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SAFETY EVALUATION REPORT

Docket No. 72-1015
NAC-UMS CASK SYSTEM
Certificate of Compliance No. 1015
Amendment No. 1

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SUMMARY

By application dated July 16, 1999, as supplemented, NAC International, Inc. (NAC) requested approval of an amendment, under the provisions of 10 CFR Part 72, Subpart K, to the Certificate of Compliance for the UMS Universal Storage System.

The NAC-UMS system (the cask) consists of the following components: (1) transportable storage canister (TSC), which contains the spent fuel; (2) vertical concrete cask (VCC), which contains the TSC during storage; and (3) a transfer cask, which contains the TSC during loading, unloading, and transfer operations. The cask stores up to 24 pressurized water reactor (PWR) fuel assemblies or 56 boiling water reactor (BWR) fuel assemblies.

For this amendment to the Certificate of Compliance, NAC requested (1) changes to authorized contents to allow Maine Yankee site-specific spent fuels within the PWR basket, including damaged or consolidated fuel in a Maine Yankee fuel can and burnups up to 50,000 MWd/MTU, (2) changes to allow longer times for PWR spent fuel cask loading operations based on reduced heat loads, (3) authorization to store, without canning, intact PWR assemblies (no fuel rod cladding defects, or with no known or suspected fuel rod cladding defects greater than pinhole leaks or hairline cracks) with missing grid spacers (up to an unsupported length of 60 inches), (4) editorial clarifications to the technical specifications (TS), and (5) deletion of a reference to the NS-4-FR trade name of the solid neutron shielding material in the VCC shield plug.

The NAC-UMS cask was evaluated against the regulatory standards in 10 CFR Part 72. NAC demonstrated the structural adequacy of the Maine Yankee site-specific fuels (MYSSF) that are intact (with and without damaged assembly hardware), consolidated, damaged, and high-burnup. The thermal evaluation verified that the cladding (including high burnup) and cask component temperatures were acceptable for all authorized spent fuel contents and configurations under normal, off-normal and accident conditions. The shielding evaluation determined that the site-specific spent fuels and various configurations, including fuel assembly hardware, are either bounded by the design basis fuel or were acceptable for meeting the applicable regulatory requirements. The criticality evaluation demonstrated that, for all proposed MYSSF configurations, the criticality requirements of 10 CFR Part 72 are met. The original NAC-UMS confinement evaluation remains valid since the design is “leak-tight.” The TS were revised and identify the necessary specifications to provide reasonable assurance that the NAC-UMS cask will allow safe storage of all authorized contents.

NRC staff reviewed the application using the guidance in NUREG-1536, “Standard Review Plan for Dry Cask Storage Systems.” Based on the statements and representations in the application, as supplemented, and the conditions discussed in this Safety Evaluation Report (SER), the staff concluded that the NAC-UMS cask meets the requirements of 10 CFR Part 72. The changes to the Certificate of Compliance are indicated by change bars in the margin. Section 12 of the SER lists the changes to the TS.

Background Information

The TSC is the confinement system for the stored fuel. The TSC assembly consists of a right circular cylindrical shell with a welded bottom plate, a fuel basket, a shield lid, two penetration port covers, and a structural lid. The cylindrical shell, plus the bottom plate and lids, constitute the confinement boundary. The stainless steel fuel basket is a right circular cylinder configuration with either 24 (PWR) or 56 (BWR) stainless steel fuel tubes laterally supported by a series of stainless steel (PWR) or carbon steel (BWR) support disks. The square fuel tubes in the PWR basket include Boral sheets on all four sides for criticality control. The square fuel tubes in the BWR basket may include Boral sheets on up to two sides for criticality control. Aluminum heat transfer disks are spaced midway between the support disks and are the primary path for conducting heat from the spent fuel assemblies to the TSC wall for the PWR basket. There are three TSC configurations of different lengths for PWR contents and two TSC configurations of different lengths for BWR contents.

The VCC is the storage overpack for the TSC and provides structural support, shielding, protection from environmental conditions, and natural convection cooling of the TSC during long-term storage. The VCC is a reinforced concrete (Type II Portland cement) structure with a carbon steel inner liner. The VCC has an annular air passage to allow the natural circulation of air around the TSC. The spent fuel decay heat is transferred from the fuel assemblies to the tubes in the fuel basket and through the heat transfer disks to the TSC wall. Heat flows by convection from the TSC wall to the circulating air, as well as by radiation from the TSC wall to the VCC inner liner. The heat flow to the circulating air from the TSC wall and the VCC liner is exhausted through the air outlets. The top of the VCC is closed by a shield plug, consisting of carbon steel plate (gamma shielding) and NS-4-FR (neutron shielding), and a carbon steel lid. The lid is bolted in place and has tamper indicating seals on two of the bolts. There are three VCC configurations of different lengths for PWR contents, and two VCC configurations of different lengths for BWR contents.

The transfer cask provides shielding during TSC movements between work stations, the VCC, or the transport cask. It is a multi-wall (steel/lead/NS-4-FR/steel) design and has a bolted top retaining ring to prevent a loaded canister from being inadvertently removed through the top of the transfer cask. Retractable (hydraulically operated) bottom shield doors on the transfer cask are used during loading and unloading operations. To minimize contamination of the TSC exterior and interior of the transfer cask, clean water is circulated in the gap between the transfer cask and the TSC during loading operations. A carbon steel extension ring can be bolted to the top of the transfer cask and used to extend the operational height of a transfer cask. This height extension allows a transfer cask designed for a specific TSC length to be used with the next longer TSC.

References

NAC International, Inc., application dated July 16, 1999. Supplements dated October 20 and November 16, 1999; and February 4 and 7, March 17, April 18, May 31, June 19, July 27, August 24, and September 1, 6 and 12, 2000.

Safety Analysis Report for the UMS Universal Storage System, Rev. 5, submitted September 29, 2000.

1.0 GENERAL DESCRIPTION

1.1 System Description

The NAC-UMS system is a transport-compatible dry storage system that uses a stainless steel TSC stored within the central cavity of a VCC. The TSC is designed to be compatible with the NAC-UMS transport cask to allow future shipment. The VCC provides radiation shielding and contains internal air flow paths that allow decay heat from the TSC spent fuel contents to be removed by natural air circulation around the canister wall.

The principal components of the NAC-UMS system are the TSC, the VCC, and the transfer cask. The transfer cask is used to move the loaded TSC to and from the VCC and provides radiation shielding while the TSC is being closed and sealed. The TSC is placed in the VCC by positioning the transfer cask on top of the VCC and subsequently lowering the TSC. Each NAC-UMS system component is assigned a safety classification (Category A, B, or C) in Table 2.3-1 of the Safety Analysis Report (SAR). The component safety classification is based on NUREG/CR-6407, “Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety.”

The NAC-UMS is designed to store up to 24 PWR or up to 56 BWR spent fuel assemblies. Based on the length of the fuel assemblies, PWR fuels are grouped into three classes (Classes 1 through 3), and BWR fuels are grouped into two classes (Classes 4 and 5). Class 1 and 2 PWR fuel assemblies include non-fuel-bearing inserts (components which include thimble plugs and burnable poison rods installed in the guide tubes). Classes 4 and 5 BWR assemblies include the zircaloy channels. The spent fuel is loaded into a TSC which contains a stainless steel gridwork referred to as a basket.

1.2 Contents

The applicant requested changes to the authorized contents to include MYSSF assemblies and configurations, as follows:

A. Allowable Contents

1. Combustion Engineering (CE) 14 x 14 PWR intact fuel assemblies meeting the original specifications.
2. PWR intact fuel assemblies may contain inserted control element assemblies (CEA) or inserted in-core instrument (ICI) thimbles.
3. PWR intact fuel assemblies with fuel rods replaced with stainless steel or zircaloy rods or with uranium oxide rods nominally enriched up to 1.95 wt % ^{235}U.
4. PWR intact 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 intact fuel assemblies with annular axial end blankets. The axial end blanket enrichment may be up to 2.6 wt % ^{235}U.
6. PWR intact fuel assemblies with solid filler rods or burnable poison rods occupying up to 16 of 176 fuel rod positions.

7. PWR intact 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.

B. Allowable contents requiring preferential loading based on shielding, criticality or thermal constraints. The preferential loading requirement for these fuel configurations is described in Table 12B2-6 of the TS.

1. PWR intact fuel assemblies with up to 176 fuel rods missing from the fuel assembly lattice.
2. PWR intact fuel assemblies with a burnup between 45,000 and 50,000 MWd/MTU.
3. PWR intact fuel assemblies with a burnable poison rod replaced by a hollow zircaloy rod.
4. Fuel enclosed in a Maine Yankee fuel can. The allowable contents of the Maine Yankee fuel can are:
    a) A PWR intact fuel assembly.
    b) PWR fuel assemblies with up to two intact and/or damaged fuel rods inserted in each fuel assembly guide tube and/or with up to two burnable poison rods inserted in each guide tube provided that the total number of fuel rods and burnable poison rods does not exceed 176. 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.
    c) A damaged fuel assembly with up to 100% of the fuel rods classified as damaged and/or damaged or missing assembly hardware components.
    d) Individual intact or damaged fuel rods in a rod type structure, which may be a guide tube, to maintain configuration control.
    e) Fuel debris consisting of fuel rods with exposed fuel pellets or individual intact or partial fuel pellets not contained in fuel rods.
    f) Consolidated fuel lattice structure with a 17 x 17 array formed by grids and top and bottom end fittings connected by four solid stainless steel rods. Maximum contents:
        - Up to 289 fuel rods
        - Lattice weight less than or equal to 2,100 pounds
    g) High burnup fuel (45,000 to 50,000 MWd/MTU).

Since the applicant's evaluation (see item A.7 above) for PWR Intact 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) was based on standard PWR fuel, a new item 1.H was added, for completeness and consistency, to Table B2-1 of the TS.

The staff reviewed the applicant's request to authorize the MYSSF as contents and concludes that they will not affect the ability of the cask to meet the requirements of 10 CFR Part 72.

1.3 Reduced PWR Fuel Heat Loads

The applicant also requested longer allowable vacuum drying and transfer cask loading times for reduced (less than the design bases) PWR fuel assembly heat loads. The designated cask heat loads are controlled in the TS and are evaluated in Section 4 of this SER. The staff concludes that the applicant's request to authorize longer allowable vacuum drying and transfer cask loading times for reduced PWR fuel assembly heat loads will not affect the ability of the cask to meet the requirements of 10 CFR Part 72.

1.4 Drawing Changes

The applicant submitted new drawings of the Maine Yankee spent fuel can assembly in support of the amendment request. The stainless steel fuel can is sized to accommodate a fuel assembly and may only be loaded in a corner position of the PWR basket. The fuel can is constructed of 18 gauge steel and is approximately 163 inches long, with a square dimension of approximately 8.7 inches. The fuel can has screened holes in each corner to allow water drainage. The fuel can lid is held in place by the canister shield lid, and thus can only be used in a Class 1 canister.

The staff concludes that the new drawings of the Maine Yankee fuel can will not affect the ability of the cask to meet the requirements of 10 CFR Part 72.

2.0 PRINCIPAL DESIGN CRITERIA

The applicant modified the principal design criteria to reflect the authorization to store MYSSF that is configured differently or that has different fuel parameters (i.e., enrichment or burnup) than the authorized design basis fuel assemblies. Different site-specific spent fuel configurations resulted from conditions that occurred during reactor operations, participation in research and development programs or from the insertion of control or other components within a fuel assembly. The applicant demonstrated that site-specific spent fuel configurations are bounded by the design basis fuel or evaluated the specific configuration separately. A description of the specific configurations analyzed was previously presented in Section 1.2 of this SER.

The applicant also described the MYSSF preferential loading provisions. Corner positions in the basket are used primarily for loading fuel with missing or replaced fuel rods, consolidated fuel lattices and damaged fuel. Peripheral positions in the basket are used for high burnup fuel. High burnup Maine Yankee fuel must be loaded as damaged fuel, i.e., in a fuel can, if the specified cladding oxide layer criteria are not met.

The staff concludes that the amended principal design criteria are acceptable and do not affect the ability of the cask to meet the requirements of 10 CFR Part 72. A more detailed evaluation of design criteria and an assessment of compliance are provided in following Sections of this SER.

3.0 STRUCTURAL

This Section evaluates site-specific design features and corresponding structural analyses of the NAC-UMS system for storing the Maine Yankee spent fuels.

3.1 Maine Yankee Intact Spent Fuel

Dead Load. Section 3.6.1.1 of the SAR determined that the weight of the design basis PWR fuel assembly of 1,567 lbs envelops that of the standard CE 14 x 14 fuel assembly of 1,360 lbs at the Maine Yankee site. The SAR stated that weights of other fuel configurations with removed fuel rods, with replaced rods, or with poison rods are less than or bounded by that of the standard CE 14 x 14 fuel assembly. On this basis, the staff concludes that the NAC-UMS system is structurally adequate, and no additional analysis for the Maine Yankee spent fuels is required for dead load effects.

Lifting Operations. The SAR limits loading of one consolidated fuel lattice, which weighs less than 2,100 lbs, into a TSC. The SAR determined that, for a fully loaded TSC at Maine Yankee, the total weight of 33,380 lbs for one consolidated fuel lattice plus 23 standard CE 14 x 14 fuel assemblies is bounded by that of 37,608 lbs for 24 design basis PWR fuel assemblies. Therefore, the staff concurs with the SAR conclusion that margins of safety evaluated, in SAR Section 3.4.3, for NAC-UMS design basis fuel lifting operations bound those for the Maine Yankee site-specific fuels.

Off-Normal Canister Handling. Section 11.1.6.1 of the SAR stated that the total weight of the canister contents for the Maine Yankee site-specific spent fuels is bounded by the PWR design basis fuels. The SAR concludes and the staff agrees that safety margins evaluated, in SAR Section 11.1.3, for off-normal canister handling loads bound the canister configuration loaded with the Maine Yankee site-specific fuels.

Cask Tip-Over Accident Deceleration g-Loads. Section 11.2.15.1.1 of the SAR presented a tip-over analysis to determine deceleration g-loads for the NAC-UMS system applicable to the Maine Yankee site. The analysis follows the same approach of SAR Section 11.2.12. To accommodate site-specific design parameters for the independent spent fuel storage installation (ISFSI) pad supported on a 4.5-foot thick upper subgrade and a 10-foot thick lower soil layer, the SAR performed a parametric study by considering 24 combinations of varying soil and concrete densities and concrete compressive strength for the NAC-UMS system. This results in the following maximum rigid-body lateral decelerations at the canister top support disk and structural lid:

	Deceleration (g)	
Cask Configuration	Top Support Disk	Top Structural Lid
PWR Class 1	32.3	35.3
PWR Class 2	34.2	37.6

On the basis of the parametric study, the staff has reasonable assurance that the above maximum decelerations are representative and adequate for evaluating the cask tip-over accident if the Maine Yankee ISFSI satisfies the pad and foundation parameters as listed in Section 12.2.15.1 of the SAR.

Support Disk Evaluation for Cask Tip-over Accident. Section 11.2.15.1.1 of the SAR determined the support disk dynamic load factors (DLFs) of 1.07 and 1.02 for the PWR Class 1 and Class 2 configurations, respectively. Applying the DLFs to the above maximum rigid body decelerations, the SAR computed peak equivalent static loads of 34.6 g and 34.9 g for the top support disks of the PWR Class 1 and Class 2, respectively. These loads are bounded by the 40-g equivalent static load used in SAR Section 11.2.12.4.1 for analyzing the support disks for the design basis fuels. Therefore, margins of safety for the Maine Yankee standard fuels are larger than those evaluated, in SAR Section 11.2.12.4.1, for the design basis fuel support disks. This is acceptable.

Vertical Concrete Cask Seismic Stability. SAR Section 11.2.15.1.4 evaluated cask seismic stability against sliding and tip-over. The evaluation assumed, at the top of the Maine Yankee ISFSI pad, a design earthquake motion of 0.38 g for the two horizontal components and 0.253 g for the vertical component. The SAR determined that a minimum horizontal component of 0.45 g is required to cause the VCC to tip-over. This corresponds to a tip-over margin of 1.18, which is greater than the required factor of safety of 1.1 per American National Standards Institute/American Nuclear Society (ANSI/ANS)-57.9. Considering the same ANSI/ANS-57.9 criteria, the SAR also determined that a static friction coefficient of 0.50 is required of the cask-to-pad interface to provide a margin greater than 1.1 in preventing the cask from sliding. To achieve this static friction coefficient, Section B3.4.2 of SAR Appendix 12B specifies that the ISFSI pad shall have a broom finish or brushed surface as defined in American Concrete Institute (ACI) 116R-90, “Cement and Concrete Technology,” and described in Sections 7.12 and 7.13.4 of ACI 302.1R, “Guide for Concrete Floor and Slab Construction.” The SAR also states that 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.

3.2 Maine Yankee Consolidated and Damaged Spent Fuels

A specially designed Maine Yankee fuel can (MYFC) is sized to hold an intact fuel assembly, consolidated fuel, or damaged fuel. The stainless steel can provides a structural restraint for maintaining the configuration of damaged fuel in its analyzed envelope. Both consolidated fuel lattices and damaged fuels must be placed in a MYFC for loading into a canister basket

Maine Yankee Fuel Can Evaluation. The 162.8-inch long MYFC has an external square dimension of 8.62 inches to allow it to be placed at the four corner positions of the NAC-UMS fuel basket. SAR Section 3.6.1.2 performed a structural analysis of the MYFC for dead weight and handling loads of normal conditions of storage. The resulting stresses in the fuel can tube are compared to the stress allowables in accordance with American Society of Mechanical Engineers (ASME) Code Section III, subsection NG. For stresses introduced to the lifting slots during handling operation, the SAR compared the calculated von Mises stress to material yield strength for a safety factor of 3. These stress analyses have shown acceptable results with large design margins.

SAR Section 11.2.15.1.3 evaluates structural performance of the MYFC for the loadings associated with the 24-inch drop and tip-over of the VCC. For the 24-inch drop, the SAR considered an axial force of 8,500 lbs, which corresponds to a 60-g bounding deceleration, to obtain a stress margin of 7.9 for the fuel can tube. The same axial force was also shown to be much less than the fuel can buckling load of 1.65×10^6 lbs. For the cask tip-over accident, the SAR applied a 60-g lateral deceleration to the fuel can for calculating fuel can tube stresses and strains with acceptable margins.

Support Disk Evaluation for Consolidated Fuel. SAR Section 11.2.15.1.2 presented a load combination parametric study of the support disk for allowing a consolidated fuel lattice held in an MYFC to be placed in one of the four corner basket positions. The study considered a 60-g canister side impact for five fuel can position cases. The "base" case placed design basis PWR fuel assembles in all 24 basket positions available. The other four cases involved possible load combinations for the placement of four MYFCs in the corner positions for which only one of them holds a consolidated fuel lattice weighing 2,100 lbs. SAR Table 11.2.15.1.2-1 compared stress results for the five cases under four support disk drop orientations. The results demonstrate that stress performance of the support disk is primarily associated with its deformation by in-plane ovalization. Therefore, the placement of one consolidated fuel lattice at a corner position does not result in stress values larger than those associated with the design basis PWR fuel assemblies weighing 1,567 lbs each. On this basis, the staff concludes that the support disks are structurally adequate to allow one consolidated fuel lattice held in a MYFC and placed at a basket corner position.

Support Disk Evaluation for Damaged Fuel. When damaged fuels are held in MYFCs, the SAR permits the placement of only four MYFCs in a TSC. The total weight of an MYFC plus a damaged standard Maine Yankee 14 x 14 fuel assembly is less than that of the design basis PWR fuel assembly. Therefore, the inertia load effects on the support disk are bounded by those evaluated in SAR Sections 11.2.12.4.1 and 11.2.15.1.2 for a cask tip-over accident. As a result, the staff concludes that the support disk is structurally adequate for storing four MYFCs at the basket corner positions.

3.3 Maine Yankee High Burnup Fuel

SAR Section 11.2.15.1.5 evaluated buckling of the Maine Yankee high burnup fuel subject to a 60-g axial impact load, the design basis deceleration which envelops the deceleration associated with a 24-inch vertical cask drop accident. Consistent with Interim Staff Guidance (ISG) -12, Rev.1, the SAR included pellet weight and derated material properties of irradiated fuel for calculating the buckling load of a CE 14 x 14 fuel rod. To account for a bounding oxide layer of 80 microns for the intact fuel up to 50,000 MWd/MTU, a net clad thickness of 0.023 inch (0.026 - 0.003 = 0.023 inch) is used for calculating the fuel rod cross-sectional moment of inertia. The SAR modeled the full length of the fuel rod to be laterally constrained at spacer grids, and uses the ANSYS code to obtain the buckling capacity of 39.0 g. By considering the 60-g design basis axial impact load as impulsive and short duration in nature, the SAR determined a DLF of 0.244 to result in an equivalent static load of 14.6 g (60 x 0.244 = 14.6 g). This load is smaller than the fuel rod buckling capacity of 39.0 g. On this basis, the staff concurs with the SAR conclusion that the Maine Yankee high burnup fuel is structurally capable of withstanding a 24-inch vertical cask drop accident.

3.4 Maine Yankee Intact Spent Fuel with Damaged Assembly Hardware

SAR Section 11.2.16 evaluates potential buckling and side impact failure of the fuel rods of an assembly with damaged or missing spacer grids. The SAR simulated the effects of missing grids by ignoring them as lateral supports of an otherwise fully supported fuel rod with nominal grid spacing.

Fuel Rod Buckling. To determine bounding buckling load, the SAR considered an unsupported length of 60 inches at the bottom end of the fuel rod subject to axial impact. This envelops the configuration of missing a grid at the 33.0-inch elevation. By considering conservatively the same bounding section and material properties as those for the high burnup fuel reviewed above, the SAR calculated a fundamental frequency of 7.9 Hz for lateral vibration of the rod to result in a DLF of 0.072 and an equivalent static load of 4.3 g (60 x 0.072 = 4.3 g). The equivalent static load is smaller than the buckling capability of 14.8 g for the fuel rod with an unsupported length up to 60 inches and is acceptable.

Fuel Rod Side Impact. For stress evaluation of the fuel rods subject to a side impact of 60 g, the SAR considered the center-to-center spacing between fuel rods and estimated an upper bound lateral deflection of 6.08 inch for the most critically stressed rod of a fuel assembly. The deflection corresponds to a deformation-limited fuel rod bending stress of 37.4 ksi, as a 60-inch-long simply supported beam under uniformly distributed load. By combining stresses for all concurrently applied loads, including the rod internal pressure, the SAR calculated a total longitudinal stress of 54.4 ksi in the clad. The stress is below the clad yield strength of 78.3 ksi and is acceptable.

On the basis of the above, the staff concludes that, within the limits evaluated for the fuel assembly damaged hardware, the intact spent fuel can be loaded directly into the TSC without using an MYFC.

3.5 Materials

The applicant’s amendment is principally concerned, within the materials arena, with storage of damaged and high burnup fuel. The evaluation of high burnup fuel issues is discussed in Section 4 of this SER. Damaged fuel is categorized as discussed elsewhere in this SER.

As discussed in SAR Section 3.6, damaged fuel storage differs slightly from other fuel assemblies. Damaged fuel is placed in an MYFC which in turn is placed into the storage cask basket. An MYFC is a square cross-section tube. All components of the can are made of type 304 stainless steel. The top and bottom of the can have screened holes to permit water to be drained from the assembly. The screen prevents migration of loose fuel material into the fuel compartment of the storage cask basket.

Design and fabrication of the MYFC is in accordance with ASME Section III, Subsection NG practices. The bottom and sides of the can are all-welded construction. The lifting arrangement for the can consists of slots machined into the top end of the can which are engaged by the lifting grapple. The lid is installed on the can after the can and the damaged fuel are loaded into the canister. The can lid is mechanically retained by the welded-on storage canister lid.

The can and damaged fuel have been evaluated for potential galvanic or adverse chemical reactions. Since the damaged fuel can is fabricated from the same materials as the rest of the storage canister, no adverse reactions are introduced or occur. The potential presence of fuel particles inside the damaged fuel can does not create any adverse chemical reactions during either the loading or storage of the fuel.

4.0 THERMAL

The thermal review verifies that the cask and fuel material temperatures of the NAC-UMS system for the MYSSF will remain within the allowable values or criteria for all design conditions.

4.1 Maine Yankee Site-Specific Fuel (MYSSF)

The maximum decay heat load of the MYSSF is limited to 23 kW per canister which is the same as the NAC-UMS design basis. Besides the standard CE 14 X 14 fuel assembly composed of intact fuel rods and non-standard variations thereof, the MYSSF includes non-standard arrangements of damaged fuel (with cladding defects greater than hairline cracks or pinholes), consolidated fuel, and high burnup (burnups between 45 and 50 GWd/MTU) fuel. The aforementioned non-standard damaged and high burnup fuels are loaded in the perimeter of the canister's basket with damaged and consolidated fuel assemblies being canned and located in any one of four perimeter corner locations, respectively. The Maine Yankee specific fuel configurations that were analyzed include:

4.1.1 Two consolidated fuel assemblies consisting of a 17 X 17 lattice with four stainless steel support rods. One has 283 fuel rods and the other has 172 fuel rods. Remaining locations are either empty or contain stainless steel dummy rods.

4.1.2 Standard MYSSF with a control element assembly inserted.

4.1.3 Standard MYSSF with damaged rods removed and replaced with stainless steel rods, solid zirconium, or 1.95 wt % ^{235}U enriched fuel rods.

4.1.4 Standard MYSSF with removed burnable poison rods and replaced with hollow zircaloy tubes. This assembly configuration may also contain an inserted CEA.

4.1.5 Standard MYSSF with in-core instrument thimbles stored in the center guide tube.

4.1.6 Standard MYSSF that has variable radial enrichment and axial blankets.

4.1.7 Standard MYSSF that has some fuel rods removed.

4.1.8 Standard MYSSF that has damaged fuel rods.

4.1.9 Standard MYSSF that has damage to the cage (fuel rods not damaged).

4.1.10 Two failed fuel rod lattices, one being a 9 X 9 array having the same dimensions as a standard fuel assembly and the other being a previously used fuel assembly lattice which contains damaged fuel rods.

4.1.11 Standard MYSSF that has damaged fuel rods stored in their guide tubes.

4.1.12 Standard MYSSF that has a burnup greater than 45 GWd/MTU but less than 50 GWd/MTU.

It should be noted that the Maine Yankee spent fuel inventory is approximately 1434 assemblies and, that in addition to the above configurations, the inventory includes a large percentage of intact fuel assemblies.

4.2 Spent Fuel Cladding

The staff verified that the cladding temperatures for storage of the Maine Yankee fuel are below the temperature which would preclude cladding damage that could lead to gross rupture. This verification was done by either a direct review of the calculated temperature or verification that the Maine Yankee heat load was bounded by that of the NAC-UMS.

The NAC-UMS temperature limits for dry storage of zircaloy fuels are based on the technical justification provided in PNL-6189, entitled “Recommended Temperature Limits for Dry Storage of Spent Light-Water Zircalloy Clad Rods in Inert Gas,” and remain unchanged for the Maine Yankee fuel for burnups up to 45 GWd/MTU.

The staff has recently evaluated the impact of storage conditions on the cladding integrity of fuels with average assembly burnups exceeding 45 GWd/MTU and documented the acceptance criteria for fuels with burnups exceeding 45 GWd/MTU in Revision 1 of ISG-11. The staff has reasonable assurance that the Maine Yankee fuels having average assembly burnups up to 50 GWd/MTU can be safely stored since the following criteria will be met:

Maine Yankee high burnup fuel assemblies may be treated as intact if both of the following conditions are met:

A1. No more than 1% of the rods in the assembly have peak cladding oxide thicknesses greater than 80 micrometers.

A2. No more than 3% of the rods in the assembly have peak cladding oxide thicknesses greater than 70 micrometers.

Maine Yankee high burnup fuel assemblies must be handled in accordance with ISG-1, “Damaged Fuel,” if either of the following conditions are met:

B1. The fuel assembly does not meet both criteria A1 and A2; or

B2. The fuel assembly contains fuel rods with oxide that has become detached or spalled from the cladding.

The administrative controls section of the TS proposed in the SAR (i.e., Section A 5.0) specifies a program to be implemented by the cask licensee to assure the criteria described above are met prior to loading the cask with high burnup fuel.

Using the Commercial Spent Fuel Management methodology as described in PNL-6189, NAC established fuel clad temperature limits that are also applicable to Maine Yankee fuels with burnups between 45 and 50 GWd/MTU because a 5% margin is imposed on the calculated value of the cladding temperature limits. This 5% margin accounts for the reduction in cladding temperature limit that corresponds to using a 1% creep strain limit in the PNL-6189 methodology.

For the purpose of performing a bounding thermal analysis, the spent fuel was assumed to be damaged and rubblized if the cladding damage was more than hairline cracks or pinhole leaks or, for high burnup fuel, if either of the aformentioned criteria B1 or B2 are met. Any rod whose cladding exceeded either of these conditions would have its entire assembly placed into a can (to contain any loose debris) and would be located only in one of the four corner locations within the basket. For bounding analysis purposes, the entire assembly in the can was assumed to become rubblized. As an alternative, the applicant could have chosen to demonstrate that the damaged spent fuel would have retained its structural integrity during all design basis conditions. The applicant's approach follows ISG-1.

The spent fuel cladding temperatures, and hence cladding integrity, have been evaluated by the staff for the maximum basket heat load of 23 kW and during reduced basket heat loads of 20 kW, 17.6 kW, 14 kW, 11 kW, and 8 kW. The maximum spent fuel cladding temperatures occur for the reduced heat loads during the loading operations of vacuum drying and while in the transfer cask. This is because the applicant has elected to lengthen the times associated with these loading operations, thus increasing cladding temperatures (because the fuel is kept at conditions with reduced heat transfer for a longer period of time). However, the staff reviewed these higher temperatures and their associated design basis calculations and determined that these cladding temperatures result in an acceptable creep evaluation based on initial loading temperature limits determined in accordance with PNL-6189.

4.3 Maine Yankee Storage Cask Thermal Design Verification

For the Maine Yankee spent fuel configurations described and numerically summarized in SER Section 4.1, the staff confirmed that for the following configurations (considering their location within the basket) their associated decay heat load was bounded by that of the standard fuel assemblies and the heat transfer mechanisms were sufficient to keep the various material temperatures below the allowable temperature limits:

> 4.1.1 Consolidated fuel (must be canned and loaded in any one of the four perimeter corner positions; only one loaded per canister);
>
> 4.1.2 Standard fuel assembly with CEA (must be loaded into a longer Class 2 canister and in any basket location; all other non-CEA must <u>not</u> be loaded in a Class 2 canister);
>
> 4.1.3 Standard fuel assembly with damaged rods removed and replaced with either stainless steel dummy rods, solid zirconium rods, or 1.95 wt % ^{235}U enriched rods (can be loaded in any location);
>
>> The staff confirmed that the overall heat load for the assembly was not increased as a result of the addition of the 1.95 wt % ^{235}U enriched rods. This was due to the 1.95 wt % ^{235}U rods being burned at least one cycle less than the rest of the rods in the assembly and confirmation from the applicant that the heat load for the 1.95 wt % ^{235}U enriched rods (on a per rod basis) was less than the standard assembly.
>
> 4.1.4 Use of hollow zircaloy tubes to replace removed burnable poison rods (must be located in corner positions of the basket's perimeter);

4.1.5 Standard fuel with in-core instrument thimbles in center guide tube (can be loaded in any location);

4.1.6 Standard fuel with variable enrichment and axial blankets (can be loaded in any location);

> The staff confirmed with the applicant that the variance in enrichment was limited to less than 0.8 %, with a minimum radial enrichment of 3.4 wt % ^{235}U, and 2.6 wt % ^{235}U for the axial blanket. Also, the maximum burnup was limited to less than 30,000 GWd/MTU for these assemblies. Consequently, the heat load for these assemblies was bounded by the standard assemblies, and the variance in enrichment did not affect the cooling times shown in Tables 12B2-8 and 12B2-9.

4.1.7 Standard fuel with removed fuel rods (must be located in the corner perimeter positions of the basket);

4.1.9 Standard fuel with damaged lattice (can be loaded in any location);

> The staff had the applicant confirm and structurally evaluate that the assemblies remain in their design configuration with grid spacers missing for all design basis loadings. Hence, since the assembly retains its configuration, it is bounded by the thermal evaluation of the standard fuel assembly.

4.1.10 Two failed fuel lattices with some damaged fuel rods (must be canned and located in four corner positions of basket's perimeter);

4.1.11 Assemblies with damaged fuel rods inserted in guide tubes (must be canned and located in four corner positions of basket's perimeter);

> The staff confirmed with the applicant that the damaged rods were from the same assembly such that there was no net increase in decay heat load for the subject assemblies.

4.1.12 High burnup fuel, greater than 45 but less than 50 GWd/MTU, is to be loaded in any one of the basket perimeter positions providing it is classified as intact fuel. If classified as damaged, the fuel must be canned and located in the four corner perimeter positions. To compensate for the higher assembly heat loads on the perimeter (i.e., 1.05 kW per assembly), the interior heat loads are limited to preserve the overall heat load rating of the canister and to meet the spent fuel cladding temperature limits.

For standard fuel assemblies with damaged fuel rods (Item 4.1.8 from SER Section 4.1 above), the applicant chose to do a bounding analysis assuming rubblization of the entire assembly in the can. In lieu of this approach, the applicant could have attempted to demonstrate the structural integrity of the entire fuel assembly or the structural integrity of the assembly with rubblization of only the damaged rods. The applicant analyzed the consequences of two rubblization schemes of assemblies with a heat load of 0.958 kW per assembly, one with 50% compaction of the debris in the can and another with 100% compaction of the debris in the can for normal conditions of storage. To be conservative, the debris was assumed to begin at the bottom of the active fuel region rather than the bottom of the fuel can. For the 100% compaction case, the results indicate a reduction in maximum material temperatures because the compacted debris is located below the radial centerline of the canister where the maximum temperatures occur. For the 50% compaction case, only a 4 degrees Fahrenheit (^{0}F) increase above the normal condition temperature of the fuel cladding and heat transfer disks was calculated. Similarly, only a 5^{0}F increase was determined for the structural support disks for the normal conditions of storage. Since the margin of safety between the calculated temperature and the material temperature limit for each of these components is greater than 35^{0}F for the normal condition of storage, the staff finds this minor temperature increase acceptable. For the other design conditions of off-normal and accident, the margins of safety are larger because of higher allowable temperatures for short-term events, and consequently, the staff finds that a small rise in temperature of the aforementioned components will have no significant impact. For storage, the cask/canister is designed not to tip over, even though it is analyzed to withstand the associated structural loadings. Since the cask/canister is designed to prevent tip over for all design basis conditions, the staff finds that the assumption of rubblized fuel only falling to the bottom of the canister is justified for storage. Also, the applicant demonstrated that using a heat load of 0.958 kW per assembly in each of the 4 canned locations was bounding compared to using 1.05 kW per assembly (due to canned high burnup fuel) since the remaining 20 assemblies would have a reduced heat load to maintain the canister maximum heat load of 23 kW.

To ensure that rubblization of the spent fuel is not a problem during transport, the staff requested the applicant to evaluate the consequences of transporting the rubblized damaged spent fuel. The staff was concerned with the possible adverse impact that the rubblized fuel would have if it were located at the axial centerline of the canister or if were located at the end of the canister near the seals of the transportation cask. The staff was concerned that this issue could possibly result in a minimum storage time prior to transport. In its response, the applicant indicated that there were no restrictions for transport of the UMS Maine Yankee fuel canisters based on the evaluation of 100% rubblized fuel within the can. The staff has determined that this will not affect the ability of the NAC-UMS storage cask to meet the requirements of 10 CFR Part 72, and will evaluate this aspect, as appropriate, for the NAC-UMS transport cask application under the requirements of 10 CFR Part 71.

4.4 Maine Yankee Storage Canister Loading Arrangement

The TSC for the Maine Yankee spent fuel storage cask can be loaded with standard fuel which has a preferential loading of hotter assemblies in the center for spent fuel with cooling times of 7 years or less and no restriction for standard fuel cooled more than 7 years. This configuration is in agreement with that approved via review of the original NAC-UMS application.

Also, the Maine Yankee spent fuel storage cask can be preferentially loaded with canned assemblies located in the 4 perimeter corner positions of the basket and/or preferentially loaded with assembly heat loads of 0.958 kW or 1.05 kW located in the 12 perimeter positions of the basket. To compensate for the higher assembly heat loads on the perimeter, the interior heat loads are limited to preserve the overall heat load rating of the canister and to meet the spent fuel cladding temperature limits. The applicant provided the results of a parametric study which compared a loading configuration with all fuel assemblies having the same heat load to a loading configuration with the same total basket heat load but a larger perimeter heat load. The results of this parametric study demonstrate that maximum cladding temperature in the basket for the higher perimeter heat load configuration was less than the uniformly loaded basket. The loading configurations for Maine Yankee are identified and controlled via TS Tables 12B2-6, Maine Yankee Site Specific Fuel Population; 12B2-7, Maine Yankee Site Specific Fuel Limits;

12B2-8, Loading Table for Maine Yankee CE 14 X 14 Fuel With No Non-Fuel Material; and 12B2-9, Loading Table for Maine Yankee CE 14 X 14 Fuel Containing CEA Cooled to Indicated Time. For Table 12B2-8, the staff derived the heat loads associated with various fuel burnups, enrichments, and cooling times to ensure the resulting heat loads did not exceed the limits established in SAR Chapter 4.

When the NAC-UMS system for the MYSSF is loaded and operated in accordance with the SAR, the staff finds that the thermal evaluation supports a conclusion that the MYSSF can be stored such that all material temperature limits are not exceeded for normal, off-normal, and accident conditions.

5.0 SHIELDING

The NAC-UMS storage cask is designed to hold up to 24 PWR spent fuel assemblies. In the initial evaluation for the NAC-UMS, the design basis PWR fuel was identified as the Westinghouse 17x17 Standard assembly. The purpose of this amendment is to authorize Maine Yankee fuel to be stored in the NAC-UMS cask. The fuel used at Maine Yankee is different than the design basis fuel previously evaluated. Therefore, an evaluation of the MYSSF was performed by the applicant to demonstrate that the Maine Yankee fuel would be bounded by the design basis fuel or to establish limits which are maintained by preferential loading administrative controls.

The standard fuel assembly used at Maine Yankee was the CE 14x14 assembly. Fuel of the same design was also supplied by Westinghouse and by Exxon. The total number of fuel assemblies in inventory is approximately 1,434 assemblies. There are 90 assemblies with a burnup between 45,000 and 50,000 MWd/MTU, with the remaining assemblies having a burnup less than or equal to 45,000 MWd/MTU.

The standard source for Maine Yankee fuel assemblies with no additional non-fuel material was determined using the SAS2H model. Then, one-dimensional shielding calculations were performed for the fuel region sources at various combinations of initial enrichment, burnup, and cool time. The resulting dose rate and source term information was used to determine the cool time required for each combination of enrichment and burnup to decay below the design basis limiting values of dose rate and heat generation rate. The standard Maine Yankee 14x14 fuel assembly with no additional hardware and burnup less than or equal to 45,000 MWd/MTU, is bounded by the original source term evaluation.

Some of the Maine Yankee fuel assemblies have additional hardware inserted into the assemblies. There are 168 assemblies with a CEA inserted and 138 assemblies with an ICI thimble inserted. Fuel assemblies containing CEA or ICI thimble hardware were specifically evaluated to establish the limiting values for storage.

The Maine Yankee CEA consists of five control rods that are inserted in the fuel assembly guide tubes. The rods are made of Inconel 625 or stainless steel and encapsulate B_4C as the primary neutron poison material. The ICI thimble is inserted in the center guide tube of the fuel assembly. The ICI thimble is made primarily of zircaloy. Prior to being placed in the TSC, the detector material and lead wire are removed from the thimble assembly . The CEA and ICI thimble are non-fuel bearing components, which due to activation of the materials of composition, add to the gamma component of the source term of the fuel assembly.

The additional contribution to dose rate due to the activated materials of the CEA and ICI thimble were computed by SAS4, a three-dimensional shielding model. Table 5.6.1-12 of the SAR lists the resulting cool times for CEAs. No significant dose rate changes occur due to the addition of ICI thimbles in an assembly.

There are 18 assemblies which have a fuel rod replaced by a stainless steel rod. These assemblies were also specifically evaluated to determine if they would fall outside of the standard loading curve. Two of the assemblies evaluated, specifically R439 and R444, are high burnup assemblies and are thus required to be loaded only in the periphery of the TSC.

There are two consolidated fuel lattices which house fuel rods taken from other assemblies. This fuel has decayed over 20 years and, therefore, does not provide a significant issue.

The Maine Yankee spent fuel inventory also contains damaged fuel rods and fuel debris. Damaged fuel rods and fuel debris will be placed in a screened fuel can prior to loading into the NAC-UMS basket. Fuel debris will be placed into a rod structure prior to loading into the screened canister. For the damaged fuel and fuel debris placed in a rod structure, the shielding evaluation for an intact fuel assembly bounds that of the damaged fuel rods. The effect of collapsed fuel in the fuel can was evaluated, and it was determined that no significant increases in personnel exposure would be expected as a result of the collapsed fuel.

Staff performed confirmatory source term calculations for the MYSSF and for the various fuel configurations. Based upon the results of the confirmatory calculations, staff has reasonable assurance that the requirements of 10 CFR Part 20, 10 CFR 72.104 and 10 CFR 72.106 will be met.

6.0 CRITICALITY

This Section evaluates the applicant's site-specific criticality analysis for storing Maine Yankee fuels in the Class 1 and Class 2 canisters of the NAC-UMS system. The staff has reviewed the site-specific design features and analysis in the context of the previously approved features and design-basis analysis of the NAC-UMS system and has performed independent criticality calculations to verify the applicant's analysis results. The staff's evaluation confirms the applicant's conclusion that all allowable loadings of Maine Yankee spent fuels yield a maximum neutron multiplication factor (k_{eff}) no greater than that for the previously approved design-basis loading with 4.2 wt % ^{235}U enriched Westinghouse 17x17 OFA fuel.

6.1 Site-Specific Design Features and Allowed Contents

Maine Yankee standard fuel assemblies have nominal specifications corresponding to the CE 14x14 fuel category in TS Table 12B2-2. Site-specific variations on this fuel category include assemblies with burnable poison rods, variable fuel enrichments, and/or annular axial end blankets. The Maine Yankee inventory also contains various configurations of modified assemblies, assemblies with damaged or missing hardware components (e.g., grid spacers), assemblies with damaged fuel rods, consolidated fuel assemblies, individual poison rods, individual intact fuel rods, individual damaged fuel rods, and fuel debris. The most highly irradiated Maine Yankee fuels have assembly-average burnups between 45 and 50 GWd/MTU. TS Tables 12B2-6 and 12B2-7 specify the allowed canister loading positions for each category of site-specific contents.

The applicant classifies fuel assemblies as structurally intact if the assemblies have no damaged fuel rods and no more than 152 cm (60 inches) of unsupported fuel between structurally intact grid spacers. This classification is based on a structural analysis showing that such assemblies maintain structural integrity under normal and accident conditions. The staff's review of the fuel structural analysis is described in Section 3 of this SER. Fuel contents classified as structurally intact need not be placed in a Maine Yankee fuel can (MYFC).

Fuel contents that have not been shown to maintain structural integrity under normal and accident conditions must be placed in an MYFC. A loaded fuel can may occupy any of the four corner loading positions in the NAC-UMS canister. As noted in TS Tables 12B2-6 and 12B2-7, specified contents requiring placement in a fuel can include fuel debris, individual fuel or poison rods, consolidated fuel assemblies, assemblies with one or more damaged fuel rods, high-burnup assemblies (45 to 50 GWd/MTU) which are to be treated as damaged in accordance with the criteria discussed in Section 4.2 of this SER, and assemblies with 152 cm (60 inches) or more of unsupported fuel between structurally intact grid spacers. The applicant's definition of damaged fuel in TS Section A.1.1 matches the NRC staff's definition in ISG-1, Rev.0. The criteria listed in Section 4.2 of this SER, which specifies the canning of certain high-burnup fuels based on cladding condition and oxidation, is consistent with the staff technical guidance in ISG-11, Rev.1.

NAC Drawings 412-501 and 412-502 show design details of the MYFC. The fuel can is designed to confine loose materials (e.g., fuel debris, rubblized fuel, individual rods) under normal and accident conditions and thereby preclude unanalyzed material configurations outside the can. To further control the normal configurations of materials inside a fuel can, fuel debris must be placed in a tube structure and individual fuel or poison rods must be placed in either a tube structure or a fuel-assembly grid structure. For individual rods, the necessary tube structures may be the guide tubes of a fuel assembly within the fuel can. Each of the fuel assembly's five guide tubes may hold up to two fuel or poison rods.

The staff agrees that the design of the MYFC provides reasonable assurance that the ranges of credible material configurations resulting from normal and accident conditions are no more reactive than those considered in the applicant's analysis.

6.2 Analysis Methods and Models

The computational methods used in the applicant's site-specific analysis are consistent with those used in the design-basis analysis. The applicant's calculations again made use of the CSAS25/ KENO-Va analysis sequence and the 27-group ENDF/B-IV cross-section library of the SCALE-4.3 PC code system. The NRC staff's independent calculations again employed the MONK8a code with its quasi-pointwise cross-section library (13,193 energy groups) derived from the JEF2.2 file of evaluated nuclear physics data.

SAR Section 6.6.1.4 shows that the neutronic parameters of the most reactive Maine Yankee fuel loadings fall within the parameter ranges of the design-basis validation benchmarks described in SAR Section 6.5. The previously reviewed analysis of those benchmark results showed no significant trends for variation of the inferred computational bias over the benchmark parameter ranges. The validation analysis, therefore, supports the addition of identical adjustments to the site-specific and design-basis results in conservatively accounting for potential biases and uncertainties in the applicant's computational methods.

The calculations presented for the site-specific analysis assume nominal dimensions of the canister components and model the fuel and fuel tubes as being centered within the support-disk holes. By consistently applying these reference cask models to both the site-specific loadings and design-basis fuel loading, the applicant's analysis shows that all allowed site-specific loadings are less reactive than the design-basis loading. The staff's independent calculations verify that the effects of worst-case dimensional tolerances and potential shifting of the fuel and fuel tubes within the canister increase the reactivity computed for the site-specific loadings by no more than the amount previously computed for the design-basis fuel loading. The staff, therefore, confirms the validity of using the reference model configurations to evaluate the relative reactivities for worst-case configurations of the site-specific and design-basis fuel loadings.

As in the design-basis analysis, the site-specific analysis conservatively models the irradiated fuel as though it were fresh and without burnable poisons and assumes flooding of the canister and fuel rods by unborated water. The reduced reactivity of irradiated fuels, the presence of boron in the water used during in-pool operations, and the absence of water in the canister after closure will lead to actual subcritical margins substantially larger than those computed in the applicant's safety analysis for normal and accident conditions.

6.3 Analysis Results and Verification

Table 6-1 in this SER presents the staff's summary of the applicant's criticality analysis results for the Maine Yankee contents. The table lists the allowed canister loading positions and the maximum or bounding neutron multiplication factors computed for each category of Maine Yankee contents. The lower portion of the table addresses contents that require loading into an MYFC. Analyses for all contents restricted to the corner loading positions appropriately consider the most reactive allowed fuel loadings in the non-corner positions.

The tabulated neutron multiplication factors are adjusted upward to conservatively account for computational biases and uncertainties as well as the effects of worst-case dimensional tolerances and shifting within the canister basket. Using the previously reviewed analysis for the design-basis contents, the staff has applied the following formula to evaluate the adjusted maximum neutron multiplication factors for the site-specific contents:

$$k_s(S) = k_s(D) * k_{ref}(S)/k_{ref}(D)$$

where $k_s(S)$ = adjusted k_{eff} for the worst-case cask model with site-specific fuel
$k_s(D)$ = adjusted k_{eff} for the worst-case cask model with design-basis fuel
= 0.9475, as reported in SAR Section 6.1
$k_{ref}(S)$ = computed k_{eff} for the reference cask model with site-specific fuel
$k_{ref}(D)$ = computed k_{eff} for the reference cask model with design-basis fuel
= 0.9192, as reported in SAR Section 6.6.1.1

The staff's calculations show that this formula conservatively approximates the more explicit derivation of $k_s(S)$ values from (a) the modeling of worst-case cask configurations loaded with site-specific contents, followed by (b) conservative adjustments for computational bias and uncertainty.

The following paragraphs summarize the criticality evaluation for the principal Maine Yankee fuel configurations.

Standard intact fuel assemblies with uniform enrichment: SAR Section 6.6.1.2.1 shows that the unrestricted loading of Maine Yankee standard fuel assemblies with the maximum uniform initial enrichment of 4.2 wt % ^{235}U is less reactive in the cask than the design-basis loading with Westinghouse 17x17 OFA fuel assemblies. The analysis considers a hybrid Maine Yankee fuel model with the most-reactive combinations of standard fuel dimensions. The model of intact standard assemblies adds further conservatism by assuming a smaller-than-standard diameter of the fuel pellets, which yields a more reactive fuel-to-moderator ratio in the assembly.

Variably enriched intact fuel assemblies: Maine Yankee variably enriched fuel assemblies have a maximum fuel rod enrichment up to 4.21 wt % ^{235}U and a maximum planar-average enrichment up to 3.99 wt % ^{235}U. The staff concurs that the variably enriched assemblies can be conservatively modeled with a uniform 4.2 wt % ^{235}U enrichment as described above.

Intact assemblies with annular axial end blankets: The applicant's model of fuel with annular axial end blankets conservatively assumes a higher-than-actual enrichment of 4.2 wt % ^{235}U in the blankets, the presence of water in the blanket annuluses, and the maximum standard pellet diameter in the blanket region. Thus modeled, the applicant's calculations show the unrestricted loading of this fuel category to be less reactive than the design-basis fuel loading, but slightly more reactive than a loading of Maine Yankee standard assemblies without end blankets.

Intact assemblies with removed fuel rods: The applicant's analysis shows the most reactive fuel assemblies to be those from which some of the fuel rods have been removed from the undermoderated fuel lattice. A series of calculations with various numbers of removed rods reveals that the in-cask k_{eff} is maximized when 24 rods are removed in a nearly uniform pattern, leaving 152 fuel rods in the assembly. In this configuration, reactivity is shown to be maximized when the fuel pellets are modeled at their maximum standard diameter. Unrestricted loading of such assemblies would give a higher k_{eff} than the design-basis fuel loading. However, the staff's calculations confirm that restricting this fuel configuration to the four corner loading positions, as specified in TS Table 12B2-7, results in a lower k_{eff} than the design-basis fuel loading.

Intact assemblies with removed fuel rods and rods inserted in the guide tubes: Staff calculations confirm that the most reactive fuel configuration in this category is an assembly with one fuel rod in each of its five guide tubes and 28 rods removed from its fuel lattice. This assembly configuration has an inherent reactivity slightly higher than that of the preceding optimum configuration with no rods in the guide tubes and 24 rods removed from the lattice. However, TS Table 12B2-7 specifies that assemblies with rods in the guide tubes must be placed in a fuel can. The staff's calculations verify that the fuel can walls introduce a negative reactivity effect that more than offsets the slightly higher inherent reactivity of this fuel assembly configuration. The canned corner loading of this fuel configuration is, therefore, less reactive than the uncanned corner loading of assemblies with no rods in the guide tubes and 24 rods removed from the lattice.

Consolidated fuel assemblies: Consolidated fuel assemblies consist of intact fuel rods that have been removed from Maine Yankee spent fuel assemblies and placed in a 17x17 lattice structure. In a flooded cask, the 17x17 lattice is undermoderated when fully loaded with fuel rods and, therefore, more reactive when some of the rod lattice positions are empty. The staff's calculations verify that a uniform pattern of 113 empty rod positions results in optimal (i.e., most-reactive) neutron moderation and scattering conditions for in-cask models of the consolidated fuel lattice. An unrestricted loading of this most-reactive configuration of consolidated assemblies is calculated to be more reactive than the design-basis fuel loading. However, the staff's calculations confirm that restricting consolidated fuel to the four corner loading positions keeps the computed k_{eff} below that of the design-basis fuel loading. TS Table 12B2-7 further restricts the allowed loading of consolidated assemblies to a single corner position of the canister and specifies that such assemblies must be placed in an MYFC.

<u>Damaged fuel and fuel debris</u>: SAR Section 6.6.1.3 describes the applicant’s criticality analysis for damaged fuel and fuel debris contained in MYFCs. Limiting the allowed loading of fuel debris to no more than the equivalent of 81 fuel rods results in a lower reactivity than other allowed contents of the fuel can. The applicant’s model for damaged fuel considers Maine Yankee spent fuel assemblies with up to 176 damaged fuel rods and consolidated assemblies with up to 289 damaged rods. By modeling loose fuel from damaged rods as homogeneously mixed with the water outside the remaining rods, the applicant’s analysis shows the most reactive damaged fuel configurations to be only marginally more reactive than the optimally moderated missing-rod configurations described above and less reactive than the design-basis loading. The analysis also shows that uneven draining of the corner-loaded fuel cans and the presence of loose fuel and fuel rods at the ends of the fuel cans, which extend above and below the ends of the basket poison panels, produce no increases in reactivity.

Table 6-1. NRC Summary of the Applicant’s Criticality Results for Maine Yankee Fuels in the NAC-UMS Storage System

Maine Yankee Fuel Configuration	Canister Positions	$k_s(S)$[1]
Fuel Can Not Required		
Intact[2] Standard Assemblies with Uniform Enrichments up to 4.2 wt %	All	0.9363
Intact Assemblies with Annular End Blankets up to 4.2 wt % ^{235}U	All	0.9381
Intact Variably-Enriched Assemblies with Peak Rod Enrichments up to 4.21 wt % ^{235}U and Peak Planar-Average Enrichments up to 3.99 wt %	All	<0.9381
Intact Assemblies with Inserted Control Element Assembly or In-Core Instrument Thimble	All	<0.9381
High-Burnup Assemblies (45-50 GWd/MTU) Treated as Intact as Described in SER Section 4.2	Periphery[3]	<0.9381
Intact Assemblies with Any Number of Original Fuel Rods Replaced by Solid Filler Rods or Fuel Rods of up to 1.95 wt % ^{235}U	All	<0.9381
Intact Assemblies with Any Number of Fuel or Poison Rods Removed	Corners	0.9414
Intact Assemblies with a Poison Rod Replaced by a Hollow Rod	Corners	<0.9414
Fuel Can Required		
Assemblies with Any Number of Fuel or Poison Rods Removed and up to Two Fuel or Poison Rods Placed in Each Guide Tube	Corners	<0.9414
Consolidated Assemblies Holding up to 289 Fuel Rods	Single Corner	<0.9442
Assemblies with Damaged Fuel (i.e., Fuel with Known or Suspected Cladding Defects Beyond Pinhole Leaks or Hairline Cracks)	Corners	0.9428
Assemblies with Hardware Configurations Not Classified as Structurally Intact[2]	Corners	0.9428
High-Burnup Assemblies (45-50 GWd/MTU) Treated as Damaged as Described in SER Section 4.2	Corners	<0.9428
Fuel Debris and/or Intact or Damaged Fuel Rods Placed in a 9x9 Lattice of Tubes	Corners	<0.9381

[1] Maximum or bounding neutron multiplication factor for normal and accident conditions.

[2] Assemblies are classified as structurally intact only if they have been shown by analysis to maintain structural integrity under normal and accident conditions in the cask.

[3] Intact high-burnup fuel is restricted to peripheral loading positions, including corners, to satisfy cladding temperature limits for the thermal evaluation described in SER Section 4.

7.0 CONFINEMENT

The pressure evaluation of the standard NAC-UMS storage canister was determined to be bounding since the original confinement evaluation assumed a burnup of 55 GWd/MTU and since some of the fuel being stored for Maine Yankee is damaged. Those damaged rods would be depressurized prior to storage. Also, since the confinement boundary is leak tested to leak tight criteria, no additional release from the MYSSF needs to be considered. Therefore, the original confinement evaluation is bounding for the MYSSF.

8.0 OPERATING PROCEDURES

The applicant provided revised operating procedures, used for the development of site-specific operating procedures, to reflect the MYSSF preferential loading specifications. Technical specifications, clearly designating corner, periphery or any location for the analyzed MYSSF are provided. Site-specific spent fuel assemblies with an inserted control element assembly are also designated for loading only within Class 2 canisters. The staff reviewed the revised operating procedures and concludes that they provide an adequate technical basis for the development of site-specific operating procedures and meet the requirements of 10 CFR Part 72.

9.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

The applicant revised this Section to reflect that the VCC can be lifted either by hydraulic jacks and moved by air pads or by using the lifting lugs and a mobile lifting frame. The maintenance program was also updated to include the maintenance program on the transfer cask, consistent with a change incorporated during the rulemaking process for the initial certification of the NAC-UMS storage system. The staff reviewed the revisions to SAR Section 9 and concludes that it provides an adequate technical basis for the development of written acceptance tests and a maintenance program and continues to meet the requirements of 10 CFR Part 72.

10.0 RADIATION PROTECTION

As determined from the review of SAR Chapter 5, Shielding Evaluation, the MYSSF assemblies and the non-fuel hardware source terms are bounded by the standard design-basis fuel for the NAC-UMS cask. The dose rates which would be measured from the Maine Yankee contents are also bounded by the dose rates for design basis fuel. Therefore, the on-site and off-site doses from the Maine Yankee fuel assemblies will be less than from the standard NAC-UMS design basis fuel and will also be bounded.

Prior to storing spent fuel at the power reactor site under a general license, Maine Yankee will have to meet the requirements cited in 10 CFR 72.212. As part of the requirement in 10 CFR 72.212(b)(6), Maine Yankee must review the radiation protection program and take appropriate action to ensure the effectiveness of the program with respect to spent fuel.

11.0 ACCIDENT ANALYSIS

The applicant evaluated the MYSSFs for off-normal and accident events. The applicant also evaluated the potential buckling and structural failure of a fuel rod with one or more missing support grids up to an unsupported 60-inch length of the fuel rod. The staff evaluated these aspects in Section 3 of this SER and found them to be acceptable.

The off-normal events of severe ambient temperatures and blockage of one-half of air inlets remain as originally analyzed for the NAC-UMS since the overall design basis heat load (i.e., 23 kW) of the storage cask has not changed and the uniform heat load of 0.958 kW per assembly remains bounding for these events.

The staff concludes that the off-normal and accident design criteria for the NAC-UMS system are in compliance with 10 CFR Part 72 and will provide for safe storage of spent fuel during credible accident situations.

12.0 CONDITIONS FOR CASK USE - TECHNICAL SPECIFICATIONS

Revised TS have been incorporated in support of the application. The revisions include:

- Definitions in Section A.1.1 for intact (undamaged) fuel assemblies or rods, damaged fuel, standard fuel, high burnup fuel, fuel debris, consolidated fuel, site-specific fuel and the MYFC.

- Modification of TS LCO 3.1.1, “CANISTER Maximum Time in Vacuum Drying,” to specify longer allowable drying times for specified PWR fuel heat loads less than the design basis.

- Modification of TS LCOs 3.1.2, 3.1.3, and 3.1.5, “CANISTER Vacuum Drying Pressure”, “Canister Helium Backfill Pressure,” and “Canister Helium Leak Rate,” respectively, to reflect the deletion of Table A3-1 and incorporate the values directly with the LCO.

- Modification of TS LCO 3.1.4, “CANISTER Maximum Time in Transfer Cask,” to specify longer allowable times for specified PWR fuel heat loads less than the design basis.

- The addition of item A5.7, “Verification of Oxide Layer Thickness on High Burnup Fuel,” to the Administrative Controls and Programs which is used for a determination of whether the high burnup fuel should be classified as damaged and thus, placed within a fuel can.

- New item B2.1.3, “Maine Yankee SITE SPECIFIC FUEL Preferential Loading,” and editorial modifications to Section B2 to properly address the incorporation of the Maine Yankee spent fuel contents.

- New item I.H for Table B2-1 to specify a maximum unsupported span of 60 inches for an intact PWR assembly.

- New MYSSF Tables B2-6, B2-7, B2-8, and B2-9, which detail the MYSSF population and preferential loading positions; the MYSSF limits as allowable contents; the MYSSF loading tables (with no non-fuel material) with respect to burnup, enrichment, and cooling time; and the MYSSF loading tables (with control element assemblies) with respect to burnup, enrichment, and cooling time, respectively.

- Clarifications to Section B3.4.1 and a new Section B3.4.2 to specify the design basis site-specific parameters and analysis that require verification by Maine Yankee.

The staff concludes that the amended conditions for use of the NAC-UMS system identify necessary specifications to satisfy 10 CFR Part 72 and that the applicable acceptance criteria have been satisfied. The Certificate of Compliance and attached appendices provide reasonable assurance that the cask will allow safe storage of spent fuel.

CONDITIONS

Condition 1.b of the Certificate of Compliance has been modified to reflect the addition of site-specific fuels as contents, the authorization to store damaged site-specific fuel within a separate fuel can, and to delete a reference to the NS-4-FR trade name of the solid neutron shielding material in the VCC shield plug.

CONCLUSION

The staff reviewed Revision 5 to the Safety Analysis Report for the NAC-UMS storage cask system. Based on the statements and representations contained in the SAR and the conditions in the Certificate of Compliance, the staff concludes that the NAC-UMS storage cask system meets the requirements of 10 CFR Part 72.

Issued with Certificate of Compliance No. 1015, Amendment No. 1,
on __February 13_, 2001.