NUCLEAR REGULATORY COMMISSION
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SAFETY EVALUATION REPORT
Docket No. 72-1040
HI-STORM UMAX Canister Storage System
Amendment No. 1
Holtec International, Inc.
Certificate of Compliance No. 1040

1.0 SUMMARY

By letter dated July 11, 2014, as supplemented October 31, 2014, Holtec International (Holtec) submitted an application to the U.S. Nuclear Regulatory Commission (NRC) to amend the HI-STORM Underground Maximum (UMAX) Canister Storage System, Certificate of Compliance (CoC) No. 1040. The amendment application provides a seismically enhanced version of the HI-STORM UMAX Canister Storage System, identified by the applicant as the "Most Severe Earthquake (MSE)" version to be used by general license users that are located in areas with higher seismic demands than those analyzed previously. Although most of the application is a revised structural analysis, there are three minor physical design changes that have been requested to ensure the structural integrity of the amended system. These are:

A. Addition of a hold-down system to the closure lid to prevent its uplift during the seismic event.

B. The fill material interstitial space between the cavity enclosure container (CEC) (referred to as Space A in the supplied revised FSAR Figure 2.4.4), is replaced with plain concrete with a minimum compressive strength of 3000 psi.

C. The multi-purpose canister (MPC) guides are strengthened to increase their load bearing capacity, and their nominal gap with the MPC is engineered to be made smaller than the original HI-STORM UMAX design.

Additionally, the staff has provided editorial and administrative corrections to CoC No. 1040, Amendment No. 1, Appendix B, Technical Specifications (TS). Holtec agreed to these changes in correspondence dated September 2, 2015, (ADAMS Accession No. ML15246A064).

The objective of this safety evaluation report (SER) is for the NRC staff (staff) to document its assessment of the structural analysis and physical design changes requested, and confirm adequacy of the structural analysis of the HI-STORM UMAX Canister Storage System, Amendment No. 1 for structures, systems, and components (SSCs) important to safety (ITS).

2.0 PRINCIPAL DESIGN CRITERIA EVALUATION

There were no requested changes affecting principal design criteria related to the ITS SSCs to ensure compliance with the relevant general criteria established in 10 CFR Part 72.

3.0 STRUCTURAL EVALUATION

The HI-STORM UMAX Canister Storage System stores a hermetically sealed canister containing spent nuclear fuel (SNF) in an in-ground vertical ventilated module (VVM). The HI-STORM UMAX Canister Storage System is designed to provide long-term underground storage of loaded multi-purpose canister (MPC) MPC-37 pressurized water reactor (PWR) fuel assemblies or MPC-89 boiling water reactor (BWR) fuel assemblies previously certified for storage.

The amendment application provides a seismically enhanced version of the HI-STORM UMAX Canister Storage System, identified by the applicant as the “Most Severe Earthquake (MSE)” version so that it can be used by general license users for areas with higher seismic demands than those analyzed previously.

The purpose of the staff’s review is to determine whether CoC No.1040, Amendment No.1 meets the applicable requirements of 10 CFR Part 72 for independent storage of spent fuel and of 10 CFR Part 20 for radiation protection.

The physical design changes for HI-STORM UMAX Amendment No. 1 are as follows:

A. Addition of a hold-down system to the closure lid of the original HI-STORM UMAX design to prevent its uplift during a seismic event.

B. The controlled low strength fill material in the interstitial space between the cavity enclosure container (CEC) (referred to as Space A in FSAR Figure 2.4.4), is replaced with plain concrete, with a minimum compressive strength of 3000 psi.

C. The MPC guides are strengthened to increase their load bearing capacity, and their nominal gap with the MPC is engineered to be made smaller than the original HI-STORM UMAX design.

The sole objective of this amendment request is to increase the acceptable level of the earthquake demand on HI-STORM UMAX Canister Storage System. The staff assessed the impact of these changes and their implications for the structural analysis/design of the HI-STORM UMAX design and have documented the results in Section 3.1 of this SER.

The review was conducted utilizing applicable regulations in 10 CFR 72.234(a) and (b), and 10 CFR 72.236(b), (c), (g), and (h) that identify the specific requirements for spent fuel storage cask approval and fabrication.

3.1 Staff Evaluation

Design Basis Seismic Model (DBSM) and Soil-Structure Interaction Analysis (SSI)

In this amendment request the applicant provided a seismic model that applied the design basis earthquake (DBE) at the support foundation pad (SFP) level 25 feet below surface grade. By

contrast, the applicant's original analysis, approved in CoC No. 1040 Rev. 0 used a design basis earthquake (DBE) specified at the ISFSI pad level with a horizontal zero period acceleration (ZPA) of 1.0g and a vertical ZPA of 0.75g. To arrive at a the seismic demand for the SFP, the applicant applied deconvolution which correctly reduced the demand to a horizontal ZPA of 0.93g and a vertical ZPA of 0.71g at the SFP. In this amendment request, the applicant used a higher seismic demand of 2.12g net horizontal ZPA and 1g vertical ZPA, applied directly to the SFP level located at 25 feet below surface grade for its analyzed model. The applicant also stated that this Amendment No. 1 UMAX system also includes concrete fill between the SFP and the top ISFSI pad which provides a more monolithic structure not requiring independent acceleration inputs at the ISFSI pad level.

Additionally, the applicant stated that this approach was required because the SHAKE 2000 computer code's veracity becomes questionable at high intensity earthquake motions, i.e. at ZPA > 1.0g, and it fails to generate reliable strain-compatible soil properties for use in the SSI analysis.

As a result of the applicant applying the DBE at the SFP level, the applicant's SSI model did not include the under-grade (Space C located below the SFP, and Space D surrounding the Space C) as shown in Figure 2.4.4 of the supplied revised Final Safety Analysis Report (FSAR) pages).

The staff notes that Regulatory Guide (RG) 1.60 indicates that the input DBE demand should typically be applied to the top of the loaded independent spent fuel storage installation (ISFSI) pad. The staff reviewed the applicant's approach and determined that applying the DBE directly at the SFP results in a higher seismic demand for the HI-STORM UMAX storage unit, than if it had been applied at the ISFSI pad level. This approach eliminates a reduction in the seismic demand that would have been seen due to the deconvolution of seismic forces, given that the support foundation pad is located at 25 feet below the ISFSI pad. Therefore the staff finds this approach to be conservative, and it meets the general intent of RG 1.60, and is therefore acceptable.

The staff notes that in the CoC No. 1040 for the HI-STORM UMAX system the applicant's dynamic simulation of the structural response of the buried VVM was performed using the commercial finite element code, LS-DYNA. There were no changes to this portion of the DBE analysis for the staff to evaluate in this SER. The applicant continued to use the same computer code LS-DYNA for the Amendment No. 1 analysis. The seismic input for the transient finite element SSI analysis for the Amendment No. 1 continues to use an acceleration-time history set developed using R.G.1.60 response spectra that complied with NUREG-0800 Section 3.7.1.

The applicant's factors of safety for structures, systems and components (SSCs) of the UMAX system were provided in Table 9.4 of Holtec Report No. HI-2125239 (Rev. 1). These factors of safety are used to evaluate the ability of the SSCs to withstand the DBE and are typically calculated as a ratio of the SSC's capacity to withstand earthquake forces to the demand that would occur during the DBE event. The applicant's factors of safety were computed by proportioning the maximum seismic demand loads calculated for the previous UMAX DBE event and the currently proposed DBE.

The staff developed and issued a request for additional information seeking further clarification on the validity of the method used to compute these factors of safety values. In response to staff's request for information (RAI), the applicant supported the validity of its approach by

stating that the ANSYS model used to evaluate the reinforced concrete independent spent fuel storage installation (ISFSI) structure is linear, and therefore the minimum factors of safety for the SFP for the higher seismic demand condition can be obtained by linearly scaling the previous results for the DBE condition according to the seismic demand ratio. Based on experience from the past, as the ANSYS model was used for the previous analysis, and the fact that it is linear, the staff determines that using simple ratio of capacities over the new seismic demands to derive the revised factors of safety is acceptable

The staff reviewed the applicant's approach to calculate seismic demand loads for the higher seismic demand condition, which used the "best estimated" strain compatible dynamic shear wave velocity, and determines that it as an acceptable approach, as it complies with the approach described in NUREG-0800 Section 3.7.1. The staff also verified that the uncertainty of the soil subgrade modulus was studied through two additional SSI simulations for the earthquake (Cases 2LL, and 2LU), which has the largest horizontal ZPA (per the supplied FSAR Table 2.4.5), by using the calculated lower bound and upper bound modulus values. The staff identified an issue with cracked concrete and its effects on the seismic demand on the storage system and subsequently issued a RAI to the applicant to provide justification why the effects of cracking of concrete on the seismic demand on the SFP were not addressed in the SSI analysis for the Amendment No. 1 application. The applicant asserted that the effects of the SFP concrete cracking were evaluated for the previous UMAX DBE condition and that they did not need to be addressed again for this Amendment No. 1 application, as the original UMAX DBE analysis demonstrated that the key seismic response (i.e., the seismic impact loading on the SFP) under the uncracked condition bounded the cracked concrete condition. The staff confirmed that the cracked concrete case does not govern and finds the applicant's response acceptable.

The staff verified that the FSAR (Rev. 2), Table 3.4.2 lists both the cracked scenarios (i.e., Scenarios 2 and 4); and the corresponding uncracked scenarios (i.e., Scenarios 1 and 3) considered in the LS-DYNA SSI analysis for the DBE event as follows:

> Scenario 1: All storage locations loaded with maximum weight MPCs, and a loaded VCT is placed at the center of the ISFSI.
>
> Scenario 2: Same as Scenario 1, except that the Young's Modulus of the SFP concrete is reduced to one-half of its nominal value to incorporate effects of cracked concrete.
>
> Scenario 3: Same as Scenario 1, except that the subgrade adjacent to one side of SES (Space A) is excavated down to the SFP and that the VCT is not considered.
>
> Scenario 4: Same as Scenario 3 except that the Young's Modulus of the SFP concrete is reduced to one-half of its nominal value to incorporate effects of cracked concrete.

The staff reviewed the applicant's supplied calculations: Holtec Report No: HI-2125228 (Rev. 4) for the SSI, and Holtec Report No: HI-2125239 (Rev. 1) for the structural analyses of HI-STORM UMAX ISFSI SSCs, and ensured that the dimensions of the new hold-down system to the closure lid, and the strengthened MPC guides were accurately translated to the ANSYS and LSDYNA analysis models, used in the revised structural analysis for the higher seismic demands (than those used for the previous model) on the storage unit. The staff also reviewed the material properties presented in the updated FSAR relevant to structural performance to verify that they were used appropriately and properly referenced, and

determined that the proper material properties and boundary conditions were used consistent with review guidelines in NUREG 1536, Rev. 1, and that the applicant's selected analytical models, assumptions, and other calculations accurately reflected the specific design parameters. The staff has determined that the information submitted by the licensee including updated FSAR sections and the addendum submitted with the responses to the RAI round No.1 included accurate information that allowed the staff to make a safety determination on the acceptability of the proposed design, including the three design changes (listed in Section 3.0 of this SER) that were incorporated in the new revised computer models used in the analysis for Amendment No. 1.

As the safety factors for all related SSCs for the revised seismic analysis were higher than 1.0 for the new DBE, and as the applicable structural design and acceptance criteria were satisfied, the staff concludes that the HI-STORM UMAX Canister Storage System, Amendment No. 1 is structurally sound, within the Certificate of Compliance (CoC) and the TS parameters.

3.2 Evaluation Findings:

F3.1 The applicant has met the requirements of 10 CFR 72.236(b). The SSCs ITS are designed to accommodate the combined loads of normal or off-normal operating conditions and accidents or natural phenomena events with an adequate margin of safety. Stresses at various locations of the cask for various design loads are determined by analysis. Total stresses for the combined loads of normal, off-normal, accident, and natural phenomena events are within the limits of applicable codes, standards, and specifications.

F3.2 The applicant has met the requirements of 10 CFR 72.236(c), for maintaining subcritical conditions. The structural design and fabrication includes structural margins of safety for those SSCs important to nuclear criticality safety. The applicant has demonstrated adequate structural safety for the handling, packaging, transfer, and storage under normal, off-normal, and accident conditions.

F3.3 The applicant has met the specific requirements of 10 CFR 72.236(g), and (h) as they apply to the structural design for spent fuel storage cask approval. The cask system structural design acceptably provides for the following required provisions:

- Storage of the spent fuel for a certified term of 20 years.
- Compatibility with wet or dry loading and unloading facilities.

F3.4 The applicant has met the requirements of 10 CFR 72.236 with regard to the inclusion of the following provisions in the structural design:

- Adequate structural protection against environmental conditions and natural phenomena.
- Adequate accessibility in emergencies.
- A confinement barrier that acceptably protects the cladding during storage.
- Structural design that is compatible with retrievability of spent nuclear fuel (SNF).

The staff concludes that the structural properties of the structures, systems, and components of the CoC No. 1040, Amendment No. 1 are in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied. The evaluation of the structural properties provides reasonable assurance that the HI-STORM UMAX Canister Storage System Amendment No. 1 will allow safe storage of SNF for a licensed (certified) life of 20 years. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices

4.0 THERMAL EVALUATION

There were no requested changes affecting the thermal criteria related to the ITS SSCs to ensure compliance with the relevant general criteria established in 10 CFR Part 72. Specifically the replacement of the fill between the CEC's with concrete in Amendment No. 1 does not affect the thermal evaluation because the fill was not credited as a heat sink in the original evaluation. Heat removal from the MPC is accomplished by natural circulation of air in the space between the MPC and the CEC.

5.0 CONFINEMENT EVALUATION

There were no requested changes affecting the confinement criteria related to the ITS SSCs to ensure compliance with the relevant general criteria established in 10 CFR Part 72.

6.0 SHIELDING EVALUATION

There were no requested changes affecting the shielding criteria related to the ITS SSCs to ensure compliance with the relevant general criteria established in 10 CFR Part 72. Specifically the replacement of the fill between the CEC's with concrete in Amendment No. 1 does not affect the shielding evaluation because the fill density is unchanged from the applicant's HI-STORM UMAX Canister Storage System application or the staff's March 26, 2014, SER.

7.0 CRITICALITY EVALUATION

There were no requested changes affecting the criticality criteria related to the ITS SSCs to ensure compliance with the relevant general criteria established in 10 CFR Part 72.

8.0 MATERIALS EVALUATION

There were no requested changes affecting the materials criteria related to the ITS SSCs to ensure compliance with the relevant general criteria established in 10 CFR Part 72.

9.0 OPERATING PROCEDURES EVALUATION

There were no requested changes affecting the operating procedures criteria related to the ITS SSCs to ensure compliance with the relevant general criteria established in 10 CFR Part 72.

10.0 ACCEPTANCE TESTS EVALUATION

There were no requested changes affecting the acceptance tests criteria related to the ITS SSCs to ensure compliance with the relevant general criteria established in 10 CFR Part 72.

11.0 RADIATION PROTECTION EVALUATION

There were no requested changes affecting the radiation protection criteria related to the ITS SSCs to ensure compliance with the relevant general criteria established in 10 CFR Part 72.

12.0 ACCIDENT ANALYSIS EVALUATION

The applicant submitted a revised structural analysis to meet seismic accident conditions required by general licensees in areas with higher seismic demands than those previously analyzed. This was evaluated in Chapter 3 of this SER.

13.0 CoC AND TECHNICAL SPECIFICATIONS

13.1 Review Objective

The staff reviewed the application to ensure that the proposed changes to the CoC and operating controls and limits for the Technical Specifications (TS) for the HI-STORM UMAX Canister Storage System, Amendment No. 1, continue to meet the requirements of 10 CFR Part 72. The evaluation is based on information provided by the applicant in this amendment request, a review of the supplied updated FSAR and NUREG 1536, Rev.1. Specifically, the proposed changes were reviewed to ensure that they acceptably supported the changes requested by the applicant. The technical and safety aspects of these TS changes were evaluated by the staff in Section 3 of this SER and were found to be acceptable.

The amendment also includes an editorial change to the CoC to modify the description in the CoC to appropriately capture the details of this amendment.

The applicant proposed the following CoC and TS changes.

- CoC description – added “HI-STORM UMAX Version Most Severe Earthquake (MSE) is a structurally strengthened embodiment of the VVM engineered for deployment at sites with its Design Basis Earthquake with ZPA up to 2.121g (resultant horizontal) and up to 1.0g (vertical).”

- Appendix B, Section 3.4, paragraph 3 – added “For HI-STORM UMAX Version MSE, the corresponding Newmark sum of the ZPAs at the top of the Support Foundation Pad is limited to 2.121g and the vertical ZPA is limited to 1.0g.”

- Appendix B, Table 3-4, 7th row – added “For Version MSE only, the Compressive Strength of plain concrete, psi ≥3000.”

- Appendix B, Table 3-4, 14th row – added “For Version MSE only, Nominal Strain Compatible Shear Wave Velocity in Space B, fps ≥ 344.”

The staff has provided the following editorial changes and administrative corrections.

- CoC, Appendix B, Section 3.4, item 6. This item should refer to Table 3.3. There is no Table 3.4-1 in the CoC as the load combinations are in Table 3.3

- CoC, Appendix B, Table 3-4. The lines describing the depth average density of Spaces A through D should include the units **(lb/ft3).** These units have been included to minimize confusion.
- CoC, Appendix B, Figure 3-1. A note was added that states: “W” is a representative dimension of the ISFSI determined by site-specific layouts. This clarifying note aligns the drawing with the FSAR Chapter 3 description.

- The figures in Appendix B, Section 2.3, added "limit" to the individual cell heat load for clarification purposes.

- CoC App B, Table 3-4 - added "Space A" to the compressive strength line for clarification purposes.

13.2 Findings

F13.1 The staff finds that CoC No. 1040 Amendment 1 identifies necessary TS to satisfy 10 CFR Part 72 and that the applicable criteria of 10 CFR 72.236 have been satisfied. The proposed TS changes provide assurance that the HI-STORM UMAX Canister Storage System MSE Version will allow safe storage of spent nuclear fuel.

14.0 CONCLUSIONS

Based on its review of HI-STORM UMAX Canister Storage System, Amendment No. 1, the staff has determined that there is reasonable assurance that: (i) the activities authorized by the amended certificate can be conducted without endangering the health and safety of the public and (ii) these activities will be conducted in compliance with the applicable regulations of 10 CFR Part 72. The staff has further determined that the issuance of the amendment will not be inimical to the common defense and security. Therefore, the amendment should be approved.

Dated: September 8, 2015

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