UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION REPORT

DOCKET NO. 72-1032
HOLTEC INTERNATIONAL
CERTIFICATE OF COMPLIANCE NO. 1032
HI-STORM FLOOD/WIND
MULTIPURPOSE CANISTER STORAGE SYSTEM
AMENDMENT NO. 3

SUMMARY

This safety evaluation report (SER) documents the U.S. Nuclear Regulatory Commission (NRC) staff's review and evaluation of the amendment request to amend Certificate of Compliance (CoC) No. 1032 for the HI-STORM Flood/Wind (FW) Multipurpose Canister (MPC) Storage System (HI-STORM FW) submitted by Holtec International (Holtec) by letter dated December 18, 2015 (Agencywide Document Access and Management System (ADAMS) Accession No. ML15364A561). Holtec modified its request on April 22, 2016 (ADAMS Accession No. ML16113A398), and supplemented it on June 22, 2016 (ADAMS Accession No. ML16180A360) and August 22, 2016 (ADAMS Accession No. ML16236A243). The proposed changes include the following:

1. Include burnup credit for the MPC-37.
2. Revise CoC Condition 8.

This revised CoC, when codified through rulemaking, will be denoted as Amendment No. 3 to CoC No. 1032.

- This SER documents the review and evaluation of the proposed amendment. The staff followed the guidance of NUREG-1536, Revision 1, "Standard Review Plan for Dry Cask Storage Systems at a General License Facility," July 2010; and Spent Fuel Storage and Transportation (SFST) Interim Staff Guidance (ISG)-8, Revision 3, "Burnup Credit in the Criticality Safety Analyses of PWR Spent Fuel in Transportation and Storage Casks," September 26, 2012.

The staff's evaluation is based on a review of Holtec's application and is focused on whether it meets the applicable requirements of Title 10 of *Code of Federal Regulations* (10 CFR) Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste," for dry storage of spent nuclear fuel. The staff's evaluation focused only on modifications requested in the amendment as supported by the submitted revised final safety analysis report (FSAR) (ADAMS Accession No. ML15177A338) and did not reassess previous revisions of the FSAR nor previous amendments to the CoC.

1.0 GENERAL INFORMATION EVALUATION

The applicant did not propose any changes that affect the staff's general description evaluation provided in the previous SER for CoC No. 1032, Amendments Nos. 0 through 2. Therefore, the staff determined that a new evaluation was not required.

2.0 PRINCIPAL DESIGN CRITERIA EVALUATION

The applicant did not propose any changes that affect the staff's principal design criteria evaluation provided in the previous SER for CoC No. 1032, Amendments Nos. 0 through 2. Therefore, the staff determined that a new evaluation was not required.

3.0 STRUCTURAL EVALUATION

The applicant did not propose any changes that affect the staff's structural evaluation provided in the previous SER for CoC No. 1032, Amendments Nos. 0 through 2. Therefore, the staff determined that a new evaluation was not required.

4.0 THERMAL EVALUATION

In the application for Amendment No. 3, the applicant proposed to revise CoC Condition No. 8. In fact, the staff has reviewed and approved the proposed CoC Condition 8 revision in Amendment No. 2 to CoC No. 1032. The applicant submitted the application for Amendment No. 3 before the staff completed the review for Amendment No. 2. Staff's evaluation for the revised CoC Condition No. 8 is documented in the SER for Amendment No. 2 to CoC No. 1032 (ADAMS Accession No. ML16280A032).

5.0 CONFINEMENT EVALUATION

The applicant did not propose any changes that affect the staff's confinement evaluation provided in the previous SER for CoC No. 1032, Amendments Nos. 0 through 2. Therefore, the staff determined that a new evaluation was not required.

6.0 SHIELDING EVALUATION

The applicant did not propose any changes that affect the staff's shielding evaluation provided in the previous SER for CoC No. 1032, Amendments Nos. 0 through 2. Therefore, the staff determined that a new evaluation was not required.

7.0 CRITICALITY EVALUATION

The applicant requested burnup credit for most of the fuel types stored in the MPC-37. The staff reviewed the request for burnup credit using the guidance in NUREG-1536, Revision 1, and SFST-ISG-8, Revision 3. Assumptions within the applicant's criticality safety analyses were based in part on information from the following documents:

- NUREG/CR-6759, ORNL/TM-2001/69, "Parametric Study of Effect of Control Rods for PWR Burnup Credit," February 2002 (ADAMS Accession No. ML020810111)

- NUREG/CR-6760, ORNL/TM-2000-321, “Study of the Effect of Integral Burnable Absorbers for PWR Burnup Credit,” March 2002 (ADAMS Accession No. ML020770436)
- NUREG/CR-6761, ORNL-TM-2000/373, “Parametric Study of the Effect of Burnable Poison Rods for PWR Burnup Credit,” March 2002 (ADAMS Accession No. ML020770329)
- NUREG/CR-6801, ORNL/TM-2001/273, “Recommendations for Addressing Axial Burnup in PWR Burnup Credit Analyses,” March 2003 (ADAMS Accession No. ML031110292)
- NUREG/CR-7108, ORNL/TM-2011/509, “An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses—Isotopic Composition Predictions,” April 2012 (ADAMS Accession No. ML12116A124)
- NUREG/CR-7109, ORNL/TM-2011/514, “An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses—Criticality (k_{eff}) Predictions,” April 2012 (ADAMS Accession No. ML12116A128)
- NUREG/CR-7205, ORNL/TM-2012/544, “Bias Estimates Used in Lieu of Validation of Fission Products and Minor Actinides in MCNP K_{eff} Calculations for PWR Burnup Credit Casks,” September 2015 (ADAMS Accession No. ML15252A062)

7.1 Criticality Design Criteria and Features

Criticality is controlled within the HI-STORM FW system based on the fixed geometry of the basket structure and neutron poison (Boron-10) present within the basket material (Metamic-HT). The HI-STORM FW system has two different basket designs: the MPC-37 is for pressurized-water reactor (PWR) fuel, and the MPC-89 is for boiling-water reactor fuel. For the MPC-37 basket, the applicant relies upon the soluble boron during loading and unloading operations for criticality control. In this amendment, the applicant requested credit for some of the actinides and fission products within the irradiated fuel that decrease reactivity in lieu of crediting the soluble boron.

The Technical Specification (TS) limits and surveillance requirements for minimum soluble boron concentrations for MPC-37 during loading and unloading operations are a limiting condition for operation (LCO) 3.3.1. In this amendment, the applicant requested to revise this LCO to state that it is not applicable if burnup credit, as described in Section 2.4 of Appendix B to the CoC, is utilized in selecting assemblies prior to loading.

The applicant also requested to revise the minimum soluble boron concentration for all 14x14 and 16x16 assembly classes with a maximum initial enrichment of 5.0 weight percent. The applicant increased the minimum soluble boron concentration from 1,500 ppmb to 1,600 ppmb. This increase in boron was necessary for incorporating damaged fuel containers (DFCs) in all 37 locations within the MPC-37 when storing the 16x16A fuel type and was approved in Amendment No. 2 (ML16280A032). The applicant did not, however, request to incorporate the DFCs in all 37 locations for the HI-STORM FW. The amendment request to include the 37 16x16A fuel assembly in DFCs was applicable to another CoC (HI-STORM UMAX, Docket No. 72-1040) that references the HI-STORM FW FSAR. The applicant included the increase in boron in HI-STORM FW Amendment No. 3 for consistency. Since the increase in boron concentration can reduce the potential for criticality the change is conservative, and since this is a conservative change, with respect to criticality safety, the staff finds it acceptable. The staff, for this amendment, only evaluated the addition of DFCs in the locations specified in the application request.

7.2 Fuel Specification

7.2.1 Assembly Types

The applicant requested burnup credit for all PWR assemblies that can be stored within the MPC-37 with the exception of all 14x14 fuel assemblies because the applicant does not expect to transport these assemblies.

In the applicant's criticality evaluation for burnup credit, it used representative assemblies for fresh and spent fuel to generate the "loading curve" which is placed in the technical specifications and used by the applicant to select the appropriate assemblies for loading. Further details on the staff's review of the applicant's loading curve is discussed in Section 7.5.5 of this SER.

There are four configurations for the fuel when using the burnup credit approach. These configurations are discussed in Sections 6.I.1.1 and 6.I.C.4 of the application. These configurations are needed to account for the presence of fresh fuel and DFCs. The applicant created separate loading curves for each configuration as discussed in Section 7.5.5 of this SER.

7.2.2 Enrichments, Burnups, and Cooling Times

The applicant performed burnup credit calculations for initial enrichments between 2.0 and 5.0 weight percent and at 3 and 7 years cooling time for the four basket configurations. NUREG/CR-7108 states in Section 3.1 that nuclides important to burnup credit reach a maximum reactivity at 3 days after discharge. After 3 days, reactivity decreases until approximately 100 years after discharge. The staff finds that using shorter cooling times of 3 and 7 years, rather than 100 years, bound longer cooling times that would reasonably be stored in the HI-STORM FW MPC-37. Therefore, the staff finds the choice of 3 and 7 years cooling time acceptable as they are minimum required cooling times and longer cooled fuel would be less reactive.

7.2.3 Non-fuel Hardware

Table 2.1-1 Item I.A.1 of Appendix B to the TS allows storage of non-fuel hardware within the MPC-37. Burnable poison rod assemblies (BPRAs), thimble plug devices, wet annular burnable absorbers, orifice rod assemblies, and vibration suppressor inserts with or without instrument tube tie rods may be stored in any fuel storage location. Fuel assemblies containing axial power shaping rods, rod cluster control assemblies, control element assemblies, control rod assemblies, or neutron source assemblies (NSAs) may only be loaded in fuel storage Regions 1 and 2 as identified in Figure 2.1-1 of Appendix B to the TS.

The applicant demonstrated in Section 6.4.7 of its FSAR for the initial certificate review of this cask system, which was confirmed by the NRC staff, that for the MPC-37 and the fuel currently approved for storage within it, the presence of non-fuel hardware decreases reactivity due to the displacement of moderator (NRC SER, ADAMS Accession No. ML111950325). This conclusion is still valid for the analysis supporting burnup credit. Because there is no soluble boron to displace, reactivity is decreased even further.

The staff found the presence of a single NSA would only minimally impact the criticality of the system as it contains no fissile material but may contain some moderating material (Beryllium). This conclusion is still valid within the analysis supporting burnup credit and the staff finds the presence of the single NSA within the MPC-37 acceptable when using burnup credit.

The presence of non-fuel hardware (such as BPRAs) during depletion will affect the discharge reactivity of an assembly and must be accounted for within the burnup credit evaluations. The applicant considered the presence of non-fuel hardware in its depletion analysis for burnup credit. The staff discusses its evaluation of the applicant's analysis in Section 7.5.1 of this SER.

7.2.4 Fuel Condition

Table 2.1-1 Item I.A.1 of Appendix B to TS allows the storage of damaged fuel assemblies and fuel debris within the MPC-37. Damaged fuel assemblies and fuel debris must be stored within a DFC and are allowed in certain configurations as described in Table 2.4-2 of Appendix B to the TS (Table 2.1.8 of the SAR). Item I.B of Appendix B to the TS allows up to 12 DFCs to be stored within the MPC-37 in peripheral locations as denoted in Figure 2.1-1 of Appendix B of the TS (Figure 2.1.1 of the SAR).

The applicant discussed the modeling of the fuel within DFCs in Section 6.I.2.3 of the application. The applicant used a similar modeling approach as used for the criticality analysis supporting boron credit discussed in Section 6.4.4 of the FSAR and reviewed and approved by the staff during the initial certificate review of this cask system. This includes fuel arranged in an array with optimum pitch for reactivity and removing all structural and cladding material. This is a conservative modeling approach for damaged fuel as damaged fuel and fuel debris are not likely to arrange into this particular configuration. Damaged fuel is more likely to be in the same array as the assembly, but the assembly may have some structural issues causing the fuel assembly to be classified as damaged, or if it is fuel debris then it is more likely to arrange in a random, less reactive, fashion. In addition, assuming no cladding or structural material is conservative as replacing these materials with water increases moderation and increases reactivity. For these reasons and from the staff's experience this approach has been consistently demonstrated by applicants to give reasonably bounding reactivity for damaged fuel, the staff found it acceptable for the MPC-37 burnup credit application within the MPC-37. With respect to the composition of the fuel, the applicant chose to model fuel debris as fresh fuel and damaged fuel having burnup of the lowest relative burnup from any axial node within an assembly allowed for storage in that location. This is a conservative assumption for fuel debris because fresh fuel is more reactive than fuel that has experienced burnup within a reactor; for damaged fuel, the rest of the fuel assembly will experience more burnup than the minimum selected by the applicant and be less reactive than what was modeled. For these reasons, the staff finds that the approach is conservative and acceptable for modeling the damaged fuel and fuel debris for the burnup credit analyses.

The applicant considered the presence of DFCs and developed loading curves for each regionalized configuration including those allowing DFCs (Configurations 2, 3, and 4 from Table 2.4-2 of Appendix B to the TS), as discussed in the information submitted on August 22, 2016. The staff discusses its review of the loading curves in Section 7.5.5.

7.3 Model Specification

The burnup credit model is based on the HI-STAR 190 (Docket No. 71-9373) cask model and MPC-37 basket. The HI-STAR 190 is the transportation cask for the HI-STORM FW. Although the HI-STAR 190 shielding and packaging is different from the HI-TRAC VW transfer cask (which is the HI-STORM FW cask configuration that requires burnup credit), the materials of construction are largely the same and far enough away from the actual fissile system that they would have negligible effect on the reactivity. In addition, the MPC-37 basket used in the HI-TRAC VW transfer cask is exactly the same as for the HI-STORM FW and, in this case, the basket determines the reactivity; therefore, the staff finds using the HI-STAR 190 cask model to represent the HI-TRAC VW acceptable.

To apply the axial profile of the burned fuel assembly, the applicant divided the assemblies into axial sections. The number of axial sections used by the applicant is consistent with SFST-ISG-8, Revision 3, and therefore the staff finds it acceptable. In each axial section, the applicant took the isotopic composition of the fuel from the corresponding depletion calculations. Sections 7.5.1 and 7.5.2 of this SER discuss the calculation and validation of the burned fuel isotopic composition.

7.3.1 Configuration

The applicant performed evaluations demonstrating that moving assemblies toward the center of the basket (within tolerances) versus moving assemblies toward the basket periphery gives the most conservative results, i.e., highest reactivity. The staff reviewed the results of the applicant’s evaluations in Table 6.I.4.3 of the application and agrees that the assumption of moving the fuel assemblies toward the center of the basket gives the most reactive configuration and is therefore acceptable.

The applicant discussed the effects of partial flooding in Section 6.I.4.2.1 of the application. The applicant performed calculations demonstrating that the most reactive condition is that of the fully flooded cask and presented its results in Table 6.I.4.1 of the application. The staff reviewed the applicant’s results and agrees with the applicant’s conclusion that the fully flooded cask is the most reactive condition and is therefore acceptable.

The applicant evaluated the effects of preferential flooding of the DFCs. Based on the design of the MPC-37 basket, the applicant stated that preferential flooding is not possible. However, the applicant performed analyses demonstrating that preferential flooding of the DFCs does not result in an increase in reactivity with a burned fuel composition. The applicant discussed this evaluation in Section 6.I.4.2.2 of the application and presented its results in Table 6.I.4.2 of the application. The applicant concluded that the preferential flooding is bounded by the fully flooded condition. The staff reviewed the applicant’s discussion and calculation results regarding the effects of preferential flooding and finds fully flooded condition bounds the preferential flooding, thus, the applicant’s conclusion acceptable.

7.3.2 Material Properties

The applicant listed the materials used in the criticality analyses in Table 6.I.3.1 of the application which includes the composition and density of the assumed materials. The materials used in the burnup credit calculations are slightly different from those in Table 6.3.4 of the FSAR used in the previously approved boron credit evaluations. The differences are small enough that the compositions are still consistent with the values within the drawings and published values of these materials and therefore the staff finds them acceptable. Metamic-HT is a Holtec proprietary material and its composition is close to that described in the proprietary report but adjusted to only credit 90% of the boron content within the criticality safety evaluation. This is consistent with the acceptance criteria in NUREG-1536 and is therefore acceptable to the staff.

The spent fuel composition for the burnup credit evaluations are discussed in Section 7.5.1 of this SER.

7.4 Criticality Analysis

7.4.1 Computer Programs

The applicant used MCNP5-1.51 and CASMO5 Version 2.00.00 for the criticality analyses of the HI-STORM FW system with burnup credit. Both codes use ENDF/B-VII cross-section data. Sections 7.5.2 and 7.5.3 of this SER discuss validation of these codes for depletion and criticality analyses for burnup credit.

7.4.2 Multiplication Factor

The applicant showed the results of the k_{eff} calculations for burnups corresponding to the bounding polynomial fits at 3- and 7-year cooling time in Tables 6.I.B.23 and 6.I.B.24 of the application, respectively. The results show that k_{eff} is always less than 0.95. The staff finds this acceptable according to the subcriticality criterion in Section 7.4 of NUREG-1536.

7.5 Burnup Credit

The applicant stated in Section 6.I.B.0 that they did not credit any nuclides outside the actinides nor fission products stated in Tables 1 and 2 of SFST-ISG-8, Revision 3. The staff reviewed the list of credited nuclides in Section 6.I.B.3 and finds the list consistent with the ISG and is therefore, acceptable.

The applicant used a burnup credit method similar to that used in the HI-STAR 100 MPC-32, previously approved by the NRC (SER dated October 12, 2006, ADAMS Accession No. ML062860201). The applicant first performed a depletion calculation to estimate the isotopic content of the spent fuel. The applicant then performed a criticality calculation to estimate the k_{eff}. The applicant performed the criticality calculations for multiple enrichments and each storage configuration. The applicant then established a polynomial function that specifies minimum burnup as a function of enrichment for each basket configuration, assembly type, and cooling time. These functions are specified in Table 2.4-1 of Appendix B of the TS. This method is consistent with the recommendations in SFST-ISG-8, Revision 3, and thus the staff found the method acceptable.

7.5.1 Depletion Analysis

The applicant depleted the fuel using relatively high boron concentrations as determined from plant data, increased (upper bound) fuel temperature and increased (upper bound) moderator temperature. Higher boron concentrations, higher fuel temperature and higher moderator temperature are conservative depletion assumptions because they generally result in higher k_{eff} as discussed in SFST-ISG-8, Revision 3. The applicant assumed an increased (upper bound) specific power during depletion. Although this has been found to be conservative when applied to actinide only compositions, as identified in SFST-ISG-8, Revision 3, this assumption is non-conservative (produces a lower reactivity) for actinide and fission product compositions. However, even considering this non-conservative depletion assumption the staff still found this evaluation acceptable as a whole since the other conservative depletion assumptions (i.e., boron concentration, fuel temperature and moderator temperature) would compensate for this non-conservative depletion assumption. The applicant shows the parameters it used in the depletion analysis in Table 6.I.B.2 of the application. This table is reflected as a condition in Appendix B to the Technical Specifications, Table 2.4-3 and with the exception of the specific power, as discussed above, the staff found that the fuel which is allowed burnup credit will be bounded the depletion parameters used. The staff finds the assumed reactor operating conditions for the depletion analysis acceptable.

The applicant considered the reactivity effect due to the presence of non-fuel hardware during depletion. It considered burnable poison rods (BPRs), control rods, axial power shaping rods (ASPRs) and integral fuel burnable absorbers (IFBAs). The applicant determined that BPRs inserted for the entire irradiation bounds the reactivity effect of the other inserts and also determined which types of BPRs are bounding based on assembly type. This assumption is consistent with the conclusions in SFST-ISG-8, Revision 3 which states that “a depletion analysis with a maximum realistic loading of BPRs … should provide an adequate bounding safety basis for fuel with or without BPRs” therefore the staff found the assumption of BPRs inserted acceptable for accounting for the reactivity effects due to BPRs, ASPRs and IFBAs. ISG-8 Rev. 3 further states “the inclusion of BPRs in the assembly irradiation model should adequately account for the potential increase in k_{eff} that may occur for typical spent nuclear fuel exposures to control rods (CRs) during irradiation” and therefore the staff finds the assumption of BPRs inserted during depletion acceptable to account for the effects of typical CR insertions.

SFST-ISG-8, Revision 3 states that “exposures to atypical CR insertions (e.g., full insertion for one full reactor operation cycle) may not be fully accounted for by inclusion of BPRs in the irradiation model, and assemblies irradiated under such operational conditions should be explicitly evaluated.” The applicant did not evaluate for control rods inserted more than 8 inches and therefore included a condition within the TS that any assemblies that have been located under a control rod bank that were permitted to be inserted more than 8 inches from the top of the active length during full power operation are permitted for storage in the Configuration 2 of MPC-37, specifically in the basket cells intended for the fresh fuel assemblies. This is a condition in Table 2.4-2 of Appendix B to the TS. Since a fresh fuel assembly is more reactive than a burned assembly with a control rod fully inserted during its operation, the staff finds that assemblies operated under atypical CR insertions are bounded by a fresh fuel assembly model and that storage in these locations is acceptable.

For fuel assemblies where BPRs are not compatible, the applicant assumed a partial insertion of control rods which demonstrated the highest increase in reactivity, in comparison to the other possible inserts. Because the applicant relied on relatively bounding assumptions staff found the assumption acceptable for the applicable assembly types.

7.5.2 Depletion Benchmarking

The applicant used the CASMO5 Version 2.00.00 with the ENDF/B-VII cross section library as the depletion code for the burnup credit evaluations. CASMO5 is a multigroup two-dimensional transport theory code.

The applicant performed benchmarking analyses by comparing calculated isotopic compositions to chemical assay data of spent nuclear fuel using data from different commercial nuclear power plants that use the same general type of assemblies that could be stored in the HI-STORM FW. The applicant listed the data it used to compare to the calculated values in Table 6.I.B.11 of the application which includes the plant names, and burnup and enrichment ranges. The staff found that the data adequately encompassed the general fuel types and burnup and enrichment ranges that could be stored using burnup credit within the HI-STORM FW and found the data acceptable.

The applicant used a method called “direct difference” which is described in NUREG/CR-7108. In accordance with this method, the applicant evaluated the uncertainty in the nuclides by comparing the k_{eff} values obtained by using calculated nuclide concentrations to k_{eff} values obtained with measured nuclide concentrations. For experiments where measured data for some isotopes was not available, the applicant used surrogate values determined by multiplying the calculated nuclide concentration by the mean value of the measured-to-calculated concentration ratio values obtained from samples with measured data. This is consistent with the approach discussed in SFST-ISG-8, Revision 3, and NUREG/CR-7108; therefore, the staff finds it acceptable.

The applicant’s comparisons showing the difference between the reactivity of the measured isotopic concentrations and reactivity of the calculated isotopic concentrations are shown in Figures 6.I.B.1 and 6.I.B.2 and Table 6.I.B.12 of the application. The results indicate that the average bias is positive and has only a very small correlation with burnup. Since the bias is positive, it is conservative to truncate this, as stated in SFST-ISG-8, Revision 3, and the applicant used a bias and presented the bias and bias uncertainty in Table 6.I.B.14 of the application. The staff found that this is acceptable pursuant to the guidance in SFST-ISG-8, Revision 3.

7.5.3 Criticality Code Benchmarking

The applicant used MCNP5-1.51 to perform the criticality evaluations. The applicant discussed the benchmarking of this code in Section 6.I.B.3.2 of the application. The applicant’s experiments for the benchmarking of the major actinides are discussed in Appendix 6.I.A of the application. The applicant only used mixed-oxide (MOX) and *Haut Taux de Combustion* (HTC) data in determining the bias and bias uncertainty for actinides and did not use data from fresh UO_2 experiments. This is consistent with the recommendations in SFST-ISG-8, Revision 3 for benchmarking actinides and therefore the staff found it appropriate. The applicant performed trending analyses to determine the maximum bias and provides the result in Tables 6.I.A.1.2, 6.I.B.13, and 6.I.B.14 of the application. The applicant performed other benchmarking studies which were in accordance with the guidance in SFST-ISG-8, Revision 3. The staff finds this acceptable.

The applicant applied a bias of 1.5 percent of the worth of the minor actinides and fission products to account for the criticality code validation bias of these nuclides. This value was evaluated as an appropriate bias in NUREG/CR-7109 for the SCALE code system for use with the ENDF/B-V, ENDF/B-VI, or ENDF/B-VII cross section libraries, and is found acceptable in accordance with the guidance in SFST-ISG-8, Revision 3. NUREG/CR-7205 has extended this value for use with MCNP; therefore, the staff finds it acceptable for use by the applicant for this application. SFST-ISG-8, Revision 3, states that in order for an applicant to use this value, it should demonstrate that the system design is similar to the GBC-32, which is a hypothetical cask model used to establish this value. The staff reviewed the design characteristics of the

HI-STORM FW and found it similar enough to the GBC-32 description to be able to apply the bias. Based on the similar fuel and materials of construction and geometry of the cask between the HI-TRAC VW transfer cask (which is the HI-STORM FW cask configuration that requires burnup credit) and GBC-32, the staff found that the two casks would also have similar neutronic characteristics.

The applicant used the bias and bias uncertainty for the minor actinides and fission products from NUREG-7109. As the bias is based on the worth of the minor actinides and fission products, and this worth is different for each different calculation (i.e., combination of burnup, enrichment, configuration and cooling time), the applicant calculated the worth separately for each bias calculation. The staff reviewed the calculated worth of the minor actinides and fission products for each calculation within the report HI-2156424, "Criticality Evaluation of HI-STAR 190," and found they do not exceed 0.1 Δk and found this acceptable as NUREG-7109 only recommends using the bias and bias uncertainty from the NUREG if the worth of the minor actinides and fission products does not exceed 0.1 Δk.

The staff notes that report HI-2156424 is docketed under the HI-STAR 190 transportation cask. As discussed in Section 7.3 of this SER, HI-STAR 190 uses the same MPC-37 canister as the HI-STORM FW. Because staff has concluded it is acceptable for the applicant to use the HI-STAR 190 burnup credit model for HI-STORM FW , as discussed in Section 7.2 of this SER, staff also finds these calculations are applicable and acceptable.

7.5.4 Burnup Profile

The applicant subdivided each assembly into axial sections to model the axial burnup profile. The applicant stated that in each axial section, the isotopic composition of the fuel is taken from the corresponding depletion calculations. This approach to modeling the axial burnup profile is consistent with the recommendations in NUREG/CR-6801 and is acceptable by the NRC staff for the current application.

The applicant used data from Yankee Atomic Engineering Corporation (YAEC)-1937, "Axial Burnup Profile Database for Pressurized Water Reactors," along with other data to determine the bounding axial profile for the burnup credit calculations. YAEC-1937 is recognized in SFST-ISG-8, Revision 3, as an acceptable source of representative data that can be used for establishing axial burnup profiles. The applicant discussed the method for determining the bounding axial burnup profile in Section 6.I.B.4.1 of the application, and referenced the method used to generate the bounding axial profile established in the HI-STAR 100 FSAR, Section 6.E.4.1. Since the reactivity effect of the axial burnup profile is specific to the fuel and not the system it is being stored (or shipped) in, the staff finds that the method would also apply to the HI-STORM FW. The staff finds the assumptions for burnup above 45 GWD/MTU acceptable based on statements from SFST-ISG-8, Revision 3, which states that intermediate burnup profiles will yield higher reactivity at higher burnups.

The applicant discussed the two assembly classes, WE 17x17D and 17x17E that have longer active fuel length than typical assemblies and those from the YAEC-1937 database. The staff finds that the applicant's modeling of these assemblies is consistent with the expected effects of longer fuel lengths, where the relative burnup of the central segments is nearly constant, and decreases at the ends of the fuel at a rate similar to fuel of shorter lengths. Any uncertainty with the modeling in the burnup profile for the longer assembly classes is likely to be small and bounded by other conservative assumptions within the application such as using the combination of basket tolerances that produces the highest reactivity, assuming the fuel to clad gap is flooded with pure water, assuming a maximum UO_2 density, and other assumptions discussed in Section 6.I.B.6 of the application. Therefore, the staff finds it acceptable. As discussed in SFST-ISG-8, Revision 3, using a uniform axial burnup is conservative for lower burned fuel assemblies. In its August 22, 2016 letter, the applicant stated that it considered uniform axial burnup, as well as that of the profile for all calculations, in determining the axial profile that yields maximum reactivity for the burnup credit loading curves. The staff finds this approach conservative and therefore acceptable.

The applicant discusses the effects of planar burnup distribution in Section 6.I.B.4.2 of the application. The applicant performed evaluations with differences in assembly quadrant burnup at a realistic maximum oriented in such a way that produces the highest reactivity. The results of the applicant's evaluations are consistent with SFST-ISG-8, Revision 3, which recognizes that variations in planar burnup are usually insignificant for larger systems. Therefore the applicant performed all design basis evaluations with a uniform planar burnup. The staff reviewed the applicant's evaluation of planar burnup and finds the applicant's conclusions acceptable.

7.5.5 Loading Curve and Burnup Verification

Determining the minimum allowable burnup for each and every possible fuel assembly at every enrichment can be challenging. SFST-ISG-8, Revision 3, states that a burnup credit evaluation should contain loading curves which specify the minimum required burnup as a function of initial enrichment, and that separate loading curves should be established for each set of applicable licensing conditions.

Rather than generate a loading curve for each fuel type, the applicant selected representative assemblies that reasonably bound all allowable fuel types to generate the loading curves. The applicant submitted specific information documenting the procedure it used to select and validate the representative assemblies in its August 22, 2016 letter. The applicant chose the representative assemblies based on the highest calculated reactivity (k_{eff}) at a specific enrichment/burnup. To demonstrate that these assemblies produce loading curves that are reasonably bounding, the applicant validated the loading curves for each configuration. The applicant performed this validation by evaluating the k_{eff} of a reasonable sampling of fuel assemblies including those of various enrichments and burnups (as calculated by the loading curves) and included validations for all allowable PWR fuel assembly classes. All of these validation calculations show that the k_{eff} is less than 0.95, which is consistent with the subcriticality criterion in Section 7.4 of NUREG-1536. As a consequence, staff has reasonable assurance that the representative assemblies are reasonably bounding.

The applicant established separate loading curves for each representative fuel assembly type, and two separate cooling times, as a function of enrichment, for the various loading configurations. The loading curves are located in Table 2.4-1 of Appendix B to the CoC. The applicant combined the three non-uniform configuration loading curves into one for simplicity and also because these curves were closely adjacent. The applicant used the maximum burnup from each of the individual curves as the minimum burnup requirement for each enrichment and derived the third-order polynomial fit using these points. As with the loading curves for the loading configurations, because the two cooling time curves, 3 and 7 years, were so similar the applicant created a third combined curve. This is discussed in 6.I.B.5.1 of the application and in its June 22, 2016 letter.

Based on the above considerations and the staff's review of the applicant's procedure for selecting the representative assemblies and generating and verifying the loading curves, as described in the applicant's August 22, 2016 letter, as well as the calculation in Holtec report No. HI-2156424, the staff finds that the applicant's process for generating loading curves is rigorous. It is within the staff's experience that the reactivity of an assembly as a function of enrichment and burnup behaves in a predictable manner thus any assembly/enrichment/burnup combination not chosen by the applicant to generate or validate the loading curves would result in an insignificant difference in reactivity. As a consequence, the staff has reasonable assurance that the process for generating the loading curves is reasonably bounding and thus finds the loading curves acceptable.

SFST-ISG-8, Revision 3, recommends that an applicant should have a method of burnup verification. The applicant stated in Section 2.1.7 of the SAR that it has two methods of burnup verification for the HI-STORM FW and further described them in Appendix 6.I.D.3 of the application. The applicant will require that the licensees either: 1) perform quantitative measurements of the burnup or, 2) verify burnup through administrative procedures and a qualitative burnup measurement supported by a misload evaluation. This approach is incorporated into Section 2.4 of Appendix B to the CoC. The staff finds that this approach is consistent with the recommendations in SFST-ISG-8, Revision 3, and is therefore acceptable.

7.5.5.1 Misload Analyses

The applicant has performed misload analyses in addition to having burnup verification requirements. SFST-ISG-8, Revision 3, states that a misload analysis should consider: (1) misloading of a single severely underburned assembly, and (2) misloading of multiple moderately underburned assemblies. SFST-ISG-8, Revision 3, states that the severely underburned assembly for the single misload analysis should be chosen such that the misloaded assembly reactivity bounds 95 percent of the discharged PWR fuel population considered unacceptable for loading in a particular storage or transportation system with 95 percent confidence. The multiple moderately underburned assemblies for this analysis should be assumed to make up at least 50 percent of the system payload, and should be chosen such that the misloaded assemblies' reactivity bounds 90 percent of the total discharged PWR fuel population. SFST-ISG-8, Revision 3, further states that the 2002 Energy Information Administration RW-859 fuel survey, or a later estimate, is acceptable as an estimate of discharged fuel population characteristics.

Section 6.I.D.3.2.3 of the application discusses the misloading analyses performed for the HI-STORM FW. The applicant performed the misload analyses in accordance with the recommendations in SFST-ISG-8, Revision 3. The staff reviewed the discussion and results of these analyses. The results of the analysis of a single severely underburned assembly are in Table 6.I.D.4 of the application and show that the cask would remain subcritical. The results of the analyses of multiple moderately underburned assemblies are in Table 6.I.D.5 of the application and show that the cask would remain subcritical. In addition, the applicant performed a misload of multiple assemblies burned with control rods fully inserted. The results of this analysis are in Table 6.I.D.6 and show that the cask would remain subcritical.

With the burnup verification methods requirement incorporated into Appendix B of the CoC and the misload analyses performed as further defense-in-depth, the staff finds that it has reasonable assurance that the HI-STORM FW will remain sub-critical.

7.6 Evaluation Findings

Based on the above evaluation, the staff has made the following findings:

> Structures, systems, and components important to criticality safety are described in sufficient detail in Chapters 1, 2, and 6 of the HI-STORM FW SAR to enable an evaluation of their effectiveness.
>
> The cask and its spent fuel transfer systems are designed to be subcritical under all credible conditions.
>
> The criticality design is based on favorable geometry, and fixed neutron poisons. An appraisal of the fixed neutron poisons shows that HI-STORM FW will remain effective for the term requested in the CoC application, and there is no credible way for the fixed neutron poisons to significantly degrade during the requested term in the CoC application; therefore, there is no need to provide a positive means to verify their continued efficacy as required by 10 CFR 72.124(b).
>
> The analysis and evaluation of the criticality design and performance have demonstrated that the cask will enable the storage of spent fuel for the term requested in the CoC application.

The staff concludes that the criticality design features for the HI-STORM FW are in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied. The evaluation of the criticality design provides reasonable assurance that the HI-STORM FW will allow safe storage of spent fuel. These findings are reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

8.0 MATERIALS EVALUATION

The applicant did not propose any changes that affect the staff's materials evaluation provided in the previous SER for CoC No. 1032, Amendments Nos. 0 through 2. Therefore, the staff determined that a new evaluation was not required.

9.0 OPERATING PROCEDURES EVALUATION

The applicant did not propose any changes that affect the staff's operating procedures evaluation provided in the previous SER for CoC No. 1032, Amendments Nos. 0 through 2. Therefore, the staff determined that a new evaluation was not required.

10.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM EVALUATION

The applicant did not propose any changes that affect the staff's acceptance tests and maintenance program evaluation provided in the previous SER for CoC No. 1032, Amendments Nos. 0 through 2. Therefore, the staff determined that a new evaluation was not required.

11.0 RADIATION PROTECTION EVALUATION

The applicant did not propose any changes that affect the staff's radiation protection evaluation provided in the previous SER for CoC No. 1032, Amendments Nos. 0 through 2. Therefore, the staff determined that a new evaluation was not required.

12.0 ACCIDENT ANALYSES EVALUATION

The applicant did not propose any changes that affect the staff's accident analysis evaluation provided in the previous SER for CoC No. 1032, Amendments Nos. 0 through 2. Therefore, the staff determined that a new evaluation was not required.

13.0 TECHNICAL SPECIFICATIONS AND OPERATING CONTROLS AND LIMITS

13.1 Review Objective

The review of the TS, and it's operating controls and limits, ensures that the operating controls and limits of the TS, including their bases and justification, meet the requirements of 10 CFR Part 72. The detailed evaluation is provided in Section 7 of this SER. The applicant's proposed change to TS is:

> LCO 3.3.1—Increase the minimum soluble boron concentration from 1,500 ppmb to 1,600 ppmb for all 14x14 and 16x16 assembly classes with a maximum initial enrichment of 5.0 wt.% U 235.

The staff reviewed the proposed TS revision against the proposed changes in SER Section 7 and determined that it is consistent and accurately reflect the proposed change.

13.2 Findings

The staff concludes that the conditions for use of the HI STORM FW system continues to identify necessary TS to satisfy 10 CFR Part 72 and that the applicable acceptance criteria have been satisfied. The TS provide reasonable assurance that the system will continue to provide for safe storage of spent fuel. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted practices.

14.0 QUALITY ASSURANCE EAVLUATION

The applicant did not propose any changes that affect the staff's quality assurance evaluation provided in the previous SER for CoC No. 1032, Amendments Nos. 0 through 2. Therefore, the staff determined that a new evaluation was not required.

15.0 CONCLUSIONS

The staff has performed a comprehensive review of the amendment application, during which the following requested changes were considered:

1. Include burnup credit for the MPC-37.
2. Revise CoC Condition 8.

Based on the statements and representations provided by the applicant in its amendment application, as modified and supplemented, the staff concludes that the changes described above to the HI-STORM Flood/Wind Multipurpose Canister Storage System do not affect the ability of the cask system to meet the requirements of 10 CFR Part 72. Amendment No. 3 for HI-STORM Flood/Wind Multipurpose Canister Storage System should be approved.

Issued with Certificate of Compliance No. 1032, Amendment No. 3
on 8/9/17.