January 24, 2007

Mr. Evan Rosenbaum
Project Manager
Holtec International
555 Lincoln Drive West
Marlton, NJ 08053

SUBJECT: REVIEW OF THE HOLTEC INTERNATIONAL HI-STORM 100U SPENT FUEL STORAGE DESIGN (TAC NO. L23850)

Dear Mr. Rosenbaum:

On May 16, 2005, Holtec International (Holtec) submitted Revision 1 to an application to amend Certificate of Compliance (CoC) No. 1014 for the HI-STORM 100 Cask System (License Amendment Request 1014-3, Revision 1) in accordance with 10 CFR Part 72. This amendment proposed to: (a) add a new underground storage design denoted as the HI-STORM 100U and (b) increase the maximum thermal decay heat load to 36.9kW (regionalized loading) for both boiling water reactor and pressurized water reactor spent nuclear fuel. The staff notified Holtec by letter dated November 18, 2006, that the review had been discontinued due to issues identified during the course of the technical review and the inability of the staff to reach any conclusions and findings based on the information provided by Holtec. Subsequently in a letter dated November 29, 2006, Holtec requested that the HI-STORM 100U design be withdrawn from consideration for approval. Holtec submitted LAR 1014-3, Revision 2, on December 22, 2006, removing reference to the HI-STORM 100U design such that the staff could move forward with review of the request for an increase in the maximum thermal decay heat load and other minor changes to the CoC.

The purpose of this letter is to provide you with the staff's evaluation of the HI-STORM 100U spent fuel storage design (Enclosure1), based on the information provided to the staff up to the time the staff discontinued its review on November 16, 2006. The staff's review considered the Nuclear Regulatory Commission's (NRC) Request for Additional Information (RAI) No. 1 issued on November 30, 2005, and RAI No. 2 issued on June 6, 2006, and Holtec's response to the RAIs submitted on February 18, 2006, and July 10, 2006, respectively. The evaluation also summarizes any identified outstanding issues and indicates where the staff was unable to make findings regarding the complex methodologies associated with your approach to the structural analysis for the underground storage design concept.

The intent of the staff's evaluation is to document its review of the HI-STORM 100U design, LAR 1014-3, application materials to the greatest extent possible. It should be noted that at the time the staff discontinued its technical review, based on issues identified in the structural discipline, review of other areas of the application was still ongoing. As such, the information contained in the enclosed staff evaluation should not be considered a comprehensive or complete Safety Evaluation Report of the HI-STORM 100U design. The enclosed staff evaluation documents the staff's findings or conclusions only for those aspects of the HI-STORM 100U design that were reviewed. This is intended to facilitate a future NRC review should Holtec choose to resubmit the HI-STORM 100U design for approval. Provided there are no changes to the application materials that might affect the review findings it may not be necessary for the staff to rereview that portion of the application. However, if any aspect of the design is modified or changed, or if the supporting documentation is revised, any findings and conclusions reached by the staff will be reconsidered.

Please refer to Docket Number 72-1014 and TAC No. L23850 in future correspondence related to this action. If you have any questions regarding our review, you may contact me at (301) 415-8500.

Sincerely,

/RA/

Christopher M. Regan, Senior Project Manager
Licensing Branch
Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety
and Safeguards

Docket No. 72-1014
TAC No. L23850

Enclosure: Staff Evaluation of Holtec International HI-STORM 100U Cask System necessary for the staff to rereview that portion of the application. However, if any aspect of the design is modified or changed, or if the supporting documentation is revised, any findings and conclusions reached by the staff will be reconsidered.

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Enclosure: Staff Evaluation of Holtec International HI-STORM 100U Cask System

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Enclosure

STAFF EVALUATION OF

HOLTEC INTERNATIONAL

HI-STORM 100U CASK SYSTEM

STAFF EVALUATION
HI-STORM 100U CASK SYSTEM
HOLTEC INTERNATIONAL

SUMMARY

By letter dated December 30, 2004, Holtec International (Holtec) submitted an application to the United States Nuclear Regulatory Commission (NRC) to amend Certificate of Compliance (CoC) No. 1014 for the HI-STORM 100 Cask System (License Amendment Request 1014-3, Revision 0), in accordance with U.S. Code of Federal Regulations, “Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste and Reactor-Related Greater than Class C Waste,” Title 10, Part 72 (10 CFR Part 72). The application included a proposal to add a new underground variation of the HI-STORM 100 Cask System, designated as the HI-STORM 100U, to CoC No. 1014.

The complexity of the material submitted, the uniqueness of the underground system, and the knowledge of prior unresolved technical issues, obligated the NRC staff, hereafter referred to as the staff, to perform a technical “acceptance review.” As a result of issues identified during the staff’s technical acceptance review, Holtec requested that staff suspend technical review in order to make improvements to the HI-STORM 100U Cask System design. Holtec submitted revised License Amendment Request 1014-3 (LAR 1014-3) on May 16, 2005. By letter dated June 14, 2005, the staff informed Holtec that the revised LAR 1014-3 application contained sufficient information for the staff to begin a technical review.

In response to staff Requests for Additional Information (RAIs) dated November 30, 2005, and June 6, 2006, Holtec supplemented LAR 1014-3 on February 18, 2006, and July 10, 2006, respectively; however, the staff notified Holtec by letter dated November 18, 2006, that the review had been discontinued due to the issues identified and the inability of the staff to reach an acceptable conclusion or findings of acceptability of the HI-STORM 100U Cask System design based on the information provided by Holtec. Subsequently, in a letter dated November 29, 2006, Holtec requested that the HI-STORM 100U Cask System design be withdrawn from consideration for approval.

The following evaluation documents the staff’s review of the HI-STORM 100U Cask System design based on the information provided to the staff up to the time the staff discontinued its review on November 16, 2006. Because the staff review was not complete at the time the review was discontinued, there are aspects of the application that are not addressed in this evaluation or are discussed only summarily. The evaluation documents those aspects of the design that are unique to the HI-STORM 100U Cask System. The staff evaluation covers the application materials pertinent to the HI-STORM 100U Cask System design to include requested changes to the Certificate of Compliance (CoC), Technical Specifications (TS), and Final Safety Analysis Report (FSAR). The evaluation considers the RAIs issued on November 30, 2005, and June 6, 2006, and Holtec’s responses to the RAIs dated February 18, 2006, and July 10, 2006, respectively. The evaluation also summarizes any identified outstanding issues and indicates where the staff was unable to draw findings of acceptability regarding the complex methodologies associated with Holtec’s approach to the structural analysis for the underground storage design concept. The findings stated at the end of each chapter are predicated on acceptable resolution of outstanding technical issues, i.e. structural. Several findings specifically indicate where structural considerations, or unresolved issues, will impact the staff's findings; however, there may be other areas the staff was not able to identify, given the information provided by the applicant, where findings may change pending resolution of the technical issues.

The staff's evaluation is based on whether the applicant met the applicable requirements of 10 CFR Part 72 for independent storage of spent fuel and of 10 CFR Part 20 for radiation protection. The staff's evaluation focuses only on modifications relevant to the HI-STORM 100U Cask System design as requested in the revised application and application supplements and does not reassess previously approved portions of the CoC, TS, and the FSAR or those areas of the FSAR modified by Holtec as allowed by 10 CFR 72.48. Also, this staff evaluation of the HI-STORM 100U cask system design does not discuss those changes requested in LAR 1014-3 which are being considered as part of a separate licensing action for rulemaking, with the exception of certain fuel parameters affecting the system thermal design that, although not specifically reviewed for the purpose of approving a higher thermal capacity, have relevance to the shielding analyses, as documented in Sections 5 and 10 of this evaluation.

1.0 GENERAL DESCRIPTION

The objective of the review of the general description of the HI-STORM 100U Cask System (HI-STORM 100U) is to ensure that Holtec provided a description that is adequate to familiarize reviewers and other interested parties with the pertinent features of the system.

1.1 General Description and Operational Features

The HI-STORM 100U Cask System is a dry cask storage system for spent light water reactor fuel. The system comprises three discrete components: the multi-purpose canister (MPC), the HI-TRAC transfer cask, and the HI-STORM 100U Vertical Ventilated Module (VVM). The staff has not determined if the HI-STORM 100 "overpack," as defined by Holtec, is appropriate for application to both an above-ground cask/silo type storage system and/or a below-ground drywell/caisson type system.

1.1.1 Multi-Purpose Canister

The MPC is the confinement system for the stored fuel. It is a welded, cylindrical canister with a honeycombed fuel basket, a baseplate, a lid, a closure ring, and the canister shell. It is made entirely of stainless steel. All MPC components that may come into contact with spent fuel pool water or the ambient environment, with the exception of neutron absorber, aluminum seals on vent and drain port caps, and optional aluminum heat conduction elements, are constructed of stainless steel. The canister shell, baseplate, lid, vent and drain port cover plates, and closure ring are the main confinement boundary components. The honeycombed basket, which is equipped with neutron absorbers, provides criticality control. There are eight approved MPC designs; MPC-24, MPC-24E, and MPC-24EF which can contain a maximum of 24 pressurized water reactor (PWR) fuel assemblies; the MPC-32 and MPC-32F which can contain a maximum of 32 PWR fuel assemblies; and the MPC-68, MPC-68F, and MPC-68FF which can contain a maximum of 68 boiling water reactor (BWR) fuel assemblies. Vibration suppressors are considered integral non-fuel hardware consisting of zircaloy or stainless steel tubes. The MPC designs remain fundamentally unchanged for use in the HI-STORM 100U. The HI-STORM 100U VVM is designed to accept all currently approved variations of the MPC.

1.1.2 HI-TRAC Transfer Cask

The HI-TRAC transfer cask provides shielding and structural protection of the MPC during loading, unloading, and movement of the MPC from the spent fuel pool to the storage VVM location. The HI-TRAC has been previously reviewed and approved by the staff for use with the HI-STORM 100 above-ground storage system. No significant design changes were made to the HI-TRAC..

1.1.3 HI-STORM 100U Vertical Ventilated Module

The HI-STORM 100U VVM provides shielding and structural protection of the MPC during storage. The VVM is a steel cylindrical vessel with an internal steel cylindrical ventilation baffle. The VVM may or may not be encased in concrete. The HI-STORM 100U includes the underground VVM which is designed to accept all MPC models for storage at an Independent Spent Fuel Storage Installation (ISFSI). The VVM provides for storage of MPCs in a vertical configuration inside a subterranean cylindrical cavity entirely below the top-of-the-grade of the ISFSI.

1.1.4 Basic Operation

The basic sequence of operations for the HI-STORM 100U is as follows: (1) the HI-TRAC transfer cask, with the MPC inside, is lowered into the spent fuel pool and the MPC is loaded; (2) the HI-TRAC transfer cask and MPC are removed from the spent fuel pool and the MPC is drained, dried, welded closed, inspected, and backfilled with an inert gas; (3) the HI-TRAC transfer cask is moved to the location of the VVM; and (4) the HI-TRAC transfer cask is placed on top of the VVM, the transfer cask mating device is opened, and the MPC is lowered into the VVM. A loaded HI-TRAC transfer cask can be handled vertically or horizontally. The HI-STORM 100U VVM differs from other HI-STORM 100 overpack designs in that it can only be loaded in situ.

1.2 Drawings

Section 1.5 of the FSAR contains the drawings for the HI-STORM 100U, which include drawings of the structures, systems, and components important to safety. The staff requested in an RAI that the Bill of Materials or equivalent information be included in the FSAR. Holtec responded that licensing Drawing 4501, included in Section 1.5 of the proposed revised FSAR, contain the material type and critical dimensions of the HI-STORM 100U components and Table 2.I.7 in the FSAR lists the material and Important to Safety (ITS) Category of the components. The staff did not identify all dimensions that are considered critical for ITS items for the analyses and design in the submitted response. For example, the thickness of the Cavity Enclosure Container (CEC) bottom plate, the thicknesses of the upper and lower MPC guides, and the thickness of the divider shell restraint did not appear to be identified on Sheets 1 through 6 of Drawing 4501 submitted in response to the staff's second RAI. Also, the NRC staff requested that Drawing 4501, Sheet 4, be revised to reflect the information for ITS items contained in Revision 0 of the drawing, using Detail K as an example of the necessary information. Holtec's response indicated the information had been restored to Sheet 4 as requested. With regard to Detail K, Holtec provided Detail M; however, the staff considers the necessary information to be missing. The pipe weight, plate size and thickness, and the plate hole size have not been identified. Also noted on Revision 2 of Sheet 4 is a note for additional "optional gusset plates" in the anchorage zone of the CEC outer shell with no explanation regarding need for use of the option. Specific structures, systems, and components are evaluated in Sections 3 through 14 of the staff evaluation, as necessary.

1.3 Alternative Materials for Important-to-Safety (ITS) Components

In the bill of materials, the applicant specified certain ASTM/ASME material grades and alternates for the VVM and CEC shell components which are classified as ITS. The alternates are not specified by reference to specific ASTM/ASME material grades. Instead, to allow flexibility, the applicant has included a definition of "equivalent" and "critical characteristic" in the terms and definitions section of the FSAR. The adopted definitions of these terms establish the requirements for the affected ITS materials. With these definitions as a guide, the applicant may use substitute materials which have the same mechanical properties (primarily strength) as the originally specified material.

However, as noted in NRC letter dated November 16, 2006, additional expansion and/or clarification is necessary regarding the use of alternative or equivalent materials for ITS components. Although the approach for defining alternative or equivalent materials is acceptable in principle, additional details must be provided. Holtec employs a new term "critical characteristic" (along with a definition for "equivalent") that mentions "attributes....in the associated material specification, as necessary to render the material's intended function." However, the specific attributes, such as chemical composition or mechanical properties (i.e., TS, YS, elongation) have not been specifically delineated in sufficient detail for each of the various materials for which an alternative material is desired.

1.4 Evaluation Findings

Based on the NRC staff's review of information provided relevant to the HI-STORM 100U Cask System, the staff determined the following:

F1.1 A general description and discussion of the HI-STORM 100U Cask System are presented in Chapter 1 of the FSAR, with special attention to design and operating characteristics, unusual or novel design features, and principal safety considerations.

F1.2 The staff has not determined if the definition of the HI-STORM 100 Cask System is appropriate for application as an element of both an above-ground cask/silo type storage system and/or a below-ground or caisson type system.

F1.3 Drawings for structures, systems, and components important to safety presented in Section 1.5 of the FSAR were reviewed. Specific structures, systems, and components are evaluated in Sections 3 through 14 of the staff evaluation, as necessary.

F1.4 Specifications for the spent fuel to be stored in the HI-STORM 100U Cask System are provided in Section 1.2.3 of the FSAR. Detailed specifications for the spent fuel are presented in Section 2.1 of the FSAR and Appendix B to the CoC.

F1.5 The technical qualifications of the applicant to engage in the proposed activities were reviewed and approved for CoC No. 1014 and were not specifically reviewed in this evaluation.

F1.6 The quality assurance (QA) program and implementing procedures are described in Chapter 13 of the FSAR. Specific changes to the QA program and program description are evaluated in Section 13 of the staff evaluation.

F1.7 The staff concludes that the information presented in this chapter of the FSAR is incomplete and requires additional description, as noted above, to satisfy the general description requirements under 10 CFR Part 72. This determination is based on a review that considered the regulation itself, Regulatory Guide 3.61, and accepted dry cask storage practices detailed in NUREG-1536.

2.0 PRINCIPAL DESIGN CRITERIA EVALUATION

The objective of evaluating the principal design criteria related to the structures, systems, and components important to safety is to ensure that they comply with the relevant general criteria established in 10 CFR Part 72.

2.1 Structures, Systems, and Components Important to Safety

Structures, systems, and components important to safety are annotated in Table 2.2.6 of the FSAR for the HI-STORM 100 Cask System (HI-STORM 100) (above-ground). Common structures, systems and components for the HI-STORM 100U Cask System (HI-STORM 100U) (below-ground) are also addressed in Table 2.2.6. Structures, systems, and components unique to the HI-STORM 100U have the assigned safety classification defined in Table 2.I.8. Table 2.I.8 does not include the concrete that may be used as an encasement for the VVM. The safety classifications provided are based on the guidance in NRC, "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety," NUREG/CR-6407, INEL-95/0551, February 1996.

Tables 2.2.6, 2.I.1, and 2.I.8 also identify the function and the governing code of the components. The governing code for the structural design of the MPC, the HI-TRAC transfer cask, and metal components of the VVM is the ASME Code. The staff noted that the governing code for the plain un-reinforced concrete in the VVM closure lid is noted to be ACI 318.1-89(92), which is an inactive code document. For the HI-STORM 100U, the applicable code reference should be Chapter 22 of the current ACI 318 code document that is the 2005 edition. Alternatives to the currently referenced codes are delineated in the FSAR.

Table 2.I.8 identifies the MPC bearing pads as Not-Important-To-Safety (NITS); however since the MPC must be supported off of and above the bottom plate of the CEC in order to maintain the plenum beneath the MPC for the thermal system to function as designed, this component should be reclassified.

Systems, structures, and component materials ITS are also discussed in Section 1.3 of this staff evaluation.

2.2 Design Bases for Structures, Systems, and Components Important to Safety

The HI-STORM 100 (above-ground) design criteria summary includes the allowed range of spent fuel configurations and characteristics, the enveloping conditions of use, and the bounding site characteristics. The HI-STORM 100U design summary includes the same design basis elements as the HI-STORM 100; however, bounding site characteristics have not been fully identified because use of this system considers site-specific parameters and analyses.

2.2.1 Spent Fuel Specifications

The HI-STORM 100U is designed to store either 24 or 32 PWR fuel assemblies and up to 68 BWR fuel assemblies. Detailed specifications for the approved fuel assemblies are provided in Section 2.1 and Supplement 2.I.1 of the FSAR. These include the maximum enrichment, maximum decay heat, maximum average burnup, minimum cooling time, maximum initial uranium mass, and detailed physical fuel assembly parameters. The limiting fuel specifications are based on the fuel parameters considered in the structural, thermal, shielding, criticality, and confinement analyses.

2.2.2 External Conditions

Section 2.2 of the FSAR identifies some of the bounding site environmental conditions and natural phenomena for which the HI-STORM 100U is analyzed. Changes made to Section 2.2 were made for consistency with those proposed changes described in greater detail elsewhere in the FSAR and which are related to proposals, some under review for separate licensing actions, for increased design basis temperatures, restoration of the helium leak test on the vent and drain port cover plate welds, and use of the ACI 318-95 Code reference discussed above.

2.3 Design Criteria for Safety Protection Systems

The principal design criteria for the MPC, the HI-STORM 100 (above-ground) overpack, and the HI-TRAC transfer cask designs are summarized in FSAR Tables 2.0.1, 2.0.2, and 2.0.3, respectively. This application requested changes to Tables 2.0.1, 2.0.2, and 2.0.3 to be consistent with those changes described in greater detail elsewhere in the FSAR. The codes and standards of the design and construction of the HI-STORM 100 and the changes to the design criteria are specified in Section 2.2 of the FSAR. For the HI-STORM 100U (below-ground), the principal design criteria for the HI-STORM 100U VVM are described in Supplement 2.I. The principal design criteria for the MPC and the HI-TRAC transfer cask for the HI-STORM 100U remain the same as for the HI-STORM 100. Tables 2.I.1, 2.I.3, 2.I.5, 2.I.6, and 2.I.8 summarize and identify the specific design criteria unique to the HI-STORM 100U. Section 2.I.0 of the FSAR provides an overview of the principal design criteria within the various technical disciplines.

2.3.1 General

Chapter 2 of the FSAR was modified to include changes associated with the MPC and to add Supplement 2.I for the HI-STORM 100U.

2.3.2 Structural

The structural analysis for the HI-STORM 100U is presented in Chapter 3 of the FSAR, and specifically, for the portions of the system that are different from the HI-STORM 100, the HI-STORM 100U structural analyses are presented in Chapter 3.I of the FSAR. The HI-STORM 100U components are designed to protect the cask contents from significant structural degradation, preserve retrievability, provide adequate shielding, and maintain subcriticality and confinement under the design basis normal, off-normal, and accident loads. The design basis normal, off-normal, and accident conditions for the HI-STORM 100 and those components of the HI-STORM 100U that are identical are defined in Section 2.2 of the FSAR. In the proposed FSAR, Section 2.I.3 states that, "Applicable loads for an MPC contained in a VVM or for a HI-TRAC that services a VVM are identical to those already identified in the main body of Chapter 2 and, ..." The staff notes that loads and the load path are different for an MPC used in the HI-STORM 100 and the HI-STORM 100U (See Section 3.0 below). For the design basis conditions as applied to those components that are unique to the HI-STORM 100U, Sections

2.I.3 through 2.I.6 of the FSAR provide the relevant information. Changes made to the structural design criteria and the structural analysis with respect to the application for the HI-STORM 100U are described in Section 3 of this staff evaluation.

2.3.3 Thermal

The thermal analysis is presented in Chapter 4 of the FSAR. The HI-STORM 100U is designed to passively reject decay heat when in its storage configuration at the ISFSI. Heat removal, by conduction, radiation, and natural convection is independent of intervening actions under normal, off-normal, and accident conditions for storage of spent nuclear fuel in the HI-STORM 100U. The thermal design criteria include maintaining fuel cladding integrity and ensuring that temperatures of materials and components important to safety are within the design limits.

2.3.4 Shielding/Confinement/Radiation Protection

The shielding and confinement analyses and the radiation protection capabilities of the HI-STORM 100U Cask System are presented in Chapters 5, 7, and 10 of the FSAR. Confinement is provided by the MPC, which has a welded closure. The MPC's confinement function is verified through pressure testing, helium leakage testing, and weld examinations. Radiation exposure is mitigated by the neutron and gamma shields and by operational procedures.

2.3.5 Criticality

The criticality analysis is presented in Chapter 6 of the FSAR. The design criterion for criticality safety is that the effective neutron multiplication factor, including statistical biases and uncertainties, does not exceed 0.95 under normal, off-normal and accident conditions. The design features relied upon to prevent criticality are the fuel basket geometry and permanent neutron-absorbing materials. The continued efficacy of the neutron-absorbing materials over a 20-year storage period is assured by the design of the system. Depletion of the ^{10}B in the neutron-absorbing materials is negligible because the neutron flux in the MPC over the storage period is low.

2.3.6 Operating Procedures

Generic operating procedures are described in Chapter 8 and Section 8.I of the FSAR. This section outlines the loading, unloading, and recovery operations and provides the basis and general guidance for more detailed, site-specific procedures.

2.3.7 Acceptance Tests and Maintenance

The acceptance test and maintenance program are presented in Chapter 9 and Section 9.I of the FSAR, including the commitments, industry standards, and regulatory requirements used to establish the acceptance, maintenance, and periodic surveillance tests.

2.3.8 Decommissioning

Decommissioning considerations for the HI-STORM 100U are presented in Section 2.I of the FSAR. The decommissioning features of the HI-STORM 100U were not evaluated by the staff.

2.4 Evaluation Findings

Based on the NRC staff's review of information provided in the HI-STORM 100 Cask System (above-ground) application that includes the HI-STORM 100U Cask System (below-ground), the staff finds the following:

F2.1 The staff concludes that the principal design criteria for the HI-STORM 100 Cask System (above-ground) utilized for part of the HI-STORM 100U Cask System (below-ground) are acceptable with regard to demonstrating compliance with the regulatory requirements of 10 CFR Part 72, except for the reliance on an inactive industry design code identified as ACI 318.1-89(92). This same inactive industry design code is referenced in the design criteria for specific components of the HI-STORM 100U Cask System and is found to be unacceptable. The staff has determined that the MPC bearing support pads should be classified at least at Level C.

3.0 STRUCTURAL EVALUATION

The objectives of this review were to assess the safety analysis of the structural design features, the structural design criteria, and the structural analysis methodology used to evaluate the expected structural performance capabilities under normal operations, off-normal operations, accident conditions and natural phenomena events for those structures, systems, and components important to safety relevant to the HI-STORM 100U Cask System (HI-STORM 100U) design as identified by Holtec.

The review was conducted against the appropriate regulations as described in 10 CFR 72.236, that identify the specific requirements for spent fuel storage cask approval and fabrication. The unique characteristics of the spent fuel to be stored are identified, as required by 10 CFR 72.236(a), so that the design basis and design criteria that must be provided for the structures, systems, and components important to safety can be assessed under the requirements of 10 CFR 72.236(b). This application was also reviewed to determine whether the HI-STORM 100U fulfils the acceptance criteria listed in Section 3 of NUREG -1536.

The application materials applicable to the HI-STORM 100U address a new concept for the storage of commercial spent nuclear fuel in that the proposed system is different than the HI-STORM 100 from the standpoint of the type of system, as defined in ANSI/ANS 57.9. The current HI-STORM 100 is an above-ground cask/silo system while the proposed HI-STORM 100U is a below-ground drywell/caisson type system, as differentiated in the ANSI/ANS reference.

The following structural reviews and evaluations were performed by the staff. The MPC and the HI-TRAC transfer cask for the HI-STORM 100U (below-ground), are identical to the existing MPC and HI-TRAC transfer cask for the HI-STORM 100 (above-ground) so no additional review or evaluations were required except for specific conditions and loading cases for the MPC behavior inside the CEC under seismic loading conditions. This is due to the fact that the MPC guides of the HI-STORM 100U VVM divider shell impose different conditions than the channel supports of the HI-STORM 100 overpack on the MPC. Therefore, it is necessary for the seismic analyses for the HI-STORM 100U to consider the effects of the MPC and its contents. The staff has not reached a finding regarding the results of these analyses methodology or sample analysis for the HI-STORM 100U.

3.1 Structural Design of the HI-STORM 100U Cask System

The HI-STORM 100U (below-ground) is made up of three major components that are used in the dry spent fuel storage system: the MPC, the HI-TRAC transfer cask, and the HI-STORM 100U VVM. The MPC and the HI-TRAC components used in the HI-STORM 100U are identical to those used in the HI-STORM 100 (above-ground). The structural sub-components of the HI-STORM 100U VVM include the following items: the steel and concrete Closure Lid, the steel CEC, the steel Divider Shell and attachments, and the steel anchor housing for the foundation. The other structural elements defined by Holtec as “interfacing systems, structures, and components (SSCs)” include the reinforced concrete support foundation, the Foundation Anchor Clip, the optional (based on surrounding subgrade materials corrosion potential) concrete encasement of the CEC, the subgrade material laterally surrounding the CEC or the concrete encased CEC, and the Top Reinforced Concrete Pad. In addition, the Transporter

Support Surface Pad that surrounds the Top Reinforced Concrete Pad and its loaded effect on the VVM must be considered since it can transmit effects to the Top Reinforced Pad and the surrounding subgrade material.

Holtec considers the "interfacing SSCs" that surround and support the VVM as not part of the Holtec HI-STORM 100U. Consequently, for events and associated loading conditions that are unique to a site, such as seismic loads with the VVM embedded in the specific site stratigraphy, the design and the resulting physical dimensions, etc., of the proposed VVM cannot be demonstrated to be a bounding design based on characteristics used to identify the acceptability of a certified spent fuel storage system at a specific site. For the HI-STORM 100U, Holtec states, "... the analysis and qualification of a VVM under the Design Basis Earthquake must be carried out for each site using its unique substrate characteristics." While a "seismic analysis methodology" has been proposed that would be described in the FSAR, and specifically required to be followed by the proposed CoC for each site intending to use the HI-STORM 100U, the staff has not reached a finding with respect to the methodology or the appropriateness of the certification of a below-ground drywell/caisson type system consistent with the provisions for use under a general license. For example, unique site conditions may require the surrounding subgrade materials, outside the zone of excavation for the VVM installation, to the represented as multiple bedded layers, that under seismic conditions can move differentially along the bed interface surfaces. This may induce other load conditions on the HI-STORM 100U that may not be captured by the proposed methodology or sample analysis. Furthermore, the results of such a site specific analysis may require site specific hardware changes since the demonstration provided for the proposed HI-STORM 100U may not bound such a site condition.

The staff noted that the application, as submitted, does not adequately describe all essential elements of the various components of the systems, structures, and components (SSCs) that are important to safety and does not provide drawings and text in sufficient detail to allow evaluation of their structural effectiveness and influence on the performance of the SSCs under the various loading conditions. For example, the number of gussets reinforcing the attachment of the outer container shell to the bottom plate is undefined and with some gussets noted as optional on a drawing with no criteria on when these are required to be used.

Individual loads for the three design conditions of normal, off-normal and accident conditions, including natural phenomena, have been addressed in proposed FSAR Sections 2.I.4, 2.I.5, and 2.I.6. It is correctly noted that the seismic analyses will utilize a detailed model of the MPC, the fuel basket, and the spent fuel in the determination of the response to seismic loads.

The loading combinations are identified in the proposed FSAR Section 3.I.4.

The allowable stresses under various service levels and temperatures are provided in Tables 3.I.3 (a) through © for the steel materials and in Table 3.I.4 for other key materials.

3.1.1 Design Criteria

The structural design criteria for the VVM whose structural steel members are made of carbon steel are based on the ASME Code, Section III, 1995 Edition with the 1997 Amendments. Plain (unreinforced) concrete encapsulated and used in the closure lid is proposed to be used under the criteria of an inactive code (See Section 2.1), reinforced concrete design criteria are proposed to be based on ACI 318-95, and the optional non-structural concrete for the encasement of the CEC is proposed to be reinforced, but with either fiber reinforcement or corrosion resistant/coated steel wire reinforcement with citations to various documents (ACI 318, ACI 544.2R: "Measurement of Properties for Fiber Reinforced Concrete," ACI 544.3R-93 or latest: "Guide for Specifying, Proportioning, Mixing, Placing and Finishing Steel and Fiber Reinforced Concrete," and ASTM C-1116-03 or latest: "Standard Specification for Fiber-Reinforced Concrete and Shotcrete" for the criteria. Holtec had indicated that where concrete encasement is used, it is used only the create an advantageous chemical environment around the CEC steel shell.

3.1.2 Weights and Centers of Gravity

Weights are presented as bounding weights and are provided in Table 3.I.1, with the centers of gravity of the various components and assembled components provided in Table 3.I.2.

3.2 Structural Analysis of HI-STORM 100U

The proposed HI-STORM 100U consists of a site-specific array of underground VVMs anchored to a subsurface flexible concrete pad embedded in soil (e.g., a 2 x 5 array is shown in Figure 1.I.3 of the FSAR). It also appears that each VVM could be placed on a separate foundation pad since Holtec has stated each VVM stores one MPC and functions completely independent of any other VVM. To determine the seismic adequacy of the design, Holtec submitted a soil-structure interaction (SSI) analysis of a single VVM and extended foundation pad anchored to bedrock and surrounded laterally by soft soil. This model was subjected to an acceleration time history defined by Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," with a peak ground acceleration (PGA) of 0.5g. Based on the results of this analysis, Holtec performed a stress evaluation of VVM components important to safety (ITS), including the MPC confinement boundary.

The staff noted that additional justification for the following was necessary: (1) a single VVM bounds the results for multiple VVMs, (2) that a rigid concrete pad (i.e., bedrock) results in a conservative structural response when compared to a flexible concrete pad, and (3) that a VVM model founded directly on bedrock provides reasonably accurate results when compared to a more realistic SSI model where soil exists on all sides and beneath the flexible concrete pad. Holtec provided a SSI analysis of a single VVM and extended foundation pad anchored directly to bedrock and surrounded laterally by soft soil as an analysis representative of a methodology that would be applied on a site-specific basis by licensees. The staff determined that this approach is not acceptable, as it does not demonstrate that such an analysis methodology could reasonably represent the critical response characteristics of an actual independent spent fuel storage installation (ISFSI) site that could be developed within the scope of the defined characteristics. The staff also determined that Holtec report HI-2053389, "Calculation Package for the HI-STORM 100U," Holtec Calculation 004, "Comparison of Shell and Brick Elements in Seismic Analysis Representation Case," does not support the Cavity Enclosure Container (CEC) being modeled as a single layer of solid (constant stress) elements as asserted in Holtec Calculation 007, "Seismic Analysis." In addition, the staff determined the stress evaluation of the MPC confinement boundary in Calculation 007 to be inconclusive with respect to the calculation of the American Society of Mechanical Engineers (ASME) Code stress intensities.

The HI-STORM 100U is described as “an alternative overpack design” (page 1.I-1). In the section on Terminology and Notation, the application proposes to revise the definition of HI-STORM 100 overpack to include the HI-STORM 100U VVM, as noted on page 1.0-6 of the proposed FSAR. Also on page 1.I-1 the statement is made that, “Each VVM stores one MPC and functions completely independent from any other VVM.” Other information within the submittal indicates that the VVMs may all be supported in groups on a continuous mat foundation pad. Once such a configuration has the backfill placed and is subjected to lateral loading from a seismic event the VVMs will not behave independently.

On pages 1.I-1 and -2 the following statement is made describing the HI-STORM 100U CEC: “In its installed configuration, the CEC is interfaced by the subgrade for most of its height except for the top region where it is surrounded by the Top Reinforced Concrete Pad and the Transporter Track Reinforced Pad.” From Drawing 4501, Sheet 2, it appears that the Transporter Track Reinforced Pad has no interface with the CEC, but has an interface with the Top Reinforced Concrete Pad through the 1" expansion joint shown on Sheet 3 of the same drawing. The staff finds this as a discrepancy in the description requiring correction.

Figures 1.I.3 and 1.I.5 do not appear to be consistent. In Figure 1.I.5, the 2x2 array appears to indicate there are three construction joints in the horizontal dimension across the concrete structures between the 12 foot spacing of the casks. There are two joints representing the interface between each Top Reinforced Concrete Pad and the Transporter Track Reinforced Pad and a joint between the adjacent widths of the Transporter Track Reinforced Pad. Across the 2-joint wide direction of the 2x5 array of Figure 1.I.3, there appears to be four construction joints. The inconsistency of the figures has continued to cause confusion regarding how the dynamic models for analysis should be created relative to how the HI-STORM 100U systems are to be connected, how they are supported, and how they will actually be constructed. The staff finds that correct information including the reasonable variants that may govern design should be addressed and analyzed.

On page 1.I-2, the following statement is made: “The Container Shell and Bottom Plate are equipped with shear keys to provide a physical connection to the underlying Support Foundation that minimizes relative lateral movement.” It is assumed that the intent is that the welded assemblage of the container shell and the bottom plate is equipped with shear keys and they are located on the bottom plate. That means there are no shear keys or shear connectors on the cylindrical container shell.

In a listing of notable design and operational features of the HI-STORM 100U, the following Item vi. is provided on page 1.I-7. The staff does not consider the statements to be correct and will have to be modified or deleted. Item vi. states: “The VVM, because of its underground configuration, does not have to contend with soil-structure interaction effects that magnify the free-field acceleration and potentially challenge the stability of an above-ground freestanding overpack. Likewise, large natural hydrological forces such as tsunamis are not a concern for the VVM.” For a coastal installation subjected to possible tsunamis there can be significant soil loading imposed that would have to be considered.

On page 1.I-8 of the proposed FSAR, there is a discussion of physical hardening of the VVM against impulsive and impactive loadings such as from a missile or a projectile. It is indicated that the design of this system is engineered to possess considerably greater strength reserve than required to prevent the design basis missiles from penetrating into the MPC storage cavity.

It is also indicated that this enhanced capability has been documented in the proposed FSAR. The staff has performed no review of the system's capability beyond the regulatory design bases.

On page 1.I-9, it is indicated that the drawing of the HI-STORM 100U VVM is provided in Section 1.5 of the FSAR in meeting the requirements of 10 CFR 72.24(c)(3). It has been determined that absent the bill of materials that provides certain dimensions of ITS items that are not reflected in the drawing (4501), the information does not provide sufficient detail for the staff to make a finding regarding the adequacy of the safety margins. See Section 1.3 of this staff evaluation for additional information on materials evaluation.

Based on the information provided up to the time the staff review was discontinued, the seismic analysis using LS-DYNA, that has been proposed by Holtec for the HI-STORM 100U, cannot be accepted. This finding is based on several issues related to the basic model as well as the elements selected for use in the analysis. Holtec has not provided a clear design concept that defines how construction of individual HI-STORM 100U VVMs will impact the variation of HI-STORM 100U used in the analysis, yet Holtec has stated that site specific analyses will be required. As such, it is postulated that physical changes may be required to the VVM depending on site characteristics which may also result in different analytical results. The staff has identified, in other interactions with Holtec, issues regarding the element type and number of integration points used in the analysis. This particular loading condition and loading combinations are considered by the staff to be the most critical for this system. In the absence of a clearly designed concept and analyses details, the staff is unable to make a finding regarding this aspect of the structural analysis. Analyses for the other loading combinations and cases have been reviewed and no significant issues have been identified.

3.3 Material Properties

Tables 2.I.3, 2.I.7, 3.I.3, and 3.I.4 provide the information on the materials used in the proposed VVM.

3.4 Corrosion mitigation for the Cavity Enclosure Container (CEC) Portion of the Vertical Ventilated Module (VVM)

The VVM is an important-to-safety buried structure configured as a caisson or like a buried silo. As a buried structure, it is susceptible to more challenging corrosion issues than a comparable above-ground steel structure. In order to provide reasonable assurance that the VVM will meet its intended Design Life of 40 years and perform its intended safety function(s), the potentially degrading effects of soil corrosion must be mitigated.

Although the CEC portion of the VVM is not part of the MPC containment boundary, it should not corrode to the extent where localized in-leakage of water occurs or where gross general corrosion prevents the CEC from performing its primary safety function. In addition, the foundation Anchor Housings (which are the only parts which cannot be inspected after installation) shall be protected from degradation over time.

Corrosion mitigation of the exterior of the CEC warrants special consideration for the following reasons: (1) inaccessibility of the exterior coated surface after installation, (2) potential for a highly aggressive (i.e. corrosive) soil environment at certain sites, and (3) potential for a high radiation field. Since the buried configuration will not allow for the inspection and re-application of surface preservative, corrosion mitigation measures shall be determined after careful evaluation of the soil's corrosivity at the user's ISFSI site.

To evaluate soil corrosivity, a "10 point" soil-test evaluation procedure, in accordance with the guidelines of Appendix A of American National Standard (ANSI) for Polyethleyene Encasement for Ductile-Iron Pipe Systems," ANSI/AWWA C105/A21, will be utilized. The classical soil evaluation criteria in this standard focuses on parameters such as: (1) resistivity, (2) pH, (3) redox (oxidation-reduction) potential, (4) sulfides, (5) moisture content, (6) potential stray current, and (7) experience with existing installations in the area. Using a procedure outlined in the aforementioned standard, the ISFSI soil environment corrosivity is categorized as either "mild" for a soil test evaluation resulting in 9 points or less or "aggressive" for a soil test evaluation resulting in 10 points or greater. The specific mitigation measures that shall be implemented based upon soil environment corrosivity shall be (as specified in the Technical specifications): (1) mild corrosivity: exterior coating with either concrete encasement or cathodic protection or both; and (2) aggressive corrosivity: exterior coating with cathodic protection, concrete encasement optional. These measures are further detailed in the following subsections.

The corrosion mitigation methods described in the FSAR have a support role to an important-to-safety system (the CEC portion of the VVM) and are required as a result of the unique design features and corrosion environment associated with underground structures. Since the important-to-safety portions of the CEC are not normally accessible for routine inspection, certain parameters of the cathodic protection system are incorporated into the technical specifications. This ensures, through operational monitoring, that the cathodic protection system is performing as designed and thus no degradation of the CEC is occurring. Operational history becomes the alternative to direct inspection, hence the requirement for technical specification control of an otherwise not-safety-related system. In the event of unforseen questions about the efficacy of the cathodic protection system (or other component of the corrosion mitigation measures), the CEC structure may be examined by means of ultrasonic inspection (UT) from the inside of a CEC cell where there is no fuel canister yet installed, by remote means in a cell where a spent fuel canister is installed, or, a cell from which the canister has been removed to allow inspection.

3.4.1 Coating

In addition to a corrosion allowance for the CEC structural steel itself, the CEC shall be coated with a radiation resistant surface preservative designed for below-grade and/or immersion service. Inorganic and/or metallic coatings are sufficiently radiation resistant for this application; therefore, radiation testing is not required for inorganic or metallic coatings. Organic coatings such as epoxy, however, must have proven radiation resistance or must be tested without failure to at least 10E7 Rads. Radiation resistance to lower radiation levels is acceptable on a site-specific basis. Radiation testing shall be performed in accordance with ASTM D 4082, "Standard Test Method for Effects of Gamma Radiation on Coatings for Use in Light Water Nuclear Power Plants," or equivalent. The coating should be conservatively treated as a service Level II coating as described in NRC Regulatory Guide 1.54. As such, the coating shall be subjected to appropriate quality assurance in accordance with the applicable guidance provided by ASTM D 3843-00, "Standard Practice for Quality Assurance for Protective Coatings Applied to Nuclear Facilities." The coating should preferably be shop applied in accordance with the manufacturer's instructions and, if appropriate, applicable guidance from ANSI C 210-03, "Standard Practice for Liquid-Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines." A Keeler & Long polyamide-epoxy coating, according to the manufacturer's product data sheet, is pre-tested to radiation levels up to 10E9 Rads without failure.

Alternative coatings may be selected by Holtec on the basis of pre-established criteria which are detailed in FSAR Chapter 3. These criteria include consideration of various environmental conditions along with a ranking of their relative importance. The aforementioned Keeler & Long epoxy meets all the criteria and is the standard coating for use.

3.4.2 Concrete Encasement

The CEC concrete encasement shall provide a minimum of 5 inches of cover to provide a pH buffering effect for additional corrosion mitigation. This concrete thickness has been selected to provide a 100-year service life based upon data provided in literature cited in the FSAR. A claim of 100-year service life brings with it some degree of uncertainty. However, the concrete thickness is conservative. The thickness specified for the concrete is greater than that specified by several recognized codes or references that are based upon a 20 year minimum design life. Thus, a working life of significantly greater than 20 years is assured. Additionally, an inspection of the interior surface of the CEC, along with a thickness survey of the CEC wall, will be performed once every 20 years to verify the continued efficacy of the corrosion protection measures.

It is well recognized that shrinkage cracks occur in concrete. Such cracks may create a path for water to intrude to the steel portions of the CEC that are being protected from corrosion by the concrete. To control the inevitable shrinkage cracks that form in concrete, the applicant has specified the addition of wire or fiber reinforcement to the concrete. The reinforcement materials will be corrosion and radiation resistant.

The staff notes that the use of reinforcement is a departure from normal practice by this vendor. Normally, reinforcement is avoided in structures where the primary purpose is radiation shielding. This is because the presence of rebar can create unintended voids in the concrete, leading to a deficient radiation shield. However, in the case of the CEC, the primary shielding will be accomplished by the earthen backfill. The purpose of the 100-U concrete encasement is to mitigate any corrosive effects from the soil, not provide for radiation shielding. Thus, use of reinforcement will enhance the corrosion prevention performance of the concrete in maintaining tight cracks while the concrete creates a chemically less corrosive environment for the steel CEC.

3.4.3 Impressed Current Cathodic Protection System (ICCPS)

Where required by soil conditions, an ICCPS will be employed. The initial start-up of the ICCPS must occur within one year after installation of the VVM to ensure timely corrosion mitigation. In addition, the ICCPS should be maintained operable at all times after initial start-up except for system shutdowns due to power outages, repair or preventive maintenance and testing, or system modifications. Because there are a multitude of ISFSI variables that will bear upon the design of the ICCPS for a particular site, the essential criteria for its performance and operational characteristics are established in the Holtec FSAR, which the detailed design work for each ISFSI site must follow, as required by 10 CFR 72.212(b)(2)(ii)(3).

Records of system operating data necessary to adequately track the operable status of the ICCPS shall be maintained in accordance with the user's QA program.

Finally, the surface preservative used to coat the CEC must meet the requirements described in the FSAR for resistance to environmental conditions and also be compatible with cathodic protection and resistant to the alkaline conditions created by cathodic protection and/or concrete encasement. Organic coatings, such as the Keeler & Long epoxy coating previously specified, are inherently compatible with these conditions.

3.5 Special Topics

The special lifting devices associated with the VVM involve the lifting location devices for the outer shell of the CEC and the divider shell, neither of which is moved with a loaded MPC present so they do not have to meet the design requirements of ANSI N14.6. The Closure Lid of the VVM must meet the ANSI N14.6 criteria since it will be lifted with a loaded MPC below the opening.

Differential thermal expansion has been addressed in the design considerations of the VVM, as discussed in Section 3.I.4.4 of the proposed FSAR.

3.6 Evaluation Findings

Based on the NRC staff's review of information provided in the HI-STORM 100U Cask System as part of the application, the staff finds the following:

F3.1 The staff finds that the proposed FSAR changes and the application for approval of the HI-STORM 100U design, as submitted, does not adequately describe all essential elements of the various components of the systems, structures, and components (SSCs) that are important to safety and does not provide drawings and text in sufficient detail to allow evaluation of their structural effectiveness and influence on the SSCs performance under the various loading conditions.

F3.2 Based on the information provided, the staff finds that the SSCs of the HI-STORM 100U Cask System that are ITS have not been adequately described in sufficient detail to enable an evaluation of their structural effectiveness and determine if they are designed to accommodate the combined loads of normal, off-normal, accident, and natural phenomena events.

F3.3 The staff finds that the applicant has specified in sufficient detail the design and operational parameters for an effective corrosion mitigation program for a range of potential environments. Additionally, operation and control of a cathodic protection system is placed into the technical specifications to ensure reliable operation of this system in the place of a routine inspection of the protected important-to-safety components of the CEC.

4.0 THERMAL EVALUATION

The thermal review ensures that the cask components and fuel material temperatures of the HI-STORM 100U Cask System (HI-STORM 100U) will remain within the allowable values or criteria for normal, off-normal, and accident conditions. These objectives include confirmation that the fuel cladding temperature will be maintained below specified limits throughout the storage period to protect the cladding against degradation that could lead to gross ruptures. This portion of the review also confirms that the cask thermal design has been evaluated using acceptable analytical techniques and/or testing methods. It should be noted that a concurrent staff review of an increase in the thermal capacity for the HI-STORM 100 cask system is ongoing at the time of issuance of this staff evaluation.

The review was conducted against the appropriate regulations as described in 10 CFR 72.236 that identify the specific requirements for spent fuel storage cask approval and fabrication. The unique characteristics of the spent fuel to be stored are identified, as required by 10 CFR 72.236(a), so that the design basis and the design criteria that must be provided for the structures, systems, and components important to safety can be assessed under the requirements of 10 CFR 72.236(b). This application was also reviewed to determine whether the HI-STORM 100U fulfills the acceptance criteria listed in Sections 4 and 11 of NUREG-1536 as well as associated Interim Staff Guidance (ISG) documents.

The following significant items, relevant to the staff's review, affect the thermal performance of the storage system are listed as follows:

1. A new ventilated design concept, designated the HI-STORM 100U.

2. Inclusion of a generalized regionalized storage approach to permit a continuum of fuel storage configurations over a range of the regionalized loading parameter X, where X is the ratio of inner region to outer region fuel storage cells heat load limits.

3. Permissible MPC heat loads of up to 34 kW (uniform loading) and 36.9 kW (regionalized loading).

4. A MPC helium operating pressure of up to 7 atm.

4.1 Spent Fuel Cladding

The applicant adopted certain guidelines of NRC, "Standard Review Plan for Dry Cask Storage Systems," NUREG-1536, January 1997, and NRC, ISG-11, Revision 3, "Cladding Considerations for the Transportation and Storage of Spent Fuel," November 17, 2003, to demonstrate the safe storage of the material content described in Chapter 2 of the FSAR and in the CoC for those aspects relevant to the HI-STORM 100U. The applicant intends to demonstrate the HI-STORM 100U will comply with all of the following eight criteria:

1. The fuel cladding temperature for long-term storage shall be limited to 752°F (400°C).

2. The fuel cladding temperature for short-term operations shall be limited to 752°F (400°C) for high burnup fuel and 1058°F (570°C) for moderate burnup fuel.

3. The fuel cladding temperature should be maintained below 1058°F (570°C) for accident and off-normal event conditions.

4. The maximum internal pressure of the Multi-Purpose Canister (MPC) should remain within its design pressures for normal, off-normal, and accident conditions.

5. The cask system materials should be maintained within their minimum and maximum temperature criteria for normal, off-normal, and accident conditions.

6. For fuel assemblies proposed for storage, the cask system should ensure a very low probability of cladding breach during long-term storage.

7. The HI-STORM 100U Cask System should be passively cooled.

8. The thermal performance of the cask system shall be in compliance with the design criteria specified in FSAR Chapters 1 and 2 for normal, off-normal, and accident conditions.

4.2 Thermal Properties of Materials

Material property tables for the HI-STORM 100U components are included in the FSAR. The temperature range for the material properties covers the range of temperatures encountered during the thermal analysis with some exceptions that were justified by the applicant.

4.3 Specifications for Components

For evaluation of HI-STORM 100U thermal performance, material temperature limits for long-term normal, short-term operations, and off-normal and accident conditions are provided in Table 4.3.1 of the FSAR. Fuel cladding temperature limits included in Table 4.3.1 of the FSAR are adopted from ISG-11. These limits are applicable to all fuel types, burnup levels, and cladding materials approved by the NRC for power generation. Temperature limits for the insulation material used in the HI-STORM 100U are specified in Table 2.I.7 of the FSAR.

The FSAR stated that Pacific Northwest National Laboratory (PNNL) has evaluated a number of bounding fuel rods for reorientation under hydride precipitation temperature for moderate burnup fuel (MBF) delineated in PNNL White Paper “Estimated Maximum Cladding Stresses for Bounding PWR Fuel Rods During Short Term Operations for Dry Cask Storage,” Lanning and Beyer, January 2004. PNNL’s study concluded that hydride reorientation is not credible during short-term operations involving low to MBF (up to 45 GWD/MTU). Accordingly, a higher temperature limit is applied to MBF, as specified in Table 4.3.1 of the FSAR.

4.4 HI-STORM 100U Cask System

4.4.1 General Description

The HI-STORM 100U "overpack" is an underground VVM designed to accept all MPC models for storage at an ISFSI. The VVM provides for storage of MPCs in a vertical configuration inside a subterranean cylindrical cavity entirely below the top-of-the-grade (TOG) of the ISFSI. The MPC storage cavity is defined by the CEC, consisting of the Container Shell integrally welded to the Bottom Plate. The top of the Container Shell is stiffened by the Container Flange (a ring shaped flange), which is also integrally welded. All of the constituent parts of the CEC are made of thick low carbon steel plate. The cylindrical surface of the Divider Shell is equipped with insulation to ensure that the heated air streaming up around the MPC in the inner coolant air space causes minimal preheating of the air streaming down the intake plenum. As discussed in Supplement 3.I.4 of the FSAR, the insulation material is selected to be water and radiation resistant and non-degradable under accidental wetting.

4.4.2 Design Criteria

To minimize the heating of the downward flowing inlet air and the upward column of heated air, the divider shell is insulated on its outside surface. The critical characteristic of the insulation is specified in Table 2.I.1 of the FSAR. This thermal insulation material is required to meet the service conditions (temperature and humidity) for the design life of the VVM. Because the thermal performance of the HI-STORM 100U relies on buoyancy-driven convection of air and because of the relative proximity of the inlet and outlet vents to each other, the effect of wind on its thermal performance is also considered. The allowable long-term and short term section-average temperature limits for concrete (used in the Closure Lid) are established in Appendix 1.D of the FSAR. Section-average temperature limits for structural steel in the VVM are provided in Table 2.I.7 of the FSAR. The VVM is designed for extreme cold conditions, as discussed in Subsection 2.2.2.2 of the FSAR. The safety of structural steel material used for the VVM from brittle fracture is discussed in Subsection 3.1.2.3 of the FSAR.

4.4.3 Design Features

The VVM is engineered for outdoor below-grade storage for the duration of its design life, and it is designed to withstand normal, off-normal, and extreme environmental phenomena as well as accident conditions of storage with appropriate margins of safety. As discussed in Supplement 1.I of the FSAR, the principal components of the VVM are the MPC Cavity Enclosure Container (CEC), and the Closure Lid.

The CEC is comprised of the following subcomponents:

1. Container Shell (a cylindrical enclosure shell)
2. Bottom Plate
3. Container Flange (a top ring flange)
4. Divider Shell
5. MPC bearing pads
6. Foundation Anchor Housings

The Closure Lid is comprised of the following subcomponents:

1. The integral steel weldment (filled with shielding concrete), and
2. The removable vent screen assemblies (inlet and outlet).

Table 2.I.1 of the FSAR provides the principal design criteria applicable to the VVM.

4.5 HI-STORM 100U System Thermal Model

The thermal performance of the HI-STORM 100U is modeled with on the FLUENT Computational Fluid Dynamics (CFD) program and has the following key attributes:

1. The airflow through the cooling passages of the VVM is modeled as turbulent, using the k-omega model with transitional option.

2. The MPC is modeled as two axisymmetric zones, as shown in Figure 4.4.2 of the FSAR for the above-ground cask analyses in Section 4.4 of the FSAR with bottom and top plenums for modeling internal convection. The use of the axisymmetric model for the MPC has been demonstrated to be conservative via comparison with three-dimensional models in Section 4.4 of the FSAR.

3. The helium flow within the MPC is modeled as laminar. This is the same modeling approach used in the above-ground cask analyses.

4. The hydraulic resistance of the fuel assemblies stored within the MPC is obtained using 3-D CFD models of design-basis assemblies specified in Chapter 2. The hydraulic resistance calculations are provided in Ref. [Section 4.4.2 of the FSAR].

   The staff considers the hydraulic resistance parameters used in the analysis for the HI-STORM 100U to be non-conservative. The applicant should either revise these parameters to correctly define the hydraulic resistance or perform 3-D analysis for all thermal conditions (normal conditions of storage, short-term loading operations, and off-normal and accident conditions). The staff, notes this revised thermal analyses and methodology, used to justify an increase in the system thermal capacity, is being evaluated for the above-ground HI-STORM 100 amendment licensing action.

5. The vertical surfaces between adjacent modules are assumed insulated.

6. The underside of the VVM foundation pad (see Figure 1.I.1 of the FSAR) is assumed supported on a subgrade at 77°F. This is the same boundary condition applied to the bottom of the ISFSI pad for the above-ground cask modeling in Section 4.4 of the FSAR.

7. Because the wind renders the problem non-axisymmetric, a 3-D half cylinder extension of the axisymmetric model of the VVM was modeled. As the VVM air

inlet and outlet ducts are 360° (axisymmetric) openings, the direction of the horizontal wind velocity vector has no bearing on the system performance.

4.6 Thermal Evaluation for Normal Conditions of Storage

The staff cannot at this time reach a finding in this area. The applicant must update the thermal analysis using correct calculations for flow resistance parameters for the MPC basket storage cells represented by a porous media. The staff, as noted above, is currently reviewing the revised thermal analyses and methodology used to justify an increase in the system thermal capacity under another licensing action and as such has made no finding in this area.

4.7 Thermal Evaluation of Short-Term Operations

The staff cannot at this time reach a finding in this area. The applicant must update the thermal analysis using correct calculations for flow resistance parameters for the MPC basket storage cells represented by a porous media. The staff, as noted above, is currently reviewing the revised thermal analyses and methodology used to justify an increase in the system thermal capacity under another licensing action and as such has made no finding in this area.

4.8 Off-Normal and Accident Events

The staff cannot at this time reach a finding in this area. The applicant must update the thermal analysis using correct calculations for flow resistance parameters for the MPC basket storage cells represented by a porous media. The staff, as noted above, is currently reviewing the revised thermal analyses and methodology used to justify an increase in the system thermal capacity under another licensing action and as such has made no finding in this area.

4.9 Conclusion

The applicant must update the thermal analysis of HI-STORM 100U using correct calculations for flow resistance parameters for the axisymmetric model or include 3-D analysis of the MPC basket. The staff, as noted above, is currently reviewing the revised thermal analyses and methodology used to justify an increase in the system's thermal capacity under another licensing action and as such has made no finding in this area.

4.10 Evaluation Findings

The thermal model provided in the FSAR appears to be adequate, with the exception of the use of non-conservative parameters. The staff, as noted above, is currently reviewing the revised thermal analyses and methodology used to justify an increase in the system thermal capacity under another licensing action and as such has made no finding with respect to the HI-STORM 100U Cask System.

5.0 SHIELDING EVALUATION

The objective of the shielding review is to verify that there is adequate protection to the public and workers against direct radiation from the cask contents. The review verifies that the proposed shielding features and contents provide adequate protection against direct radiation to the operating staff and members of the public and that direct radiation exposures can satisfy regulatory requirements during normal operating, off-normal, and design-basis accident conditions. The objective includes a review of the shielding design description, radiation source definition, shielding model specification, and shielding analyses for the proposed HI-STORM 100U Cask System (HI-STORM 100U).

The regulatory requirements for providing adequate radiation protection to licensee personnel and members of the public include 10 CFR Part 20, 10 CFR 72.104, 10 CFR 72.106(b), 10 CFR 72.212, and 10 CFR 72.236(d). Because 10 CFR Part 72 dose requirements for members of the public include direct radiation, effluent releases, and radiation from other uranium fuel-cycle operations, an overall assessment of compliance with these regulatory limits is provided in Section 10 of this staff evaluation.

The applicant proposed a new spent fuel storage design, designated the HI-STORM 100U. The HI-STORM 100U uses a vertical ventilated module (VVM) that is placed below grade and incorporates a novel shielding design for the module lid. The VVM was shown to have dose rates significantly lower than the above-ground HI-STORM 100 Cask System (HI-STORM 100) overpack designs. The HI-STORM 100U uses the same MPCs and HI-TRAC transfer casks as the HI-STORM 100 above-ground overpacks. The shielding evaluation in this section pertains to the HI-STORM 100U VVM and, since the proposed contents differ from those approved for storage in the HI-STORM 100, the MPCs and HI-TRAC transfer casks as appropriate. Based upon the analysis and dose rates for the HI-STORM 100U, the applicant developed a radiation protection program in a proposed Technical Specification (TS) 5.7 that incorporates appropriate dose rate limits for the HI-STORM 100U VVM.

The applicant proposed allowable contents with specifications similar to those currently approved for the HI-STORM 100, but with some significant differences. First, the applicant proposed contents with burnup and cooling time combinations to reflect a proposed higher allowable heat load; however, the maximum permissible burnups of 65 and 68.2 GWD/MTU for BWR and PWR assemblies remain the same. The staff review and findings regarding the proposed thermal capacity for the HI-STORM 100U are discussed in Section 4 of this staff evaluation. The proposed higher heat load, as related to the HI-STORM 100U design, and the resulting decreased margin, necessitated the calculation of new burnup equation coefficients, used to determine allowable PWR assembly parameters, that include a 5% decay heat penalty. Second, the applicant proposed an increased number of allowable storage locations for Axial Power Shaping Rods (APSRs) in the MPC-32/32F and for Control Rod Assemblies (CRAs), Rod Cluster Control Assemblies (RCCAs), and Control Element Assemblies (CEAs) in the MPC-24, MPC-24E/24EF, and MPC-32/32F than currently allowed in the HI-STORM 100. The applicant's analysis and the staff's shielding review of the HI-STORM 100U include these proposed contents.

5.1 Shielding Design Features and Design Criteria

5.1.1 Shielding Design Features

The HI-STORM 100U "overpack" is a VVM. The HI-STORM 100U is compatible with and uses all of the MPCs and HI-TRAC transfer casks approved for use with the HI-STORM 100 above-ground overpacks. The shielding design of the HI-STORM 100U VVM utilizes the concrete and steel of the module for gamma shielding, with neutron shielding provided by the module concrete. However, since a MPC placed in the VVM is below the surface of the surrounding soil, additional shielding is provided by the soil. Due to this design feature, the dose rates at the site boundary from a HI-STORM 100U VVM are less than, and bounded by, the dose rates from the above-ground HI-STORM 100 overpacks. The applicant performed the shielding analysis for the HI-STORM 100U containing an MPC-32 loaded with intact design-basis fuel and determined dose rates for the positions shown in FSAR Figure 5.I.1.

The staff evaluated the shielding design features of and the analysis results relevant to the HI-STORM 100U VVM, as presented in the FSAR. The shielding design features associated with the HI-STORM 100U VVM include the steel cavity enclosure container (CEC), the above-ground concrete pad surrounding the module, an optional concrete encasement surrounding the below-grade portion of the module, and the surrounding soil, since the HI-STORM 100U VVM provides for subterranean spent fuel storage. With regard to the conditions currently described in the FSAR, the staff finds the shielding design features to be acceptable. However, conditions that have not been considered must be addressed in order for the staff to reach a complete finding of acceptability of the shielding design. It should be noted that statements in this staff evaluation regarding acceptability of various shielding design aspects may be affected by conditions that have not yet been addressed (see Finding F5.5).

5.1.2 Shielding and Source Term Design Criteria

The overall radiological protection design criteria are the regulatory dose requirements in 10 CFR Part 20 and 10 CFR 72.104, 72.106(b), 72.212, and 72.236(d). The applicant analyzed the 100U loaded with spent fuel and hardware having the characteristics described in Section 2.1.9 of the FSAR. Although there are no numerical limits in the regulations for surface dose rates, the dose rates on the surface of the cask system serve as design criteria to assure there is sufficient shielding to meet radiological limits, in accordance with 72.236(d). The applicant proposed maximum surface dose rate criteria for the HI-STORM 100U VVM based on the source terms of the contents. Due to the below-ground configuration of the HI-STORM 100U, the applicable criteria are those for the storage VVM top and air vent openings, which the applicant proposed to be 60 mrem/hr and 175 mrem/hr, respectively. Based on these design criteria, the applicant calculated bounding dose rates on the exterior of the HI-STORM 100U. The applicant calculated bounding dose rates that are less than the proposed design criteria (see Section 5.4 of this staff evaluation).

The staff reviewed the design criteria and found them acceptable. The shielding and source term design criteria defined in the FSAR provide reasonable assurance that the HI-STORM 100U can meet the radiological requirements of 10 CFR Part 20 and 10 CFR Part 72. Each user will be required to protect personnel and minimize dose in accordance with As Low As Reasonably Achievable (ALARA) principles and the regulations of 10 CFR Part 20. A radiation protection program is defined in proposed TS 5.7 to assure compliance with these requirements. Dose rate limits based on the bounding shielding analysis are incorporated into the proposed TS 5.7 for the top of the HI-STORM 100U. Limits related to maximum decay heat, maximum burnup, minimum cooling time, maximum uranium loadings, and the burnup equation coefficients for the proposed system contents are incorporated into Appendix B of the proposed CoC.

5.1.3 Preferential Loading Criteria

The HI-STORM 100U is designed to store fuel in either a uniform loading pattern or regional loading pattern (preferential), as discussed in Section 2.1.9.1 of the FSAR. Both loading patterns are limited by maximum allowable decay heat limits for individual fuel assemblies, as specified in Sections 2.4.1 and 2.4.2 of Appendix B to the proposed CoC. The application indicates that the uniform loading pattern provided in Chapter 5 of the FSAR provides bounding radial dose rates, as compared to the preferential loading pattern for the various combinations of fuel parameters allowed by the decay heat limits and the burnup equation method. Therefore, the applicant calculated bounding dose rates in the primary shielding analysis for the uniform loading pattern. The staff reviewed the use of preferential loading and uniform loading specifications for the fuel categories with respect to shielding. Based on the statements provided by the applicant, the staff has reasonable assurance that the uniform loading pattern generally results in bounding dose rates over the preferential loading pattern for various combinations of fuel parameters. The staff notes that each site user must perform an analysis under 10 CFR 72.212 to verify dose limits and will have to consider the specific loading pattern that will be used within each cask.

5.2 Source Specification

The design-basis source specifications for bounding calculations are presented in Section 5.2 of the FSAR. The applicant calculated design-basis source terms at higher burnups and lower cooling times to represent bounding source terms allowed by the burnup equation method. These source term calculations were performed with the same design-basis fuel types, uranium loading, and source term method previously approved for the HI-STORM 100. Based on the burnup equation method, the PWR and BWR fuel may have combinations of burnups up to 68.2 GWD/MTU and 65 GWD/MTU, respectively, and cooling times as low as 3 years. The exact combinations of parameters are limited by the allowable maximum decay heats specified in Sections 2.4.1 and 2.4.2 of Appendix B to the proposed CoC for uniform and regionalized loading. For the MPC-32, the applicant calculated bounding source terms for 45 GWD/MTU and 3-year cooling and 69 GWD/MTU and 5-year cooling. For the MPC-24 bounding calculations, the applicant calculated source terms for 60 GWD/MTU and 3-year cooling and 75 GWD/MTU and 5-year cooling. For the MPC-68 bounding calculations, the applicant calculated source terms for 50 GWD/MTU and 3-year cooling. The burnup and cooling time combinations and their associated decay heats conservatively bound the allowable decay heats defined in Sections 2.4.1 and 2.4.2 of Appendix B to the CoC, as proposed in the application.

5.2.1 Gamma Source

The design-basis gamma source terms for the MPC-24, MPC-32, and MPC-68 are listed in Tables 5.2.4 through 5.2.13 and Table 5.2.22 of the FSAR. The design-basis source terms for the proposed non-fuel hardware contents (e.g., Burnable Poison Rod Assemblies – BPRAs, Axial Power Shaping Rods – APSRs, etc.) are listed in Tables 5.2.31, 5.2.34 and 5.2.35. For the bounding source terms and development of the coefficients for the burnup equation method, the applicant used the same neutron flux scaling factors, cobalt impurities, elemental compositions, and axial gamma peaking factors as previously approved for the HI-STORM 100. The applicant indicated that there is uncertainty in the gamma source terms associated with the ORIGEN-S calculations and provided references which discuss that uncertainty. Based on review of data, the applicant noted that errors in Cs-134 and Eu-154 (significant gamma contributors) could range from 2 to 20%. The applicant indicated that the uncertainty is off-set by the conservatisms in the source term and shielding calculations in the rest of the shielding analysis.

5.2.2 Neutron Source

The design-basis neutron source terms for the MPC-24, MPC-32, and MPC-68 are listed in Tables 5.2.15 through 5.2.20 and Table 5.2.23 of the FSAR. The applicant used the same axial neutron peaking factors as previously approved for the HI-STORM 100. The applicant indicated that there is uncertainty in the neutron source terms associated with the ORIGEN-S calculations and provided references which discuss that uncertainty. The method used to determine the neutron source will result in a localized under-prediction for assemblies which have axial blankets containing natural uranium. The applicant provided justification that this under-prediction is a localized effect and does not significantly increase the total assembly neutron source. The staff reviewed this justification and has found it to be acceptable.

5.2.3 Burnup Equation Coefficients

The applicant used a curve-fitting method to develop a seven-coefficient equation and tables of values for the coefficients. The decay heat calculations were performed with the SAS2H/ORIGEN-S computer code, and are similar to the calculations preformed for the design-basis source terms. The applicant did not include thermal contributions from non-fuel hardware in deriving the coefficients. The applicant indicated that the user will be required to verify each fuel assembly conforms with established thermal limits and to account for non-fuel hardware, as necessary. The coefficients were developed by fitting ORIGEN-S calculated data for specific cooling times ranging from 3 to 20 years for each fuel assembly class in the proposed contents. The ORIGEN-S calculations were performed for enrichments ranging from 0.7 wt% to 5.0 wt% U-235. The applicant used the GNUPLOT computer code to perform the data fit and to calculate the coefficients, including an adjustment to assure all data points are bounded by the fit. The derived coefficient values are specified in Tables 2.1.28 and 2.1.29 of the FSAR. The applicant also indicated that there is uncertainty associated with the ORIGEN-S calculations. The applicant estimated errors in decay heat calculations to be between 1.5% and 5.5% depending on fuel cooling times. Therefore, the applicant applied a 5% decay heat penalty to the derivation of fuel coefficients for both the PWR and BWR array classes.

5.2.4 Staff Evaluation

The staff reviewed the source term analyses and burnup equation method in Section 5.2 of the FSAR. The staff has reasonable assurance that the design-basis bounding gamma and neutron source terms determined for the shielding analyses are acceptable. The staff performed confirmatory analyses of selected bounding burnups and cooling times with SAS2. The staff also has reasonable assurance that the coefficients generated by the applicant for the burnup equation are acceptable. The graphical representations presented by the applicant demonstrate that the curve-fitting technique is acceptable. The staff performed confirmatory calculations for selected coefficients for selected fuel classes to test the validity of the equation and coefficients. The staff calculated decay heat source terms with SAS2 at selected burnups and cooling times and compared them to the values associated with the burnup equation method. The calculated decay heats for selected combinations were in general agreement with burnups and associated thermal values applied in the burnup equation method.

The staff also finds that the applicant has reasonably addressed thermal uncertainties in high burnup fuel with respect to the proposed HI-STORM 100U and its contents. The staff's confirmatory analysis of the derivation of the burnup equation coefficients indicated the 5% decay heat penalty was incorporated for both the PWR and BWR fuel classes. The applicant did not explicitly quantify the dose impact of conservatisms in the shielding analysis versus the uncertainties in the neutron and gamma source terms in the bounding analysis. However, the staff has reasonable assurance that there are conservatisms in the source term analyses because the applicant applied extreme burnups (e.g., > 65 GWD/MTU) that exceed the maximum burnups and the maximum decay heats allowed for loading. The staff notes that this does not constitute automatic approval of these extreme burnup source terms as acceptable fuel for future designs. Each user should also consider accounting for any uncertainties in its 10 CFR 72.212 dose analyses. Limits on the allowable contents specifications, such as burnup, cooling time, and the burnup equation and the associated coefficients, are incorporated into Appendix B of the proposed CoC. In addition, dose limits based on the shielding analysis are incorporated into criteria for the proposed TS 5.7.

5.3 Shielding Model Specifications

The HI-STORM 100U shielding and source configuration is described in Section 5.I.3 as well as Sections 5.3 and 5.4 of the FSAR. The applicant performed the analysis with the MCNP-4A computer code, using shielding model specifications and methods similar to those previously approved for the HI-STORM 100, to calculate bounding near-field and off-site dose rates. Configuration and model features unique to the HI-STORM 100U VVM are described in Section 5.I.3 of the FSAR.

5.3.1 Shielding and Source Configuration

The applicant used a shielding and source configuration similar to the configuration previously approved for the HI-STORM 100, accounting for differences in the modeled VVM and the contents. The applicant indicated the source configuration of damaged fuel in the MPC-32 configuration would behave similar to damaged fuel configurations already analyzed and approved for the MPC-24 and MPC-68, as documented in the HI-STORM 100 FSAR. Therefore, the applicant concluded the shielding performance of the MPC-32 would not be affected by the damaged fuel.

5.3.2 Material Properties

The applicant used the same material properties as previously approved for the HI-STORM 100 with the exception of the soil properties, which are new for the HI-STORM 100U. The applicant noted that neutron absorbing panels in the basket have been represented as BORAL®. The applicant indicated that the use of METAMIC® as an alternate neutron material would not significantly affect the shielding ability of the canisters.

The applicant also reduced the minimum allowable concrete density to 140 lb/ft^3. This minimum density was used to determine all of the dose rates provided in the FSAR. Section 5.3.2 of the FSAR notes that the concrete density can be increased up to 200 lb/ft^3 at the request of the user to improve the shielding characteristics of the system and address potential ALARA considerations.

5.3.3 Staff Evaluation

The staff evaluated the shielding models and found them acceptable. The shielding model, shielding and source configuration, and material properties are similar to those previously approved by NRC for the HI-STORM 100 except for the soil properties which are new for the HI-STORM 100U. Based on the statements and calculations presented by the applicant, the staff finds the model is valid for the HI-STORM 100U and its proposed contents. The staff does note, however, that the application lacks justification of the selected soil properties. This justification is needed to fully determine the properties' acceptability. Calculation models should use appropriate properties that bound, for shielding purposes, those soils where the HI-STORM 100U will be used. Thus, the applicant's analysis and these findings may be affected.

5.4 Shielding Analyses

The applicant presented dose rates for the HI-STORM 100U for both normal conditions and accident conditions in Sections 5.I.4, 11 and 11.I of the FSAR. The applicant indicated it used the same shielding analysis techniques as previously approved for the HI-STORM 100. Though not affected by the HI-STORM 100U VVM design, dose rates for the HI-TRAC transfer casks are also discussed in this review, as appropriate, in evaluating the use of HI-TRAC transfer casks with the HI-STORM 100U and its proposed contents.

5.4.1 Normal Conditions

The applicant presented bounding dose rates for various locations surrounding the above-ground portion of the HI-STORM 100U VVM loaded with an MPC-32. The maximum surface dose rates on the lid and the air vents are reported as approximately 28 mrem/hr and 69 mrem/hr, respectively. While dose rates for the HI-TRAC transfer cask are unaffected by the storage overpack/VVM design, the proposed contents result in a greater source term than analyzed in the HI-STORM 100 FSAR and, therefore, increased maximum surface dose rates from the HI-TRAC transfer casks. However, the dose profiles presented in FSAR Figures 5.1.5 through 5.1.11 for the HI-TRAC transfer cask show that the dose rates significantly decrease from peak locations to the edges of the top, bottom, and sides of the cask. Also, Section 10 of the FSAR indicates that exposures from localized peak dose rates may be mitigated by ALARA practices such as controlling actual locations of personnel and using temporary shielding during loading and unloading operations.

5.4.2 Occupational Exposures

The applicant estimated occupational exposures for the HI-STORM 100U using estimates calculated for the HI-STORM 100 loaded with design-basis contents having the same specifications proposed for the HI-STORM 100U. The applicant provided justification for using the estimates for the above-ground overpack system, provided in Chapter 10 of the FSAR, to represent or bound the estimates for the HI-STORM 100U. The staff reviewed the justification and found use of the occupational exposures estimated for the above-ground overpack system as estimates for the HI-STORM 100U to be acceptable, as discussed in Section 10 of this staff evaluation.

5.4.3 Off-site Dose Calculations

The applicant estimated offsite dose rates at the site boundary for a HI-STORM 100U VVM. The results, listed in Table 5.I.2 of the FSAR, indicate that a single HI-STORM 100U VVM (assuming design-basis fuel and full occupancy) can meet the annual dose limit of 25 mrem at 100 meters. Thus, the doses from the HI-STORM 100U are significantly less than the doses from a single HI-STORM 100, which requires a minimum distance of 350 meters to meet the annual dose limit for design-basis fuel having the same proposed specifications. While the applicant did not estimate dose rates from an array of HI-STORM 100U VVMs, the comparison between a single HI-STORM 100U and a single above-ground overpack indicates that those dose rates will be bounded by the dose rates from an equivalent array of above-ground overpacks, an analysis for which indicated that the minimum distance necessary to satisfy the annual dose limit is 450 meters. Off-site dose calculations for both direct radiation and releases are discussed further in Section 10.4 of this staff evaluation.

5.4.4 Accident Conditions

Chapter 11 of the FSAR does not identify an accident that significantly degrades the shielding of the HI-STORM 100U VVM; the estimated accident dose rates for this design are the same as those estimated for normal conditions. Therefore, as for the HI-STORM 100, loss of water in the HI-TRAC transfer cask water jacket is the bounding accident for direct radiation. The applicant estimated, in Section 5.1.2 of the FSAR, that the HI-TRAC transfer cask accident dose rates would be approximately 3 mrem/hr at 100 meters. Based on this dose rate, the accumulated dose at the controlled area boundary would be approximately 2.2 rem, assuming a 30-day occupancy. The applicant concluded that the 5 rem limit in 10 CFR 72.106(b) would not be exceeded for the most severe design-basis shielding accident identified in Chapter 11 of the FSAR.

5.4.5 Staff Evaluation

Section 10 of this staff evaluation examines the overall dose (i.e., direct radiation and hypothetical radionuclide release) from the HI-STORM 100U. The staff reviewed the dose calculations for normal operations and found them acceptable. Dose rates were calculated for the HI-STORM 100U loaded with the proposed allowable contents.

The staff has reasonable assurance that compliance with 10 CFR Part 20 and 10 CFR 72.104(a) from direct radiation can be achieved by general licensees. The actual doses to individuals beyond the controlled area boundary depend on several site specific conditions such as fuel characteristics, cask-array configurations, topography, demographics, and distances. In addition, 10 CFR 72.104(a) includes doses from other fuel cycle activities, such as reactor operations. Each general licensee is responsible to verify compliance with 10 CFR 72.104(a) in accordance with 10 CFR 72.212. In addition, a general licensee will also have an established radiation protection program as required by 10 CFR Part 20, Subpart B, and will demonstrate compliance with dose limits to individual members of the public and workers, as required, by evaluation and measurements. The staff notes that the proposed contents result in direct radiation dose rates that are significantly higher than those previously approved for the HI-STORM 100, a concern primarily for operations involving the HI-TRAC transfer cask (i.e., loading, unloading, and transport) for the HI-STORM 100U. Thus, each user may be required to take additional ALARA precautions to minimize doses to personnel and to make additional use of realistic fuel characteristics and distances to demonstrate compliance with public dose limits in 10 CFR Part 20 and 10 CFR Part 72.

The staff reviewed the accident dose analysis and found it acceptable for the design and contents requested in the application. The staff has reasonable assurance that the direct radiation from the HI-STORM 100U satisfies 10 CFR 72.106(b) at or beyond a controlled boundary of 100 meters from the design-basis accidents. Staff notes that one accident condition for which dose rates change from those of the normal conditions is the loss of water in the HI-TRAC transfer cask's water jacket. For this condition, the estimated dose to members of the public at 100 meters and at further distances for a conservative exposure time of 30 days is approximately 50% below the 5 rem accident limit in 10 CFR 72.106(b). The staff also notes that, while the estimated off-site accident dose may be less accurate because precise exposure times cannot be predicted, the 30-day exposure is conservative based upon realistic considerations and direct radiation being relatively easy to mitigate within a reasonable amount of time.

As discussed in Section 10.4 of this staff evaluation, general criteria for a radiation protection program that are tailored to the dose rates from the HI-STORM 100U VVM are provided in the proposed TS 5.7 (see Section 10.4 of this staff evaluation). The decay heat limits are specified in Appendix B of the proposed CoC. The burnup equation and associated limits for burnup, cooling time, enrichment, and fuel assembly characteristics are also incorporated into Appendix B of the proposed CoC.

5.5 Evaluation Findings

Based on the NRC staff's review of information provided for the HI-STORM 100U Cask System application, the staff finds the following:

F5.1 The FSAR sufficiently describes shielding design features and design criteria for the structures, systems, and components important to safety.

F5.2 Radiation shielding features of the HI-STORM 100U Cask System are sufficient to meet the radiation protection requirements of 10 CFR Part 20, 10 CFR 72.104, and 10 CFR 72.106.

F5.3 Operational restrictions to meet dose and ALARA requirements in 10 CFR Part 20, 10 CFR 72.104 and 72.106 are the responsibility of each general licensee. The HI-STORM 100U Cask System shielding features are designed to satisfy these requirements.

F5.4 The staff concludes that the design of the radiation protection system of the HI-STORM 100U Cask System can be operated in compliance with 10 CFR Part 72 and that the applicable design and acceptance criteria have been satisfied. The evaluation of the radiation protection system design provides reasonable assurance that the HI-STORM 100U Cask System will provide safe storage of spent fuel. This finding is based on a review that considered the regulation itself, the appropriate regulatory guides, applicable codes and standards, the applicant's analyses, the staff's confirmatory analyses, and acceptable engineering practices.

F5.5 These findings are predicated upon the condition that the construction of the complete ISFSI array of HI-STORM 100U Cask System VVMs, will be finished prior to the loading of any of the VVMs in the array. Conditions that vary from this assumed condition may invalidate these findings. Thus, the applicant must consider any potential conditions that differ from the condition upon which these findings are based and modify its current analyses as appropriate. For example, excavation work performed to install additional VVMs adjacent, or near, to loaded VVMs is currently not analyzed in the application. In such cases, personnel may receive greater exposure during related operations since the soil relied upon for shielding has been reduced. Accident condition analyses as well as normal condition analyses may be affected. Descriptions of such analyses should include the assumptions and parameters the analyses rely upon, with appropriate justification. Consideration should also be given to the need for addressing these conditions in the Technical Specifications to ensure that conditions do not arise that are not bounded by the applicant's analyses. Staff is also aware that there are significant structural issues which are unresolved. The applicant will need to consider how the resolution of these issues impacts the current shielding analysis. Additionally, there remains a concern regarding the soil properties used in the shielding analysis, which may also affect these findings (see Section 5.3.3 of this staff evaluation).

F5.6 There currently exists an inconsistency between the shielding and thermal reviews discussed in this staff evaluation. While the source terms and dose rates from the proposed modification to the affected fuel parameters bound those resulting from the currently approved parameters, the thermal review does not support use of the proposed parameter values and burnup equation coefficients at this time. Use of the proposed coefficients and fuel parameter values requires approval of the proposed higher heat load/capacity, which is currently under review only in a separate licensing action.

6.0 CRITICALITY EVALUATION

The purpose of the criticality review is to ensure that all credible normal, off-normal, and accident conditions have been identified and their potential consequences on criticality considered for the proposed HI-STORM 100U Cask System (HI-STORM 100U) such that the cask system will meet the criticality requirements of 10 CFR Part 72. These requirements include: 10 CFR 72.124(a), 72.124(b), 72.236©, and 72.236(g). The FSAR was also reviewed to determine whether the cask system fulfills the acceptance criteria listed in Section 6 of NUREG-1536.

The criticality analysis for the HI-STORM 100U relies upon the analysis previously performed for the currently approved HI-STORM 100 Cask System. The use of the HI-STORM 100U VVM does not significantly affect the criticality design of the system. Analyses in the currently approved HI-STORM 100 amendments have analyzed for storage conditions with the overpack and MPC fully reflected by water of varying densities (the MPC is dry inside for storage conditions). The maximum k-effective for these conditions (~0.50) is significantly below the limiting k-effective, which occurs for a fully flooded MPC in a flooded HI-TRAC transfer cask. Also, the variations in the k-effective value were small. Use of the HI-STORM 100U VVM will not significantly affect this result. Therefore, the staff finds reasonable assurance that the HI-STORM 100U will remain sub-critical, with an adequate safety margin, under all credible normal, off-normal, and accident conditions.

The staff does note that there are significant structural issues that have yet to be resolved. The resolution of these issues may affect the criticality analysis and findings. For example, current practice is to consider the MPC interior as dry for criticality analyses of accident conditions in the storage configuration. Acceptance of this practice for the HI-STORM 100U may be influenced by the manner in which the structural issues are resolved.

7.0 CONFINEMENT EVALUATION

The objective of the confinement review of the HI-STORM 100U Cask System (HI-STORM 100U) is to ensure that radiological releases to the environment will be within the limits established by the regulations and that the spent fuel cladding and fuel assemblies will be sufficiently protected during storage against degradation that otherwise might lead to gross ruptures. The objective includes review of the confinement design characteristics and confinement analyses for the HI-STORM 100U proposed in the application. Since the HI-STORM 100U uses a MPC already approved for use with the above-ground HI-STORM 100 Cask System (HI-STORM 100), there is no change to the confinement system. The application includes an editorial change to Chapter 7 that does not affect either the confinement evaluation or the Technical Specifications.

The HI-STORM 100U, which holds the same internal canister system as the HI-STORM 100 Cask System, uses a fully welded austenitic stainless steel MPC design to maintain confinement. The confinement boundary on the MPC design includes the following: MPC Shell, bottom baseplate, MPC lids (including vent and drain port cover plates), MPC closure ring, and associated welds. Penetrations to the confinement boundary consist of two penetrations, the MPC vent and drain ports. All components of the confinement boundary are important to safety, Category A, as specified in the applicant's FSAR Table 2.2.6. The MPC confinement boundary is designed, fabricated, inspected, and tested in accordance with ASME Code, Section III, Subsection NB. NRC approved alternatives to the ASME Code are identified in Table 3-1 of the TS. The confinement system design for the HI-STORM 100U does not differ from the previously approved HI-STORM 100 design. It should be noted however that, as discussed in Section 10 of this evaluation, the staff has not reached a finding regarding the seismic analyses of the HI-STORM 100U and the potential effect on the confinement function of the MPC and it's response under design-basis accidents or natural phenomena events.

7.1 Evaluation Findings

Based on the NRC staff's review of information provided in the HI-STORM 100U Cask System application, the staff finds the following:

F7.1 Chapter 7 of the FSAR describes confinement structures, systems, and components important to safety in sufficient detail to permit evaluation of their effectiveness.

F7.2 The design of the Multi Purpose Canister adequately protects the spent fuel cladding against degradation that might otherwise lead to gross ruptures. Section 4 of this staff evaluation discusses any relevant temperature considerations.

F7.3 The design of the Multi-Purpose Canister (MPC) provides redundant sealing of the confinement system closure joints using dual welds on the MPC lid and the MPC closure ring.

F7.4 The MPC has no bolted closures or mechanical seals. The confinement boundary contains no external penetrations for pressure monitoring or over-pressure protection. No instrumentation is required to remain operational under accident conditions.

Because the MPC uses an entirely welded redundant closure system, no direct monitoring of the closure is required.

F7.5 The staff concludes that the design of the Multi-Purpose Canister (MPC) confinement system is in compliance with 10 CFR Part 72 and that the applicable design and acceptance criteria have been satisfied. However, the staff makes no finding regarding performance of the MPC as used in the HI-STORM 100U Cask System.

8.0 OPERATING PROCEDURES

The objective of the review of the operating procedures is to ensure that the applicant's FSAR presents acceptable operating sequences, guidance, and generic procedures for key operations.

The applicant proposed a new design designated as the HI-STORM 100U Cask System (HI-STORM 100U). Changes to the operating procedures for the HI-STORM 100 Cask System (HI-STORM 100) to address the below-ground concept are described in Supplement 8.I. Only those changes that affect operating procedures are discussed in this section. The staff reviewed the HI-STORM 100U FSAR pages and proposed CoC and TS to ensure the operating procedures described in Supplement 8.I. of the FSAR meet the following regulatory requirements: 10 CFR 72.104(b), 72.122(l), 72.212 (b)(9), 72.234(f), and 72.236(h) and (l). The FSAR was also reviewed to determine whether the cask system fulfills the acceptance criteria listed in Section 8 of NUREG-1536. The staff's evaluation, summarized below, is based on information provided in the application and supplemental materials provided.

8.1 HI-STORM 100U Cask System

The operating procedures for the HI-STORM 100U system do not substantially differ from those for the HI-STORM 100 Cask System. One of the greatest differences is the location of the operations for unloading the MPC from the HI-TRAC transfer cask into the overpack/VVM. For the HI-STORM 100 overpacks, these operations occur about 18 feet above the ground. For the HI-STORM 100U, the operations occur at essentially ground level. Thus, there would be the opportunity for greater occupational exposures while unloading the MPC from the HI-TRAC transfer cask into the HI-STORM 100U VVM. However, the procedures call for the use of supplemental shielding and/or keeping personnel away from the area around the mating device to reduce exposure, the site licensee determining the necessary action based upon ALARA considerations. Based upon a review from a shielding and radiation protection standpoint, the staff finds the procedures for the HI-STORM 100U to be acceptable.

8.2 PWR Control Components' Storage Locations

In its review of the shielding analysis, the staff noted that the proposed contents result in significantly higher dose rates than those resulting from the previously approved contents for the HI-STORM 100. For the HI-STORM 100U, these higher dose rates are of particular concern for operations involving the HI-TRAC transfer cask (i.e., loading, unloading, and transport). Therefore, each user may be required to take additional ALARA precautions during these operations to minimize doses to personnel.

8.3 Evaluation Findings

Based on the NRC staff's review of information provided for the HI-STORM 100U Cask System, the staff finds the following:

F8.1 The HI-STORM 100U Cask System can be wet loaded and unloaded. General procedure descriptions for these operations are summarized in Section 8 of the FSAR. These procedures appropriately include the design of the HI-STORM 100U Cask

System proposed by the applicant. Detailed procedures will need to be developed and evaluated on a site-specific basis.

F8.2 The staff concludes that the generic procedures and guidance for the operation of the HI-STORM 100U Cask System are in compliance with 10 CFR Part 72 and that the applicable acceptance criteria have been satisfied. The evaluation of the operating procedure descriptions provided in the FSAR offer reasonable assurance that the cask will enable safe storage of spent fuel. This finding is based on a review that considered the regulations, appropriate regulatory guides, applicable codes and standards, and accepted practices.

9.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

The objective of the review of the acceptance tests and maintenance program is to ensure that the applicant's FSAR includes the appropriate acceptance tests and maintenance programs for the HI-STORM 100U Cask System (HI-STORM 100U).

9.1 Impressed Current Cathodic Protection System

The impressed current cathodic protection system (ICCPS), where soil conditions may dictate it's use, provides reasonable assurance that corrosion will not cause degradation of the CEC, including the bottom plate, to the extent that the CEC structural integrity is challenged, or allow in-leakage of ground water into the storage cavity. Normally, the ICCPS must remain operational at all times to the extent practicable. Consequently, a monthly surveillance of the ICCPS operation is required (Section B, Bases). Since the cathodic protection system is an active system, consideration of system outages for maintenance or other reasons must be made.

For ICCPS outages, regardless of cause, a limiting condition of operation (LCO) is established which provides a maximum allowable time limit (of 6 months) for a non-functioning ICCPS. Because corrosion in this case is an intrinsically slow process, there is sufficient time available to perform repairs and other corrective actions. In the event that the LCO period is exceeded, the user may opt to demonstrate continued integrity of the affected CEC components by means of an engineering evaluation, including tests. A time period of one year from the initiation of the ICCPS outage is allowed under this option. Other LCOs are imposed by the CoC to address other situations regarding the amount of time the ICCPS has been intermittently inoperable over a period of time.

The staff finds that the surveillance and maintenance programs outlined are sufficient for establishing the continued integrity of the CEC and that appropriate LCOs have been established for the ICCPS.

9.2 Other Surveillance

Other in-service inspection for long-term interior or below-grade degradation shall be performed on a site-specific basis in accordance with Holtec prepared long-term maintenance guidelines and the licensee's preventive maintenance program. In many cases, this will be a visual inspection of accessible areas. The frequency of in-service inspection is specified in FSAR Table 9.I.1. Additional in-service inspection activities may include more thorough inspections for corrosion or insulation degradation by use of remote viewing systems or other non-destructive examinations. VVM closure lid removal and temporary MPC transfer into a HI-TRAC shielded transfer vehicle may be warranted if access to a VVM compartment is deemed desirable for a comprehensive examination. Such additional examinations with consequent findings and dispositions would be controlled by the licensee's corrective actions program.

9.3 Evaluation Findings

Based on the NRC staff's review of information provided in the HI-STORM 100 Cask System application, the staff finds the following:

F9.1 The staff concludes, with respect to the ICCPS, that the modifications made to the acceptance tests and maintenance program for the HI-STORM 100U Cask System are in compliance with 10 CFR Part 72 and that the applicable acceptance criteria have been satisfied.

F9.2 The staff makes no finding with respect to the proposed shielding effectiveness testing program described in Section 9 of the FSAR. This program will be evaluated when the HI-STORM 100U Cask System is submitted for NRC approval.

10.0 RADIATION PROTECTION EVALUATION

The objective of the review of this section is to ensure that the capability of the radiation protection design features, design criteria, and operating procedures, as appropriate, of the HI-STORM 100U Cask System (HI-STORM 100U) can meet regulatory dose requirements for the proposed contents. The regulatory requirements for providing adequate radiation protection to site licensee personnel and members of the public include 10 CFR Part 20, 10 CFR 72.104(a), 72.106(b), 72.212(b), and 72.236(d).

Calculated occupational exposures from the HI-STORM 100U are based on the direct radiation dose rates calculated for the HI-STORM 100 Cask System (HI-STORM 100) – provided in Chapter 5 of the FSAR – loaded with design-basis contents having the same specifications proposed for the HI-STORM 100U and the operating procedures for the HI-STORM 100. Chapter 8 of the FSAR indicates that the operating procedures for the HI-STORM 100U are nearly the same as those for the HI-STORM 100, with some differences resulting from the fixed, subterranean nature of the HI-STORM 100U VVM design. Calculated doses to individuals beyond the controlled area boundary (members of the public) are determined from the direct radiation (including skyshine) dose rates calculated in Chapter 5 of the FSAR. The dose calculations were based upon the allowable contents proposed in the application.

The proposed HI-STORM 100U was reviewed to determine if the radiation protection design features, as described in the FSAR, are acceptable to the staff. The staff's conclusions, summarized below, are based upon the information provided in the application. With regard to the conditions currently described in the FSAR, the staff finds the radiation protection design features to be acceptable. However, conditions that have not been considered must be addressed in order for the staff to reach a complete finding of acceptability of the radiation protection design. It should be noted that statements in this staff evaluation regarding acceptability of various radiation protection design aspects may be affected by conditions that have not yet been addressed (see Finding F5.5 and F10.9).

10.1 Radiation Protection Design Criteria and Design Features

The radiological protection design criteria are the limits and requirements of 10 CFR Part 20, 10 CFR 72.104, and 10 CFR 72.106. As required by 10 CFR Part 20 and 10 CFR 72.212, each general licensee is responsible for demonstrating site-specific compliance with these requirements. In addition, proposed TS 5.7 establishes direct radiation dose rate limits and other radiation protection criteria for the cask system. These criteria are based on bounding dose rate values, which are used to determine occupational and off-site exposures, and other design-specific factors important in the radiation protection system. The radiation protection design features are described in Chapter 10 of the FSAR.

The staff reviewed the design criteria. Sections 5, 7, and 8 of this staff evaluation discuss the staff's reviews of the design criteria and features for the shielding system, confinement system, and operating procedures, as appropriate. Section 11 of this staff evaluation discusses staff's reviews of the capability of the shielding and confinement features during off-normal and accident conditions, as appropriate.

10.2 ALARA

The ALARA objectives, procedures, practices, and policies are the same as those previously approved for the HI-STORM 100. Each site licensee will apply its additional site-specific ALARA objectives, policies, procedures, and practices for members of the public and personnel.

The staff considered the previously approved ALARA assessment for the HI-STORM 100 and found it acceptable for the HI-STORM 100U for the described dose rates. Section 8 of this staff evaluation discusses the staff's review of the operating procedures with respect to ALARA principles and practices, as appropriate. Operational ALARA objectives, policies, procedures, and practices are the responsibility of the site licensee, as required by 10 CFR Part 20 and 10 CFR 72.104(b). The staff also noted that the proposed contents result in significantly higher direct radiation dose rates from those previously approved for the HI-STORM 100. For the HI-STORM 100U, these higher dose rates are of particular concern for operations involving the HI-TRAC transfer cask (i.e., loading, unloading, and transport). Therefore, each user may be required to take additional ALARA precautions during these operations to minimize doses to personnel and to make additional use of realistic fuel characteristics and distances to demonstrate compliance with public dose limits in 10 CFR Part 20 and 10 CFR Part 72.

10.3 Occupational Exposures

The staff reviewed the overall occupational dose estimates and found them acceptable. The occupational dose exposure estimates provide reasonable assurance that occupational limits in 10 CFR Part 20, Subpart C, can be achieved. The staff expects actual operating times and personnel exposure rates will vary for each system, depending on site-specific operating conditions, including detailed procedures and special measures taken to maintain exposures ALARA. The collective exposures will be distributed among multiple personnel responsible for various tasks. Each licensee will have an established radiation protection program, as required in 10 CFR Part 20, Subpart B. In addition, each licensee will demonstrate compliance with occupational dose limits in 10 CFR Part 20, Subpart C, and other site-specific 10 CFR Part 50 license requirements with evaluations and measurements. Staff's review of and findings regarding the operating procedures are presented in Section 8 of this staff evaluation.

10.4 Public Exposures From Normal and Off-Normal Conditions

The applicant estimated offsite direct radiation dose rates at the site boundary for a HI-STORM 100U VVM. Based on Table 5.I.2 in the FSAR, the analyses indicated that a single HI-STORM 100U VVM (assuming design-basis fuel and full occupancy) can meet the annual dose limit of 25 mrem at 100 meters. Thus, the doses from the HI-STORM 100U are significantly less than the doses from a single HI-STORM 100 above-ground overpack, which requires a minimum distance of 350 meters to meet the annual dose limit for design-basis fuel having the same specifications as proposed for the HI-STORM 100U contents. While the applicant did not estimate dose rates from an array of HI-STORM 100U VVMs, the comparison between a single 100U and a single above-ground overpack indicates that those dose rates will be bounded by the dose rates from an equivalent array of above-ground overpacks, an analysis for which indicated that the minimum distance necessary to satisfy the annual dose limit is 450 meters.

The staff has reasonable assurance that compliance with 10 CFR 72.104(a) can be achieved by each general licensee. The general licensee using the HI-STORM 100U must perform a site-specific evaluation, as required by 10 CFR 72.212(b), to demonstrate compliance with 10 CFR 72.104(a). The actual doses to an individual beyond the controlled area boundary depend on several site-specific conditions such as fuel characteristics, cask-array configurations, topography, demographics, distances, and use of engineered features (e.g., berm). In addition, the dose limits in 10 CFR 72.104(a) include doses from other fuel cycle activities such as reactor operations. Consequently, final determination of compliance with 10 CFR 72.104(a) is the responsibility of each general licensee. The NRC may inspect the site-specific use of the HI-STORM 100U for compliance with radiological requirements.

The general licensee will also have an established radiation protection program as required by 10 CFR Part 20, Subpart B, and will demonstrate compliance with dose limits to individual members of the public, as required in 10 CFR Part 20, Subpart D, by evaluations and measurements.

Based on its shielding analyses, the applicant developed criteria for the radiation protection program in its proposed TS 5.7 for the HI-STORM 100U storing the proposed contents. The criteria include the requirements for the cask user to: (1) establish cask specific surface dose limits based on its 10 CFR 72.212 analyses, (2) assure maximum surface dose rates are below values based on the bounding shielding calculations for the top of the VVM, (3) measure dose rates at specific locations on the cask, and (4) implement specific corrective actions if measured doses during operations exceed the limits.

10.5 Public Exposures From Design-Basis Accidents and Natural Phenomena Events

Chapter 11 of the FSAR presents direct radiation dose rates for accident conditions and natural phenomena events for individuals beyond the controlled area. While recognizing that common MPC designs are used in the HI-STORM 100U and HI-STORM 100 designs, as discussed in Section 7 of this staff evaluation, the staff has not reached a finding regarding the seismic analyses of the HI-STORM 100U and the potential effect on the confinement function of the MPC and it’s response under design-basis accidents or natural phenomena events. As discussed in Section 5.4.4 of this staff evaluation, the accident direct-radiation dose analysis indicates the worst case shielding conditions – loss of water in the water jacket of a loaded HI-TRAC transfer cask – result in a dose at the controlled area boundary that is 50% below the regulatory limit specified in 10 CFR 72.106(b). The FSAR does not identify an accident that significantly degrades the shielding of the HI-STORM 100U VVM. Chapter 11 of the FSAR discusses the corrective actions for each design-basis accident, as appropriate.

The staff evaluated the public dose estimates for a HI-STORM 100U storing the proposed contents for accident conditions and natural phenomena events. Discussions of the staff’s review of and findings regarding the shielding and confinement analyses for the relevant design-basis accidents are presented in Sections 5 and 7 of this staff evaluation, respectively. A discussion of the staff’s review of and findings regarding the accident conditions and recovery actions is presented in Section 11 of this staff evaluation. The staff has reasonable assurance that the effects of direct radiation from bounding design-basis accidents and natural phenomena will be below the regulatory limits in 10 CFR 72.106(b).

10.6 Evaluation Findings

Based on the NRC staff's review of information provided in the HI-STORM 100U Cask System application, with the exception of information necessary as described in finding F10.9, the staff finds the following:

F10.1 The FSAR sufficiently describes the radiation protection design bases and design criteria for the structures, systems, and components important to safety.

F10.2 Radiation shielding features are sufficient to meet the radiation protection requirements of 10 CFR Part 20, 10 CFR 72.104, and 10 CFR 72.106.

F10.3 The HI-STORM 100U Cask System is designed to provide redundant sealing of the confinement system.

F10.4 The HI-STORM 100U Cask System is designed to facilitate decontamination to the extent practicable.

F10.5 The FSAR sufficiently evaluates the HI-STORM 100U Cask System and its systems important to safety and how they will reasonably maintain confinement of radioactive material under normal, off-normal, and accident conditions.

F10.6 The FSAR sufficiently describes the means for controlling and limiting occupational exposures for the proposed contents within the dose and ALARA requirements of 10 CFR Part 20.

F10.7 Operational restrictions necessary to meet dose and ALARA requirements in 10 CFR Part 20, 10 CFR 72.104, and 10 CFR 72.106 are the responsibility of the site licensee. The HI-STORM 100U Cask System is designed to assist in meeting these requirements.

F10.8 The staff concludes that the design of the radiation protection system of the HI-STORM 100U Cask System is in compliance with 10 CFR Part 72 and that the applicable design and acceptance criteria have been satisfied. The evaluation of the radiation protection system design provides reasonable assurance that the HI-STORM 100U Cask System will provide safe storage of spent fuel. This finding is based on a review that considered the regulation itself, the appropriate regulatory guides, applicable codes and standards, the applicant's analyses, the staff's confirmatory analyses, and acceptable engineering practices.

F10.9 These findings are predicated upon the condition that the construction of the complete ISFSI array of HI-STORM 100U Cask System VVMs will be finished prior to the loading of any of the VVMs in the array. As discussed in Section 5 of this staff evaluation (see finding F5.5), conditions other than this assumed condition may invalidate these findings. Thus, the applicant must consider any potential conditions that differ from the condition upon which these findings are based and modify its current analyses as appropriate. Additionally, there remains a concern regarding some material properties used in the shielding analysis, which may also affect these findings (see Finding F5.5).

Staff is also aware that there are significant structural issues which remain unresolved. The applicant will also need to consider how the resolution of these issues impacts the applicant's current shielding analysis, confinement analysis, and radiation protection system design.

11.0 ACCIDENT ANALYSIS EVALUATION

The objective of the accident analysis review is to evaluate the applicant's identification and analysis of hazards, as well as the summary analysis of system responses to both off-normal and accident or design-basis events. This ensures that the applicant has conducted thorough accident analyses, as reflected by the following factors:

- Identified all credible accidents
- Provided complete information in the FSAR
- Analyzed the safety performance of the cask system in each review area
- Fulfilled all applicable regulatory requirements

The objective includes review of changes to the applicant's description and conclusions regarding the cause of an event, detection of an event, summary of event consequences and regulatory compliance, and corrective course(s) of action.

The regulatory requirements applicable to accident analysis changes proposed by this application include 10 CFR 72.104(a), 10 CFR 72.106(b), 10 CFR 72.122(b)(2), (3), (d), (g), (h)(4), (I), and (I), 10 CFR 72.124(a), 10 CFR 72.236©, (d), and (I), and 10 CFR 72.212(b). This application was also reviewed to determine whether the modifications to the HI-STORM 100 Cask System fulfill the acceptance criteria listed in Section 11 of NUREG-1536.

The following proposal was evaluated:

> A new design concept, designated HI-STORM 100U Cask System (HI-STORM 100U) to include associated design analyses.

The staff's conclusions, summarized below, are based on information provided by the applicant with respect to the HI-STORM 100U.

11.1 Off-Normal Operations

Off-normal operations are Design Event II as defined by ANSI/ANS 57.9. These events can be expected to occur with moderate frequency or on the order of once per year. The HI-STORM 100U Cask System off-normal operations are described in Chapter 11 of the FSAR. The off-normal conditions described in the FSAR include:

- Off-Normal Pressures
- Off-Normal Environmental Temperatures
- Leakage of One MPC Seal Weld
- Partial Blockage of Air Inlets
- Off Normal Handling of HI-TRAC Transfer Cask
- Malfunction of FHD System
- SCS Power Failure
- Off-Normal Loads
- Off-Normal Wind

Section 11 of this staff evaluation evaluates only those aspects of the analysis pertinent to the HI-STORM 100U and documents the staff evaluation up to the time when the review was discontinued.

11.1.1 Dose Limits for Off-Normal Events

Outstanding technical issues, as well as continuing structural concerns, may affect the following findings (see also Section 5 of this evaluation, finding F5.5). The staff reviewed the consequences of postulated off-normal events as proposed in the application, with respect to 10 CFR 72.104(a) dose limits, and found them acceptable. The radiation consequences from off-normal events described in the application are essentially the same as for normal conditions of operation for the proposed contents and design. The staff has reasonable assurance that the dose to any individual beyond the controlled area will not exceed the limits in 10 CFR 72.104(a) during off-normal conditions (anticipated occurrences). Sections 5, 7, and 10 of this staff evaluation further examine the radiological doses applicable to off-normal events, as appropriate.

11.2 Accident Events and Conditions

Accident events and conditions are classified as Design Event III and IV. They include natural phenomena and human-induced low probability events. The HI-STORM 100U postulated accidents are described in Chapter 11 of the FSAR.

11.2.1 Dose Limits for Design-Basis Accidents and Natural Phenomena Events

Outstanding technical issues, as well as continuing structural concerns, may affect the following findings (see also Section 5 of this evaluation, finding F5.5). The staff reviewed the design-basis accident analyses as proposed in the application with respect to 10 CFR 72.106(b) dose limits and found them acceptable. The staff has reasonable assurance that the dose to any individual at or beyond the controlled area boundary of 100 meters will not exceed the limits in 10 CFR 72.106(b) for the proposed contents and design under the conditions analyzed in the FSAR. Sections 5, 7, and 10 of this staff evaluation further examine the estimated radiological doses during accident conditions.

11.3 Evaluation Findings

Based on the NRC staff's review of information provided in the HI-STORM 100U Cask System application, the staff finds the following:

F11.1 Because instrumentation and control systems are not required, no instruments or control systems are required to remain operational under accident conditions.

F11.2 The applicant has evaluated certain off-normal and design-basis accident conditions to demonstrate with reasonable assurance that the HI-STORM 100U Cask System radiation shielding and confinement features are sufficient to meet the requirements in 10 CFR 72.104(a) and 10 CFR 72.106(b). However, the staff makes no finding regarding the overall adequacy of the shielding and confinement features in light of outstanding issues associated with the design and implementation of the HI-STORM 100U Cask System.

12.0 CONDITIONS FOR CASK USE —TECHNICAL SPECIFICATIONS

The objective of this review is to assess whether the applicant has proposed language for the Certificate of Compliance (CoC) 1014 Conditions and Appendix A to the CoC (Technical Specifications) (TS) and if the proposed language is appropriate to accommodate the design requested by the applicant. This review focused on evaluating whether the Conditions and TS ensure that the safety limits and regulations are met.

The staff reviewed information related to the HI-STORM 100U Cask System (HI-STORM 100U). The CoC, Appendix B, specified corrosion control requirements for the HI-STORM 100U. The HI-STORM 100U VVM/CEC container shell and bottom plate shall be protected from corrosion due to the corrosive nature of most soils by use of one or more listed methods. Choice of which method(s) to use first rests upon characterization of site specific soil corrosivity.

Soil corrosivity is categorized as either mild or aggressive in accordance with the method specified in the FSAR. That method employs the guidelines of appendix A of ANSI/AWWA C105/A21. This classical soil evaluation method focuses on parameters such as 1) resistivity, 2) pH, 3) redox (Oxidation-reduction) potential, 4) sulfides, 5) moisture content, 6) potential for stray current, and 7) experience with existing installations in the area. The soil environment is categorized as either "mild" or "aggressive" depending upon the outcome of the various evaluations.

Given a "mild" corrosivity index, the corrosion mitigation measures shall include use of an inorganic coating or an inorganic coating on the exterior of the CEC plus choice of either concrete encasement or cathodic protection (or both). For an "aggressive" soil condition, a coating and a cathodic protection system is required. Concrete encasement may also be optionally used with the other two measures.

12.1 Conditions for Use

The conditions for use of the HI-STORM 100U were modified to add descriptions of the design changes requested in the application. The staff reviewed the proposed CoC and TS changes. At the time the review was discontinued the staff had not made any finding in this area with respect to changes made for the HI-STORM 100U Cask System.

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12.2 Technical Specifications

Table 12-1 of the proposed FSAR lists the TS for the HI-STORM 100U Cask System. At the time the review was discontinued the staff had not made any finding in this area with respect to changes made for the HI-STORM 100U Cask System.

12.3 Approved Contents and Design Features

The applicant provided a proposed CoC, Appendix B, Approved Contents and Design Features, to reflect a new cask system design, the HI-STORM 100U Cask System. The staff has reviewed the information supporting the proposed design to determine if the applicant provided sufficient information to ensure that all the contents to be stored in the HI-STORM 100U Cask System meet the design basis evaluated by the staff in Sections 3 through 11 of this evaluation.

At the time the review was discontinued the staff had not made any finding in this area with respect to changes made for the HI-STORM 100U Cask System

12.4 Evaluation Findings

Based on the NRC staff's review of information provided for the HI-STORM 100U Cask System application, the staff finds the following:

F.12.1 The staff finds the proposal for identifying and mitigating corrosion for the HI-STORM 100U Cask System to be acceptable.

Due to the discontinuing of the staff review of the application before completion, no additional findings have been made regarding Conditions for Cask Use, Technical Specifications.

13.0 QUALITY ASSURANCE EVALUATION

The purpose of this review and evaluation is to determine whether the applicant has a quality assurance (QA) program that complies with the requirements of 10 CFR Part 72, Subpart G, as applicable to the proposed application changes.

Introduction of the HI-STORM 100U Cask System design does not alter the staff's previous assessment of the QA program, as documented in approval of the HI-STORM 100 cask system. Therefore, the staff did not reevaluate this area.

14.0 DECOMMISSIONING

The introduction of the HI-STORM 100U Cask System design has not altered the staff's previous assessment of decommissioning considerations, as related to the HI-STORM 100 Cask System. Therefore, the staff did not reevaluate this area.

15.0 CONCLUSIONS

The staff has reviewed the Final Safety Analysis Report for the HI-STORM 100U Cask System. This evaluation provides documentation of the staff's review of the proposed design. Where appropriate, conclusions and findings have been provided for those areas the staff reviewed. Unless specifically noted, the staff either did not, or could not, complete a technical review and therefore has not provided a finding. Absence of a staff evaluation or finding should not be interpreted to be acceptance of any portion of the proposed design or supporting analyses.

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