainless steel clad fuel assemblies, all remaining fuel assemblies in the MPC shall meet the maximum decay heat generation limit for the stainless steel clad fuel assemblies.

c. For MPCs partially loaded with DAMAGED FUEL ASSEMBLIES or FUEL DEBRIS, all remaining Zircaloy clad INTACT FUEL ASSEMBLIES in the MPC shall meet the maximum decay heat generation limits for the DAMAGED FUEL ASSEMBLIES.

c. For MPC-68's partially loaded with array/class 6x6A, 6x6B, 6x6C, or 8x8A fuel assemblies, all remaining Zircaloy clad INTACT FUEL ASSEMBLIES in the MPC shall meet the maximum decay heat generation limits for the 6x6A, 6x6B, 6x6C, and 8x8A fuel assemblies.

### 1.1.2 Preferential Fuel Loading

Preferential fuel loading shall be used whenever fuel assemblies with significantly different post-irradiation cooling times (equal to or greater than one year) are to be loaded in the same MPC. That is, fuel assemblies with the longest post-irradiation cooling times shall be loaded into fuel storage locations at the periphery of the basket. Fuel assemblies with shorter post-irradiation cooling times shall be placed toward the center of the basket.

## 1.2 Functional and Operating Limits Violations

If any Fuel Specifications defined in Section 1.1 are violated, the following actions shall be completed:

a. The affected fuel assemblies shall be placed in a safe condition without delay and in a controlled manner.

b. Within 24 hours, notify the NRC Operations Center.

c. Within 30 days, submit a special report which describes the cause of the violation, and actions taken to restore compliance and prevent recurrence.

The above actions are not a substitute for the reporting requirements contained in 10 CFR 72.75

## 1.3 Codes and Standards

The American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), 1995 Edition with Addenda through 1997, is the governing Code for the HI-STAR 100 Cask System, as clarified in Specification 1.3.1 below.

### 1.3.1 Exceptions to Codes, Standards, and Criteria

Table 1.3-1 lists approved exceptions to the ASME Code for the design of the HI-STAR 100 Cask System.

### 1.3.2 Construction/Fabrication Exceptions to Codes, Standards, and Criteria

Proposed alternatives to the ASME Code, Section III, 1995 Edition with Addenda through 1997 including exceptions allowed by Specification 1.3.1 may be used when authorized by the Director of the Office of Nuclear Material Safety and Safeguards or designee. The request for such alternative should demonstrate that:

1. The proposed alternatives would provide an acceptable level of quality and safety, or

2. Compliance with the specified requirements of the ASME Code, Section III, 1995 Edition with Addenda through 1997, 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

## 1.4 Site Specific Parameters and Analyses

Site-specific parameters and analyses that will need verification by the system user, as a minimum, are as follows:

1. The temperature of 80°F is the maximum allowed average yearly temperature.

2. The allowed temperature extremes, averaged over a three day period, shall be greater than -40°F, and less than 125 °F.

3. The horizontal and vertical seismic acceleration levels are bounded by the values listed below in Table 1-4.

Table 1-4
Design-Basis Earthquake Input on the Top Surface of an ISFSI Pad

| Horizontal g-level in each of two orthogonal directions | Horizontal g-level Vector Sum | Corresponding Vertical g-level (upward) |
|---|---|---|
| 0.222 g | 0.314 g | 1.00 x 0.222 g = 0.222 g |
| 0.235 g | 0.332 g | 0.75 x 0.235 g = 0.176 g |
| 0.24 g | 0.339 g | 0.667 x 0.24 g = 0.160 g |
| 0.25 g | 0.354 g | 0.500 x 0.25 g = 0.125 g |

4. The analyzed flood condition of 13 fps water velocity and a height of 656 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 on-site transporter fuel tank will contain no more than 50 gallons of combustible transporter fuel.

6. In addition to the requirement of 10 CFR 72.212(b)(2)(ii), the cask storage pads and foundation shall include the following characteristics as applicable to the drop and tipover analyses:

   a. Concrete thickness: ≤ 36 inches

   b. Concrete compressive strength: ≤ 4,200 psi

   c. Reinforcement top and bottom (Both Directions):
      Reinforcement area and spacing determined by analysis
      Reinforcement yield strength: ≤ 60,000 psi

   d. Soil effective modulus of elasticity: ≤ 28,000 psi

      An acceptable method of defining the soil effective modulus of elasticity applicable to the drop and tipover analyses is provided

in Table 13 of NUREG/CR-6608 with soil classification in accordance with ASTM-D2487-93, Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System USCS) and density determination in accordance with ASTM-D1586-84, Standard Test Method for Penetration Test and Split/Barrel Sampling of Soils.

7. In cases where engineered features (i.e., berms, shield walls) are used to ensure that the 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.

## 1.5 Design Specifications

### 1.5.1 Specifications Important for Criticality Control

#### 1.5.1.1 MPC-24

1. Minimum flux trap size: 1.09 in

2. Minimum $^{10}B$ loading in the Boral neutron absorbers: 0.0267 g/cm$^2$

#### 1.5.1.2 MPC-68 and MPC-68F

1. Minimum fuel cell pitch: 6.43 in

2. Minimum $^{10}B$ loading in the Boral neutron absorbers: 0.0372 g/cm$^2$ in the MPC 68, and 0.01g/cm$^2$ in the MPC-68F.

### 1.5.2. Specifications Important for Thermal Performance

#### 1.5.2.1 OVERPACK

The painted surface of the HI-STAR 100 OVERPACK must have an emissivity no less than 0.85.

Table 1.1-1
Fuel Assembly Limits

I. MPC MODEL: MPC-24

A. Allowable Contents

1. Uranium oxide, PWR INTACT FUEL ASSEMBLIES listed in Table 1.1-2 and meeting the following specifications:

| | | |
|---|---|---|
| a. | Cladding Type: | Zircaloy (Zr) or Stainless Steel (SS) as specified in Table 1.1-2 for the applicable fuel assembly array/class |
| b. | Initial Enrichment: | As specified in Table 1.1-2 for the applicable fuel assembly array/class. |
| c. | Decay Heat Per Assembly: | |
| | i. Zr Clad: | An assembly decay heat as specified in Table 1.1-4 for the applicable post-irradiation cooling time. |
| | ii. SS Clad: | $\leq$ 575 Watts |
| d. | Post-irradiation Cooling Time and Average Burnup Per Assembly: | |
| | i. Zr Clad: | An assembly post-irradiation cooling time and average burnup as specified in Table 1.1-5. |
| | ii. SS Clad: | An assembly post-irradiation cooling time $\geq$ 9 years and an average burnup $\leq$ 30,000 MWD/MTU.<br><br>OR<br><br>An assembly post-irradiation cooling time $\geq$ 15 years and an average burnup $\leq$ 40,000 MWD/MTU. |

e. Nominal Fuel Assembly Length: ≤ 176.8 inches

f. Nominal Fuel Assembly Width: ≤ 8.54 inches

g. Fuel Assembly Weight: ≤ 1,680 lbs

B. Quantity per MPC: Up to 24 fuel assemblies.

C. Fuel assemblies shall not contain control components.

D. DAMAGED FUEL ASSEMBLIES and FUEL DEBRIS are not authorized for loading into the MPC-24.

II. MPC MODEL: MPC-68

A. Allowable Contents

1. Uranium oxide, BWR INTACT FUEL ASSEMBLIES listed in Table 1.1-3, with or without Zircaloy channels, and meeting the following specifications:

| | |
|---|---|
| a. Cladding Type: | Zircaloy (Zr) or Stainless Steel (SS) as specified in Table 1.1-3 for the applicable fuel assembly array/class. |
| b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT: | As specified in Table 1.1-3 for the applicable fuel assembly array/class. |
| c. Initial Maximum Rod Enrichment: | As specified in Table 1.1-3 for the applicable fuel assembly array/class. |
| d. Decay Heat Per Assembly: | |
| i. Zr Clad: | An assembly decay heat as specified in Table 1.1-4 for the applicable post-irradiation cooling time, except for array/class 6x6A, 6x6C,and 8x8A fuel assemblies, which shall have a decay heat ≤ 115 Watts. |
| ii. SS Clad: | ≤ 95 Watts |

| | | |
|---|---|---|
| e. | Post-irradiation Cooling Time and Average Burnup Per Assembly: | |
| | i. Zr Clad: | An assembly post-irradiation cooling time and average burnup as specified in Table 1.1-5, except for array/class 6x6A, 6x6C, and 8x8A fuel assemblies, which shall have a cooling time $\geq$ 18 years and an average burnup $\leq$ 30,000 MWD/MTU. |
| | ii. SS Clad: | An assembly cooling time after discharge $\geq$ 10 years and an average burnup $\leq$ 22,500 MWD/MTU. |
| f. | Nominal Fuel Assembly Length: | $\leq$ 176.2 inches |
| g. | Nominal Fuel Assembly Width: | $\leq$ 5.85 inches |
| h. | Fuel Assembly Weight: | $\leq$ 700 lbs, including channels |

2. Uranium oxide, BWR DAMAGED FUEL ASSEMBLIES, with or without Zircaloy channels, placed in DAMAGED FUEL CONTAINERS. BWR DAMAGED FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6A, 6x6C, 7x7A, or 8x8A, and meet the following specifications:

| | |
|---|---|
| a. Cladding Type: | Zircaloy (Zr) |
| b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT: | As specified in Table 1.1-3 for the applicable fuel assembly array/class. |
| c. Initial Maximum Rod Enrichment: | As specified in Table 1.1-3 for the applicable fuel assembly array/class. |
| d. Decay Heat Per Assembly: | ≤ 115 Watts |
| e. Post-irradiation Cooling Time and Average Burnup Per Assembly: | An assembly post-irradiation cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTU. |
| f. Nominal Fuel Assembly Length: | ≤ 135.0 inches |
| g. Nominal Fuel Assembly Width: | ≤ 4.70 inches |
| h. Fuel Assembly Weight: | ≤ 400 lbs, including channels |

3. Mixed oxide (MOX), BWR INTACT FUEL ASSEMBLIES, with or without Zircaloy channels. MOX BWR INTACT FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6B, and meet the following specifications:

| | |
|---|---|
| a. Cladding Type: | Zircaloy (Zr) |
| b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT: | As specified in Table 1.1-3 for fuel assembly array/class 6x6B. |
| c. Initial Maximum Rod Enrichment: | As specified in Table 1.1-3 for fuel assembly array/class 6x6B. |
| d. Decay Heat Per Assembly: | $\leq$ 115 Watts |
| e. Post-irradiation Cooling Time and Average Burnup Per Assembly: | An assembly post-irradiation cooling time $\geq$ 18 years and an average burnup $\leq$ 30,000 MWD/MTIHM. |
| f. Nominal Fuel Assembly Length: | $\leq$ 135.0 inches |
| g. Nominal Fuel Assembly Width: | $\leq$ 4.70 inches |
| h. Fuel Assembly Weight: | $\leq$ 400 lbs, including channels |

4. Mixed oxide (MOX), BWR DAMAGED FUEL ASSEMBLIES, with or without Zircaloy channels, placed in DAMAGED FUEL CONTAINERS. MOX BWR DAMAGED FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6B, and meet the following specifications:

| | |
|---|---|
| a. Cladding Type: | Zircaloy (Zr) |
| b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT: | As specified in Table 1.1-3 for array/class 6x6B. |
| c. Initial Maximum Rod Enrichment: | As specified in Table 1.1-3 for array/class 6x6B. |
| d. Decay Heat Per Assembly: | $\leq$ 115 Watts |
| e. Post-irradiation Cooling Time and Average Burnup Per Assembly: | An assembly post-irradiation cooling time $\geq$ 18 years and an average burnup $\leq$ 30,000 MWD/MTIHM. |
| f. Nominal Fuel Assembly Length: | $\leq$ 135.0 inches |
| g. Nominal Fuel Assembly Width | $\leq$ 4.70 inches |
| h. Fuel Assembly Weight: | $\leq$ 400 lbs, including channels |

B. Quantity per MPC: Any combination of DAMAGED FUEL ASSEMBLIES in DAMAGED FUEL CONTAINERS and INTACT FUEL ASSEMBLIES UP TO A TOTAL OF 68.

C. Fuel assemblies with stainless steel channels are not authorized for loading in the MPC-68.

III. MPC MODEL: MPC-68F

A. Allowable Contents

1. Uranium oxide, BWR INTACT FUEL ASSEMBLIES, with or without Zircaloy channels. BWR INTACT FUEL ASSEMBLIES shall meet the criteria in Table 1.1-3 for fuel assembly array class 6x6A, 6x6C, 7x7A or 8x8A, and meet the following specifications:

| | |
|---|---|
| a. Cladding Type: | Zircaloy (Zr) |
| b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT: | As specified in Table 1.1-3 for the applicable fuel assembly array/class. |
| c. Initial Maximum Rod Enrichment: | As specified in Table 1.1-3 for the applicable fuel assembly array/class. |
| d. Decay Heat Per Assembly: | ≤ 115 Watts. |
| e. Post-irradiation Cooling Time and Average Burnup Per Assembly: | An assembly post-irradiation cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTU. |
| f. Nominal Fuel Assembly Length: | ≤ 176.2 inches |
| g. Nominal Fuel Assembly Width: | ≤ 5.85 inches |
| h. Fuel Assembly Weight: | ≤ 700 lbs, including channels |

2. Uranium oxide, BWR DAMAGED FUEL ASSEMBLIES, with or without Zircaloy channels, placed in DAMAGED FUEL CONTAINERS. BWR DAMAGED FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6A, 6x6C, 7x7A, or 8x8A, and meet the following specifications:

| | |
|---|---|
| a. Cladding Type: | Zircaloy (Zr) |
| b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT: | As specified in Table 1.1-3 for the applicable fuel assembly array/class. |
| c. Initial Maximum Rod Enrichment: | As specified in Table 1.1-3 for the applicable fuel assembly array/class. |
| d. Decay Heat Per Assembly: | $\leq$ 115 Watts |
| e. Post-irradiation Cooling Time and Average Burnup Per Assembly: | A post-irradiation cooling time after discharge $\geq$ 18 years and an average burnup $\leq$ 30,000 MWD/MTU. |
| f. Nominal Fuel Assembly Length: | $\leq$ 135.0 inches |
| g. Nominal Fuel Assembly Width: | $\leq$ 4.70 inches |
| h. Fuel Assembly Weight: | $\leq$ 400 lbs, including channels |

3. Uranium oxide, BWR FUEL DEBRIS, with or without Zircaloy channels, placed in DAMAGED FUEL CONTAINERS. The original fuel assemblies for the BWR FUEL DEBRIS shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6A, 6x6C, 7x7A, or 8x8A, and meet the following specifications:

| | | |
|---|---|---|
| a. | Cladding Type: | Zircaloy (Zr) |
| b. | Maximum PLANAR-AVERAGE INITIAL ENRICHMENT: | As specified in Table 1.1-3 for the applicable original fuel assembly array/class. |
| c. | Initial Maximum Rod Enrichment: | As specified in Table 1.1-3 for the applicable original fuel assembly array/class. |
| d. | Decay Heat Per DFC: | ≤ 115 Watts |
| e. | Post-irradiation Cooling Time and Average Burnup Per Assembly: | A post-irradiation cooling time after discharge ≥ 18 years and an average burnup ≤ 30,000 MWD/MTU for the original fuel assembly. |
| f. | Nominal Original Fuel Assembly Length: | < 135.0 inches |
| g. | Nominal Original Fuel Assembly Width: | ≤ 4.70 inches |
| h. | Fuel Debris Weight: | ≤ 400 lbs, including channels |

4. Mixed oxide (MOX), BWR INTACT FUEL ASSEMBLIES, with or without Zircaloy channels. MOX BWR INTACT FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6B, and meet the following specifications:

| | |
|---|---|
| a. Cladding Type: | Zircaloy (Zr) |
| b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT: | As specified in Table 1.1-3 for fuel assembly array/class 6x6B. |
| c. Initial Maximum Rod Enrichment: | As specified in Table 1.1-3 for fuel assembly array/class 6x6B. |
| d. Decay Heat Per Assembly: | $\leq$ 115 Watts |
| e. Post-irradiation Cooling Time and Average Burnup Per Assembly: | An assembly post-irradiation cooling time after discharge $\geq$ 18 years and an average burnup $\leq$ 30,000 MWD/MTIHM. |
| f. Nominal Fuel Assembly Length: | $\leq$ 135.0 inches |
| g. Nominal Fuel Assembly Width: | $\leq$ 4.70 inches |
| h. Fuel Assembly Weight: | $\leq$ 400 lbs, including channels |

5. Mixed oxide (MOX), BWR DAMAGED FUEL ASSEMBLIES, with or without Zircaloy channels, placed in DAMAGED FUEL CONTAINERS. MOX BWR DAMAGED FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6B, and meet the following specifications:

| | | |
|---|---|---|
| a. | Cladding Type: | Zircaloy (Zr) |
| b. | Maximum PLANAR-AVERAGE INITIAL ENRICHMENT: | As specified in Table 1.1-3 for fuel assembly array/class 6x6B. |
| c. | Initial Maximum Rod Enrichment: | As specified in Table 1.1-3 for fuel assembly array/class 6x6B. |
| d. | Decay Heat Per Assembly: | $\leq$ 115 Watts |
| e. | Post-irradiation Cooling Time and Average Burnup Per Assembly: | A post-irradiation cooling time after discharge $\geq$ 18 years and an average burnup $\leq$ 30,000 MWD/MTIHM. |
| f. | Nominal Fuel Assembly Length: | $\leq$ 135.0 inches |
| g. | Nominal Fuel Assembly Width: | $\leq$ 4.70 inches |
| h. | Fuel Assembly Weight: | $\leq$ 400 lbs, including channels |

6. Mixed Oxide (MOX), BWR FUEL DEBRIS, with or without Zircaloy channels, placed in DAMAGED FUEL CONTAINERS. The original fuel assemblies for the MOX BWR FUEL DEBRIS shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6B, and meet the following specifications:

| | | |
|---|---|---|
| a. | Cladding Type: | Zircaloy (Zr) |
| b. | Maximum PLANAR-AVERAGE INITIAL ENRICHMENT: | As specified in Table 1.1-3 for original fuel assembly array/class 6x6B. |
| c. | Initial Maximum Rod Enrichment: | As specified in Table 1.1-3 for original fuel assembly array/class 6x6B. |
| d. | Decay Heat Per DFC: | ≤ 115 Watts |
| e. | Post-irradiation Cooling Time and Average Burnup Per Assembly: | A post-irradiation cooling time after discharge ≥ 18 years and an average burnup ≤ 30,000 MWD/MTIHM for the original fuel assembly. |
| f. | Nominal Original Fuel Assembly Length: | ≤ 135.0 inches |
| g. | Nominal Original Fuel Assembly Width: | ≤ 4.70 inches |
| h. | Fuel Debris Weight: | ≤ 400 lbs, including channels |

B. Quantity per MPC:

Up to four (4) DFCs containing uranium oxide or MOX BWR FUEL DEBRIS. The remaining MPC-68F fuel storage locations may be filled with array/class 6x6A, 6x6B, 6x6C, 7x7A, and 8x8A fuel assemblies of the following type, as applicable:

a. Uranium oxide BWR INTACT FUEL ASSEMBLIES;

b. MOX BWR INTACT FUEL ASSEMBLIES;

c. Uranium oxide BWR DAMAGED FUEL ASSEMBLIES placed in DFCs; or

d. MOX BWR DAMAGED FUEL ASSEMBLIES placed in DFCs.

C. Fuel assemblies with stainless steel channels are not authorized for loading in the MPC-68F.

Table 1.1-2
PWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

| Fuel Assembly Array/Class | 14x14A | 14x14B | 14x14C | 14x14D | 15x15A |
|---|---|---|---|---|---|
| Clad Material (note 2) | Zr | Zr | Zr | SS | Zr |
| Design Initial U (kg/assy.) | ≤ 402 | ≤ 402 | ≤ 410 | ≤ 400 | ≤ 420 |
| Initial Enrichment (wt % $^{235}U$) | ≤ 4.6 | ≤ 4.6 | ≤ 4.6 | ≤ 4.0 | ≤ 4.1 |
| No. of Fuel Rods | 179 | 179 | 176 | 180 | 204 |
| Clad O.D. (in.) | ≥ 0.400 | ≥ 0.417 | ≥ 0.440 | ≥ 0.422 | ≥ 0.418 |
| Clad I.D. (in.) | ≤ 0.3514 | ≤ 0.3734 | ≤ 0.3840 | ≤ 0.3890 | ≤ 0.3660 |
| Pellet Dia. (in.) | ≤ 0.3444 | ≤ 0.3659 | ≤ 0.3770 | ≤ 0.3835 | ≤ 0.3580 |
| Fuel Rod Pitch (in.) | ≤ 0.556 | ≤ 0.556 | ≤ 0.580 | ≤ 0.556 | ≤ 0.550 |
| Active Fuel Length (in.) | ≤ 150 | ≤ 150 | ≤ 150 | ≤ 144 | ≤ 150 |
| No. of Guide Tubes | 17 | 17 | 5(note 3) | 16 | 21 |
| Guide Tube Thickness (in.) | ≥ 0.017 | ≥ 0.017 | ≥ 0.040 | ≥ 0.0145 | ≥ 0.0165 |

Table 1.1-2 (continued)
PWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

| Fuel Assembly Array/Class | 15x15B | 15x15C | 15x15D | 15x15E | 15x15F |
|---|---|---|---|---|---|
| Clad Material (note 2) | Zr | Zr | Zr | Zr | Zr |
| Design Initial U (kg/assy.) | ≤ 464 | ≤ 464 | ≤ 475 | ≤ 475 | ≤ 475 |
| Initial Enrichment (wt % $^{235}U$) | ≤ 4.1 | ≤ 4.1 | ≤ 4.1 | ≤ 4.1 | ≤ 4.1 |
| No. of Fuel Rods | 204 | 204 | 208 | 208 | 208 |
| Clad O.D. (in.) | ≥ 0.420 | ≥ 0.417 | ≥ 0.430 | ≥ 0.428 | ≥ 0.428 |
| Clad I.D. (in.) | ≤ 0.3736 | ≤ 0.3640 | ≤ 0.3800 | ≤ 0.3790 | ≤ 0.3820 |
| Pellet Dia. (in.) | ≤ 0.3671 | ≤ 0.3570 | ≤ 0.3735 | ≤ 0.3707 | ≤ 0.3742 |
| Fuel Rod Pitch (in.) | ≤ 0.563 | ≤ 0.563 | ≤ 0.568 | ≤ 0.568 | ≤ 0.568 |
| Active Fuel Length (in.) | ≤ 150 | ≤ 150 | ≤ 150 | ≤ 150 | ≤ 150 |
| No. of Guide Tubes | 21 | 21 | 17 | 17 | 17 |
| Guide Tube Thickness (in.) | ≥ 0.015 | ≥ 0.0165 | ≥ 0.0150 | ≥ 0.0140 | ≥ 0.0140 |

## Table 1.1-2 (continued)
## PWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

| Fuel Assembly Array/ Class | 15x15G | 16x16A | 17x17A | 17x17B | 17x17C |
|---|---|---|---|---|---|
| Clad Material (note 2) | SS | Zr | Zr | Zr | Zr |
| Design Initial U (kg/assy.) | ≤ 420 | ≤ 430 | ≤ 450 | ≤ 464 | ≤ 460 |
| Initial Enrichment (wt % $^{235}U$) | ≤ 4.0 | ≤ 4.6 | ≤ 4.0 | ≤ 4.0 | ≤ 4.0 |
| No. of Fuel Rods | 204 | 236 | 264 | 264 | 264 |
| Clad O.D. (in.) | ≥ 0.422 | ≥ 0.382 | ≥ 0.360 | ≥ 0.372 | ≥ 0.377 |
| Clad I.D. (in.) | ≤ 0.3890 | ≤ 0.3320 | ≤ 0.3150 | ≤ 0.3310 | ≤ 0.3330 |
| Pellet Dia. (in.) | ≤ 0.3825 | ≤ 0.3255 | ≤ 0.3088 | ≤ 0.3232 | ≤ 0.3252 |
| Fuel Rod Pitch≤ (in.) | ≤ 0.563 | ≤ 0.506 | ≤ 0.496 | ≤ 0.496 | ≤ 0.502 |
| Active Fuel Length (in.) | ≤ 144 | ≤ 150 | ≤ 150 | ≤ 150 | ≤ 150 |
| No. of Guide Tubes | 21 | 5 (note 3) | 25 | 25 | 25 |
| Guide Tube Thickness (in.) | ≥ 0.0145 | ≥ 0.0400 | ≥ 0.016 | ≥ 0.014 | ≥ 0.020 |

Notes:
1. Initial Uranium weights and all dimensions are design nominal values. Actual uranium weights may be up to 2.0% higher, within the manufacturers tolerance. Maximum and minimum dimensions are specified to bound variations in design nominal values among fuel assemblies within a given array/class.
2. Zr designates cladding material made of Zirconium or Zirconium alloys.
3. Each guide tube replaces four fuel rods.

Table 1.1-3
BWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

| Fuel Assembly Array/Class | 6x6A | 6x6B | 6x6C | 7x7A | 7x7B | 8x8A |
|---|---|---|---|---|---|---|
| Clad Material (note 2) | Zr | Zr | Zr | Zr | Zr | Zr |
| Design Initial U (kg/assy.) | ≤ 108 | ≤ 108 | ≤ 108 | ≤ 100 | ≤ 195 | ≤ 120 |
| Maximum PLANAR-AVERAGE INITIAL ENRICHMENT (wt.% $^{235}U$) | ≤ 2.7 | ≤ 2.7 for the $UO_2$ rods. See Note 3 for MOX rods | ≤ 2.7 | ≤ 2.7 | ≤ 4.2 | ≤ 2.7 |
| Initial Maximum Rod Enrichment (wt.% $^{235}U$) | ≤ 4.0 | ≤ 4.0 | ≤ 4.0 | ≤ 4.0 | ≤ 5.0 | ≤ 4.0 |
| No. of Fuel Rods | 36 | 36 (up to 9 MOX rods) | 36 | 49 | 49 | 64 |
| Clad O.D. (in.) | ≥ 0.5550 | ≥ 0.5625 | ≥ 0.5630 | ≥ 0.4860 | ≥ 0.5630 | ≥ 0.4120 |
| Clad I.D. (in.) | ≤ 0.4945 | ≤ 0.4945 | ≤ 0.4990 | ≤ 0.4200 | ≤ 0.4990 | ≤ 0.3620 |
| Pellet Dia. (in.) | ≤ 0.4940 | ≤ 0.4820 | ≤ 0.4880 | ≤ 0.4110 | ≤ 0.4880 | ≤ 0.3580 |
| Fuel Rod Pitch (in.) | ≤ 0.694 | ≤ 0.694 | ≤ 0.740 | ≤ 0.631 | ≤ 0.738 | ≤ 0.523 |
| Active Fuel Length (in.) | ≤ 110 | ≤ 110 | ≤ 77.5 | ≤ 79 | ≤ 150 | ≤ 110 |
| No. of Water Rods | 0 | 0 | 0 | 0 | 0 | 0 |
| Water Rod Thickness (in.) | N/A | N/A | N/A | N/A | N/A | N/A |
| Channel Thickness (in.) | ≤ 0.060 | ≤ 0.060 | ≤ 0.060 | ≤ 0.060 | ≤ 0.120 | ≤ 0.100 |

## Table 1.1-3 (continued)
## BWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

| Fuel Assembly Array/Class | 8x8B | 8x8C | 8x8D | 8x8E | 9x9A | 9x9B |
|---|---|---|---|---|---|---|
| Clad Material (Note 2) | Zr | Zr | Zr | Zr | Zr | Zr |
| Design Initial U (kg/assy.) | $\leq$ 185 | $\leq$ 185 | $\leq$ 185 | $\leq$ 180 | $\leq$ 173 | $\leq$ 173 |
| Maximum PLANAR-AVERAGE INITIAL ENRICHMENT (wt.% $^{235}$U) | $\leq$ 4.2 | $\leq$ 4.2 | $\leq$ 4.2 | $\leq$ 4.2 | $\leq$ 4.2 | $\leq$ 4.2 |
| Initial Maximum Rod Enrichment (wt.% $^{235}$U) | $\leq$ 5.0 | $\leq$ 5.0 | $\leq$ 5.0 | $\leq$ 5.0 | $\leq$ 5.0 | $\leq$ 5.0 |
| No. of Fuel Rods | 63 | 62 | 60 | 59 | 74/66 (Note 4) | 72 |
| Clad O.D. (in.) | $\geq$ 0.4840 | $\geq$ 0.4830 | $\geq$ 0.4830 | $\geq$ 0.4930 | $\geq$ 0.4400 | $\geq$ 0.4330 |
| Clad I.D. (in.) | $\leq$ 0.4250 | $\leq$ 0.4250 | $\leq$ 0.4190 | $\leq$ 0.4250 | $\leq$ 0.3840 | $\leq$ 0.3810 |
| Pellet Dia. (in.) | $\leq$ 0.4160 | $\leq$ 0.4160 | $\leq$ 0.4110 | $\leq$ 0.4160 | $\leq$ 0.3760 | $\leq$ 0.3740 |
| Fuel Rod Pitch (in.) | $\leq$ 0.641 | $\leq$ 0.641 | $\leq$ 0.640 | $\leq$ 0.640 | $\leq$ 0.566 | $\leq$ 0.569 |
| Design Active Fuel Length (in.) | $\leq$ 150 | $\leq$ 150 | $\leq$ 150 | $\leq$ 150 | $\leq$ 150 | $\leq$ 150 |
| No. of Water Rods | 1 | 2 | 1 - 4 (Note 6) | 5 | 2 | 1 (Note 5) |
| Water Rod Thickness (in.) | $\geq$ 0.034 | > 0.00 | > 0.00 | $\geq$ 0.034 | > 0.00 | > 0.00 |
| Channel Thickness (in.) | $\leq$ 0.120 | $\leq$ 0.120 | $\leq$ 0.120 | $\leq$ 0.100 | $\leq$ 0.120 | $\leq$ 0.120 |

Table 1.1-3 (continued)
BWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

| Fuel Assembly Array/Class | 9x9C | 9x9D | 9x9E | 9x9F | 10x10A |
|---|---|---|---|---|---|
| Clad Material | Zr | Zr | Zr | Zr | Zr |
| Design Initial U (kg/assy.) | ≤ 173 | ≤ 170 | ≤ 170 | ≤ 170 | ≤ 182 |
| Maximum PLANAR-AVERAGE INITIAL ENRICHMENT (wt.% $^{235}U$) | ≤ 4.2 | ≤ 4.2 | ≤ 4.2 | ≤ 4.2 | ≤ 4.2 |
| Initial Maximum Rod Enrichment (wt.% $^{235}U$) | ≤ 5.0 | ≤ 5.0 | ≤ 5.0 | ≤ 5.0 | ≤ 5.0 |
| No. of Fuel Rods | 80 | 79 | 76 | 76 | 92/78 (Note 7) |
| Clad O.D. (in.) | ≥ 0.4230 | ≥ 0.4240 | ≥ 0.4170 | ≥ 0.4430 | ≥ 0.4040 |
| Clad I.D. (in.) | ≤ 0.3640 | ≤ 0.3640 | ≤ 0.3590 | ≤ 0.3810 | ≤ 0.3520 |
| Pellet Dia. (in.) | ≤ 0.3565 | ≤ 0.3565 | ≤ 0.3525 | ≤ 0.3745 | ≤ 0.3455 |
| Fuel Rod Pitch (in.) | ≤ 0.572 | ≤ 0.572 | ≤ 0.572 | ≤ 0.572 | ≤ 0.510 |
| Design Active Fuel Length (in.) | ≤ 150 | ≤ 150 | ≤ 150 | ≤ 150 | ≤ 150 |
| No. of Water Rods | 1 | 2 | 5 | 5 | 2 |
| Water Rod Thickness (in.) | > 0.020 | ≥ 0.0305 | ≥ 0.0305 | ≥ 0.0305 | ≥ 0.0300 |
| Channel Thickness (in.) | ≤ 0.100 | ≤ 0.100 | ≤ 0.100 | ≤ 0.100 | ≤ 0.120 |

## Table 1.1-3 (continued)
## BWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

| **Fuel Assembly Array/Class** | **10x10B** | **10x10C** | **10x10D** | **10x10E** |
|---|---|---|---|---|
| Clad Material (note 2) | Zr | Zr | SS | SS |
| Design Initial U (kg/assy.) | $\leq$ 182 | $\leq$ 180 | $\leq$ 125 | $\leq$ 125 |
| Maximum PLANAR-AVERAGE INITIAL ENRICHMENT (wt.% $^{235}$U) | $\leq$ 4.2 | $\leq$ 4.2 | $\leq$ 4.0 | $\leq$ 4.0 |
| Initial Maximum Rod Enrichment (wt.% $^{235}$U) | $\leq$ 5.0 | $\leq$ 5.0 | $\leq$ 5.0 | $\leq$ 5.0 |
| No. of Fuel Rods | 91/83 (note 8) | 96 | 100 | 96 |
| Clad O.D. (in.) | $\geq$ 0.3957 | $\geq$ 0.3790 | $\geq$ 0.3960 | $\geq$ 0.3940 |
| Clad I.D. (in.) | $\leq$ 0.3480 | $\leq$ 0.3294 | $\leq$ 0.3560 | $\leq$ 0.3500 |
| Pellet Dia. (in.) | $\leq$ 0.3420 | $\leq$ 0.3224 | $\leq$ 0.3500 | $\leq$ 0.3430 |
| Fuel Rod Pitch (in.) | $\leq$ 0.510 | $\leq$ 0.488 | $\leq$ 0.565 | $\leq$ 0.557 |
| Design Active Fuel Length (in.) | $\leq$ 150 | $\leq$ 150 | $\leq$ 83 | $\leq$ 83 |
| No. of Water Rods | 1 (Note 5) | 5 (Note 9) | 0 | 4 |
| Water Rod Thickness (in.) | > 0.00 | $\geq$ 0.034 | N/A | $\geq$ 0.022 |
| Channel Thickness (in.) | $\leq$ 0.120 | $\leq$ 0.055 | $\leq$ 0.080 | $\leq$ 0.080 |

1. Initial uranium weights and all dimensions are design nominal values. Actual uranium weights may be up to 1.5% higher, within the manufacturer's tolerance. Maximum and minimum dimensions are specified to bound variations in design nominal values among fuel assemblies within a given array/class.
2. Zr designates cladding material made of Zirconium or Zirconium alloys.
3. $\leq$ 0.612 wt.% $^{235}$U and $\leq$ 1.578 wt.% total fuel fissile plutonium ($^{239}$Pu and $^{241}$Pu).
4. This assembly class contains 74 rods; 66 full length rods and 8 partial length rods.
5. Square, replacing nine fuel rods.
6. Variable
7. This assembly class contains 92 total fuel rods; 78 full length rods and 14 partial length rods.
8. This assembly class contains 91 total fuel rods; 83 full length rods and 8 partial length rods.
9. One diamond shaped water rod replacing the four center fuel rods and four rectangualr water rods dividing the assembly into four quadrants.

Table 1.1-4
FUEL ASSEMBLY COOLING AND DECAY HEAT GENERATION

| Post-irradiation Cooling Time (years) | MPC-24 PWR Assembly Decay Heat (Watts) | MPC-68 BWR Assembly Decay Heat (Watts) |
|---|---|---|
| 5 | ≤ 792 | ≤ 272 |
| ≤ 6 | ≤ 773 | ≤ 261 |
| ≤ 7 | ≤ 703 | ≤ 238 |
| ≤ 8 | ≤ 698 | ≤ 236 |
| ≤ 9 | ≤ 692 | ≤ 234 |
| ≤ 10 | ≤ 687 | ≤ 232 |
| ≤ 11 | ≤ 683 | ≤ 231 |
| ≤ 12 | ≤ 678 | ≤ 229 |
| ≤ 13 | ≤ 674 | ≤ 228 |
| ≤ 14 | ≤ 669 | ≤ 227 |
| > 14 | ≤ 665 | ≤ 226 |

Table 1.1-5
FUEL ASSEMBLY COOLING AND AVERAGE BURNUP

| Post-irradiation Cooling Time (years) | MPC-24 PWR Assembly Burnup (MWD/MTU) | MPC-68 BWR Assembly Burnup (MWD/MTU) |
|---|---|---|
| ≥ 5 | ≤ 28,700 | ≤ 26,000 |
| ≥ 6 | ≤ 32,800 | ≤ 29,100 |
| ≥ 7 | ≤ 33,300 | ≤ 29,600 |
| ≥ 8 | ≤ 35,600 | ≤ 31,400 |
| ≥ 9 | ≤ 37,000 | ≤ 32,800 |
| ≥ 10 | ≤ 38,300 | ≤ 33,800 |
| ≥ 11 | ≤ 39,300 | ≤ 34,800 |
| ≥ 12 | ≤ 40,200 | ≤ 35,500 |
| ≥ 13 | ≤ 40,900 | ≤ 36,200 |
| ≥ 14 | ≤ 41,500 | ≤ 36,900 |
| ≥ 15 | ≤ 42,100 | ≤ 37,600 |

## LIST OF ASME CODE EXCEPTIONS FOR HI-STAR 100 SYSTEM

Table 1.3-1

| Component | Reference ASME Code Section/Article | Code Requirement | Exception, Justification & Compensatory Measures |
|---|---|---|---|
| MPC | NB-1100 | Statement of requirements for Code stamping of components. | MPC enclosure vessel 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. |
| MPC | NB-2000 | Requires materials to be supplied by ASME-approved material supplier. | Materials will be supplied by Holtec approved suppliers with Certified Material Test Reports (CMTRs) in accordance with NB-2000 requirements. |
| MPC Lid and Closure Ring Welds | NB-4243 | Full penetration welds required for Category C Joints (flat head to main shell per NB-3352.3) | MPC lid and closure ring are not full penetration welds. They are welded independently to provide a redundant seal. Additionally, a weld efficiency factor of 0.45 has been applied to the analyses of these welds. |
| MPC Closure Ring, Vent and Drain Cover Plate Welds | NB-5230 | Radiographic (RT) or ultrasonic (UT) examination required. | Root and final liquid penetrant examination to be performed in accordance with NB-5245. The MPC vent and drain cover plate welds are leak tested. The closure ring provides independent redundant closure for vent and drain cover plates. |

| Component | Reference ASME Code Section/Article | Code Requirement | Exception, Justification & Compensatory Measures |
|---|---|---|---|
| MPC Enclosure Vessel and Lid | NB-6111 | All completed pressure retaining systems shall be pressure tested. | The MPC enclosure vessel is seal welded in the field following fuel assembly loading. The MPC enclosure vessel shall then be hydrostatically tested as defined in Chapter 9. Accessibility for leakage inspections preclude a Code compliant hydrostatic test. All MPC enclosure vessel welds (except the lid-to-shell and closure ring and vent/drain cover plate) are inspected by RT or UT. The MPC lid-to-shell root and final weld layers are PT examined and the entire weld is either UT examined or multilayer PT examined. The vent/drain cover plate weld is confirmed by leakage testing and liquid penetrant examination and the closure ring weld is confirmed by liquid penetrant examination. The inspection process, including findings, (indications) shall be made a permanent part of the certificate holder's records by video, photographic, or other means which provide an equivalent retrievable record of weld integrity. The video or photographic records should be taken during the final interpretation period described in ASME Section V, Article 6, T-676. The inspection of the weld must be performed by qualified personnel and shall meet the acceptance requirements of ASME Code Section III, NB-5350 for PT or NB-5332 for UT. |

| Component | Reference ASME Code Section/Article | Code Requirement | Exception, Justification & Compensatory Measures |
|---|---|---|---|
| MPC Enclosure Vessel | NB-7000 | Vessels are required to have overpressure protection. | No overpressure protection is provided. Function of MPC enclosure vessel is to contain radioactive contents under normal, off-normal, and accident conditions of storage. MPC vessel is designed to withstand maximum internal pressure considering 100% fuel rod failure and maximum accident temperatures. |
| MPC Enclosure Vessel | NB-8000 | States requirements for nameplates, stamping and reports per NCA-8000. | HI-STAR 100 System to be marked and identified in accordance with 10CFR71 and 10CFR72 requirements. Code stamping is not required. QA data package to be in accordance with Holtec approved QA program. |
| Overpack Helium Retention Boundary | NB-1100 | Statement of requirements for Code stamping of components. | Overpack helium retention boundary 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. |
| Overpack Helium Retention Boundary | NB-2000 | Requires materials to be supplied by ASME approved Material Supplier. | Materials will be supplied by Holtec approved suppliers with CMTRs per NB-2000. |
| Overpack Helium Retention Boundary | NB-7000 | Vessels are required to have overpressure protection. | No overpressure protection is provided. Function of overpack vessel is to contain helium contents under normal, off-normal, and accident conditions. Overpack vessel is designed to withstand maximum internal pressure and maximum accident temperatures. |

| Component | Reference ASME Code Section/Article | Code Requirement | Exception, Justification & Compensatory Measures |
|---|---|---|---|
| Overpack Helium Retention Boundary | NB-8000 | Statement of Requirements for nameplates, stamping and reports per NCA-8000. | HI-STAR 100 System to be marked and identified in accordance with 10CFR71 and 10CFR72 requirements. Code stamping is not required. QA data package to be in accordance with Holtec's approved QA program. |
| MPC Basket Assembly | NG-2000 | Requires materials to be supplied by ASME approved Material Supplier. | Materials will be supplied by Holtec approved supplier with CMTRs in accordance with NG-2000 requirements. |
| MPC Basket Assembly | NG-8000 | States requirements for nameplates, stamping and reports per NCA-8000. | The HI-STAR 100 System will be marked and identified in accordance with 10CFR71 and 10CFR72 requirements. No Code stamping is required. The MPC basket data package will be in conformance with Holtec's QA program. |
| Overpack Intermediate Shells | NF-4622 | All welds, including repair welds, shall be post-weld heat treated (PWHT). | Intermediate shell-to-top flange welds and intermediate shell-to-bottom plate welds do not require PWHT. These welds attach non-pressure retaining parts to pressure retaining parts. The pressure retaining parts are > 7 inches thick. Localized PWHT will cause material away from the weld to experience elevated temperatures which will have an adverse effect on the material properties. |
| Overpack Helium Retention Boundary | NG-2000 | Perform radiographic examination after post-weld heat treatment (PWHT) | Radiography of the helium retention boundary welds after PWHT is not required. All welds (including repairs) will have passed radiographic examination prior to PWHT of the entire containment boundary. Confirmatory radiographic examination after PWHT is not necessary because PWHT is not known to introduce new weld defects in nickel steels. |

| Component | Reference ASME Code Section/Article | Code Requirement | Exception, Justification & Compensatory Measures |
|---|---|---|---|
| Overpack Intermediate Shells | NF-2000 | Requires materials to be supplied by ASME approved Material Supplier. | Materials will be supplied by Holtec approved supplier with CMTRs in accordance with NF-2000 requirements. |
| Overpack Helium Retention Boundary | NB-2330 | Defines the methods for determining the $T_{NDT}$ for impact testing of materials. | $T_{NDT}$ shall be defined in accordance with Regulatory Guides 7.11 and 7.12 for the helium retention boundary components. |