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

July 21, 2017

Ms. Kimberly Manzione
Licensing Manager
Holtec International
One Holtec Drive
Marlton, NJ 08053

SUBJECT: AMENDMENT NO. 12 TO CERTIFICATE OF COMPLIANCE NO. 1014 FOR THE HI-STORM 100 CASK SYSTEM – REQUEST FOR ADDITIONAL INFORMATION

Dear Ms. Manzione:

By letter dated June 14, 2016, as supplemented on July 22 and November 4, 2016, Holtec International (Holtec) submitted an amendment request to the U.S. Nuclear Regulatory Commission (NRC) to revise Certificate of Compliance (CoC) No. 1014 for the HI-STORM 100 Multipurpose Canister (MPC) Storage System. The proposed certificate amendment seeks to include a new heat load pattern for MPC-68M to enable a more efficient packaging of fuel, the addition of certain duplex stainless steels to the list of materials previously authorized for use in the HI-STORM 100 Cask System certificate, changes to the cask's vacuum drying procedures, a new open loop low pressure drying method for MPC-68M, and changes to the loading configuration of damaged fuel canisters.

The staff has determined that further information is needed to complete its technical review. The request for additional information (RAI) is in the enclosure. Your response should be provided by October 4, 2017. If you are unable to meet this deadline, please notify us in writing, at least one week in advance, of your new submittal date and the reasons for the delay. The staff will then assess the impact of the new submittal date and notify you of a revised schedule.

Please reference Docket No. 72-1014 and CAC No. L25127 in future correspondence related to this licensing action. If you have any questions, please contact me at (301) 415-1018.

Sincerely,

/RA/

Yen-Ju Chen, Senior Project Manager
Spent Fuel Licensing Branch
Division of Spent Fuel Management
Office of Nuclear Material Safety
and Safeguards

Docket No.: 72-1014

CAC No.: L25127

Enclosure:
As stated

SUBJECT: AMENDMENT NO. 12 TO CERTIFICATE OF COMPLIANCE NO. 1014 FOR THE HI-STORM 100 CASK SYSTEM – REQUEST FOR ADDITIONAL INFORMATION, DOCUMENT DATE: JULY 21, 2017

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Request for Additional Information

Docket No. 72-1014
Certificate of Compliance No. 1014
HI-STORM 100 Dry Cask Storage System
Amendment No. 12

By letter dated June 14, 2016, as supplemented on July 22, and November 4, 2016, Holtec International (Holtec) submitted an amendment request to the U.S. Nuclear Regulatory Commission (NRC) to revise Certificate of Compliance (CoC) No. 1014 for the HI-STORM 100 Multipurpose Canister Storage System.

This request for additional information (RAI) identifies additional information needed by the NRC staff in connection with its review of the amendment application. The requested information is listed by topic and/or page number in the application and associated documentation. The staff in its review of the application used NUREG-1536, Revision (Rev. 1), "Standard Review Plan for Dry Cask Storage Systems".

Each individual RAI section describes information needed by the staff to complete its review of the application and to determine whether the applicant has demonstrated compliance with the regulatory requirements.

Chapter 4 - Thermal Evaluation

4-1 Clarify the inconsistency regarding the Basket-to-MPC Radial Growth between Holtec Report HI-2043317, Appendix P, Section P.5.2(a)) and Note 17 to Drawing No. 7195, Rev. 11 of HI-STORM 100 FSAR Rev. 13.

In Holtec Report, HI-2043317, Appendix P, Section P.5.2(a), thermal expansion calculations for Basket-to-MPC Radial Growth state that the combined radial cold gap between the basket and basket shim, and the basket shim and MPC shell is less than or equal to 0.28125 inch (7.14 mm). However, Note 17 on the Drawing No. 7195, Rev. 11 of HI-STORM 100 FSAR, Rev. 13, states that the average as-built total combined radial air gap between the basket, extruded shims and the enclosure shell shall be a minimum of 0.101 inch and a maximum of 0.175 inch. These values appear to be inconsistent. The values in the drawing note are assumed to be at assembly temperatures; therefore, the computed radial expansion at operating temperature would be greater than the minimum total as-built gap specified.

This information is needed to determine compliance with 10 CFR 72.236(f).

4-2 Clarify the inconsistency in the thermal expansion values for the Fuel Basket-to-MPC Radial Gap.

The applicant calculated thermal expansion in the Fuel Basket-to-MPC Radial Gap, as shown in the proposed FSAR Supplement, Table 4.III.8 and Holtec Report, HI-2043317, Appendix P, Table P.2. However, the thermal expansion of 3.24 mm (0.128 inch) in FSAR Supplement Table 4.III.8 is different from that of 3.03 mm (0.119 inch) in Holtec Report HI-2043317, Appendix P, Table P.2. This inconsistency should be corrected.

Enclosure

This information is needed to determine compliance with 10 CFR 72.236(f).

4-3 (a) Clarify the differences in thermal inertias between FSAR Table 4.5.2 and proposed FSAR Table 4.III.13 (and Holtec Report HI-2043317, Appendix P, Table P.8), and (b) provide calculations or the results to show how the time-to-boil for water in the MPC-68M at QSHL and 42.8 kW, shown in proposed FSAR Table 4.III.14, are derived.

The applicant stated in the proposed FSAR Supplement Section 4.III.5.2 and Holtec Report HI-2043317 Appendix P Section P.5.4 that the time to boil for QSHL pattern was calculated using the methodology described in FSAR Section 4.5.2 and using the thermal inertia of the constituent components in the proposed FSAR Supplement Table 4.III.13 and Appendix P Table P.8. The applicant presented the results in the proposed FSAR Supplement Table 4.III.14 and Appendix P Table P.9.

The staff finds that some thermal inertias (e.g., Alloy-X MPC, fuel, MPC cavity water) in FSAR Table 4.5.2 "HI-TRAC Transfer Cask Lowerbound Weights and Thermal Inertias" are different from those in the proposed FSAR Supplement Table 4.III.13 (and Appendix P Table P.8) "HI-TRAC Transfer Cask with **MPC-68M**: Lowerbound Weights and Thermal Inertias."

This information is needed to determine compliance with 10 CFR 72.236(f).

4-4 Clarify/revise the inconsistency in the gas dew point described in Appendix A (Note 9 to Table 3-1) and FSAR Supplement Section 4.III.5.3.3.

The applicant stated in Appendix A, Table 3-1 (Note 9) that "LPD means an open loop drying method. The acceptance criteria is MPC cavity pressure shall be ≤ 3 torr for ≥ 30 minutes or gas dew point exiting the MPC shall be **≤ 22.9°F** for ≥ 30 minutes." Then the applicant described in FSAR Supplement Section 4.III.5.3.3 that "Therefore, at or below QL, the vacuum drying operation can be continued for as long as necessary to achieve the target vacuum pressure of 3 torr (or dew point of the contained helium gas **<u><21°F</u>**)" and "The "dew point" of the exiting vapor (**target ≤ 21°F**) provides the definitive proof as to whether the canister has been dried to the requisite level."

The applicant should clarify or revise inconsistency in gas dew point described in Appendix A and FSAR Supplement.

This information is needed to determine compliance with 10 CFR 72.236(f).

4-5 Provide information to show how the low pressure drying (LPD) moisture removal method can be performed and controlled effectively to maintain the PCT below 400˚C in the drying operations.

In order for the LPD moisture removal method to have no limitations on time duration, the mass flow rate of helium through the canister (as described in the proposed FSAR Supplement Section 4.III.5.3.3) must be sufficient to remove the total decay heat from the fuel to maintain conditions where the PCT is below the 400°C (752°F) limit. The canister pressure is maintained in the range 0.5 to 1.0 atm (see FSAR Chapter 8, Section 8.5.1, newly added comments/notes in Step 6, per response to request for supplemental information (RSI)). This criterion suggests that the flow rate of helium through the canister must be fairly high throughout the duration of the LPD operation. In normal storage conditions with external air ventilation, the MPC is pressurized to at least 5 atm in order to increase the heat-carrying capacity of the helium gas circulating through the cavity by means of the natural thermo-siphon. At the lower pressure of no more than 1 atm during LPD operation, and consequently lower helium gas density, the rate of helium gas circulation within the cavity must be much higher than the natural circulation rate at a density corresponding to 5 to 7 atm of pressurization in order to remove an equivalent amount of heat. Yet an explicit requirement of the LPD approach is that the "feed and bleed" must be slow enough to encourage "quiescent conditions" in the cavity to allow the gas mixture to stratify to some degree. The heavier water vapor is expected to drift preferentially downward to near the bottom of the cavity, such that the gas mixture removed through the drain line would tend to contain more moisture than it would if the two gases were fully mixed.

Beside the mass flow rate of helium, the mixing of helium fed into the MPC must be sufficient inside the MPC to remove moisture from all fuel assemblies, basket cells and the interior of the MPC.

a) Demonstrate that the mixing of helium gas fed into the MPC for the LPD will be sufficient inside the MPC to flow through all basket cells, instead of a limited number of basket cells, to keep the spatial distribution of cladding temperatures below 400°C.

b) Explain how the "quiescent conditions" in the cavity required for efficient operation of this process will be achieved, while at the same time maintaining sufficiently high flow rate of helium through the canister to assure that the peak clad temperature is maintained below the 400°C (752°F) limit at all times during the operation.

c) Explain how the helium through the cavity will be monitored and maintained at sufficiently high flow rate and sufficient mixing to assure an essentially steady-state heat removal rate for the given decay heat load in the specific MPC undergoing drying with this methodology.

This information is needed to determine compliance with 10 CFR 72.236(f).

4-6 Explain how the slow withdrawal of gas through the drain port is expected to preferentially remove water vapor, rather than helium gas, from the cavity in the LPD operation.

The discussion in the proposed FSAR Supplement Section 4.III.5.3.3 specifically states that the slow withdrawal of the gas mixture through the drain line during the LPD operation, "...steadily dew scavenges the water vapor from the cask, reducing the helium mass' relative humidity." As a technical term, "scavenging" implies some particular affinity for one material to bond with another, generally as an aid in its removal from a system. Helium, being a noble gas, has no noticeable affinity for other gases within a mixture, beyond that resulting from similar velocities in response to a pressure gradient or other external physical force. Therefore, slow withdrawal of gas at the drain port may tend to pull more helium out of the cavity and leave the heavier water vapor behind.

The applicant needs to explain how the slow withdrawal of gas through the drain port is expected to preferentially remove water vapor, rather than helium gas, from the cavity assuming that the desired “quiescent conditions” can actually be achieved within the cavity during this operation.

This information is needed to determine compliance with 10 CFR 72.236(f).

4-7 Clarify how the fuel within an MPC-68M, being dried by the LPD method, does not undergo thermal cycling in excess of the maximum of 10 cycles with the allowed range of change in the PCT of no more than 65°F.

The LPD methodology defines an operational envelope for a specific MPC-68M canister based on a steady-state result obtained with the FLUENT model for the given decay heat load and applicable boundary conditions. In the actual drying operation, the fuel within the canister will be undergoing a transient of potentially very long duration, with the flow of helium through the system repeatedly adjusted in some manner to maintain the cavity pressure at nominally 0.5 to 1 atm throughout the operation. The proposed FSAR Supplement Section 4.III specifically makes the point that this process avoids “cyclic heating and quenching of the fuel” that is provisionally permitted for up to 10 cycles (per ISG-11, Rev. 3) for vacuum drying operations (FSAR Supplement Section 4.III.5.3.1). However, the LPD process has the potential to subject the fuel within the cavity to an unanalyzed thermal transient that may involve multiple cycles of increasing and decreasing PCTs, which could be more than 10 cycles of unknown duration and amplitude, depending on how the pressure and flow rate is controlled in the actual operation for a particular canister.

ISG-11 Rev 3 and NUREG-1536 Revision 1 Section 8.8 show that thermal cycling of cladding can enhance the amount of hydrogen that eventually re-precipitates in the form of radial hydrides. The formation of radial hydrides can significantly alter the mechanical properties of cladding which in turn may pose post-operational safety problems with respect to the removal of the fuel from storage.

The intent of the thermal cycling acceptance criteria in ISG-11 Rev 3 and NUREG-1536 Revision 1 Section 8.8 is to limit precipitation of radial hydrides during loading operations. The requirements of 10 CFR 72.236(m) seek to ensure safe fuel storage and handling and to minimize post-operational safety problems with respect to the removal of the fuel from storage. In accordance with this regulation, the spent fuel cladding must be protected during storage against degradation that leads to gross rupture of the fuel and must be otherwise confined such that degradation of the fuel during storage will not pose operational problems with respect to its removal from storage. Additionally, 10 CFR 72.236(m) require that the storage system be designed to allow ready retrieval of the spent fuel from the storage system for further processing or disposal.

a) Provide additional information which demonstrates that the fuel within an MPC-68M being dried by the LPD method does not undergo thermal cycling in excess of the maximum of 10 cycles with the allowed range of change in the PCT of no more than 65°F, as specified in ISG-11, Rev.3.

b) Specifically define how it will be assured, that the LPD method is consistent with the thermal cycling limitations defined in ISG-11, Rev. 3, during moisture removal operations.

This information is needed to determine compliance with 10 CFR 72.236(f).

4-8 Explain how the drying criteria for the LPD method would detect the effect of residual water in the liquid phase remaining in the canister, based on the “drying criteria” proposed in Amendment No. 12.

The “drying criteria” for the LPD method is defined as achieving conditions where the water vapor in the gas mixture of helium and water vapor extracted from the cavity has a saturation value of 21°F or lower. A gas mixture extracted from a canister undergoing moisture removal by the LPD method would be expected to initially be at a temperature significantly above 21°F since the helium gas is removing the decay heat from the fuel such that the PCT is maintained below the 400°C (752°F) limit. If this gas mixture contains more water vapor than what could be held in the vapor phase at 21°F, the gas mixture would condense as ice or frost when cooled to 21°F.

The proposed FSAR presents the “drying criteria” as simply being able to demonstrate that the gas mixture can be cooled to below 21°F before the water vapor will change phase. In the proposed FSAR, this is called the “dew point,” which is interpreted as evidence that the partial pressure of water vapor in the gas mixture is at or slightly below 3 torr. This is correct, in that the saturation pressure for water at this temperature is, indeed, 3 torr for equilibrium conditions, as per the standard phase diagram for water (generally available in any thermodynamics textbook). However, as a drying criteria, it is incomplete in that for the LPD operation, it is only one measurement point that provides an estimate of a lower bound on the partial pressure of water vapor in the gas mixture within the cavity for the extracted sample.

The common practice for demonstrating a sufficiently dry canister has been the ability to demonstrate that the sealed cavity can *maintain* ***total pressure below 3 torr without vacuum pumping*** **for a period of time, usually defined as 30 minutes**. The test is to demonstrate that there is no significant source of residual liquid water left in the cavity, and any modest increase in pressure over the time period of the test can be reasonably attributed simply to thermal expansion of the gas mixture and not to additional evolution of water changing from the liquid phase to the vapor phase. Experience with vacuum drying operations has shown that this test can generally be met fairly easily, except for systems with components where liquid water has been absorbed into porous material, such as ceramic Boral plates. In such systems, the liquid water must have some finite time to migrate out of the ceramic matrix and evaporate or sublimate into the surrounding gas, before the system is likely to be dry enough to pass the test of a 30-minute “hold” at or below the target pressure. The test is in the stability of the system in holding the target pressure, not the specific pressure of 3 torr, in and of itself.

As described in the proposed FSAR for Amendment No. 12, it appears that the drying criteria for the LPD method would not necessarily detect the effect of residual water in the liquid phase remaining in the canister, even if the specified “drying criteria” were met.

Explain how the drying criteria for the LPD method would detect the effect of residual water in the liquid phase remaining in the canister, by using the specified “drying criteria” documented in the proposed FSAR.

This information is needed to determine compliance with 10 CFR 72.236(f).

4-9 Clarify whether the LPD method is applicable only to the MPC-68M, in any loading patterns or only for QSHL, with decay heat load above 29 kW. Provide additional documentation in FSAR to specify the use of the LPD method.

As documented in the proposed FSAR for Amendment No. 12, it appears that the LPD method is applicable only to the MPC-68M, with decay heat load above 29 kW. If this is the intent, state this explicitly in the FSAR. If not, provide additional documentation specifying any other MPC configurations that the LPD method will be applied to.

This information is needed to determine compliance with 10 CFR 72.236(f).

4-10 Provide the surface temperatures at/near the weld surface areas for applicability of liquid penetrant examination during loading operations to ensure weld integrity and confinement effectiveness for MPC-68M (QSHL pattern with a heat load up to 42.8 kW).

The applicant stated in FSAR Rev. 13, Section 1.2.2.2, Sequence of Operation, for loading operation with MPC placed in the HI-TRAC:

a) MPC water level is lowered slightly and the MPC lid is sealed-welded using automated welding system or other approved welding process. <u>Liquid penetrant examination</u> is also performed on the MPC lid-to-shell weld to ensure weld integrity.

b) Following moisture removal, the MPC is backfilled with a pre-determined amount of helium gas. Cover plates are installed and seal-welded over the MPC vent and drain ports with <u>liquid penetrant examinations</u> performed on the welds to ensure weld integrity.

c) The MPC closure ring is then placed on the MPC, aligned, tacked in place, and seal welded, providing redundant closure of the MPC lid and cover plates confinement closure welds. Tack welds are visually examined and the root and final welds are inspected using the <u>liquid penetrant examination</u> to ensure weld integrity.

Compared to a temperature of 309°F at lid bottom plate under normal storage for the MPC-68M with a QSHL pattern and a heat load up to 42.8 kW (Holtec Report HI-2043317, Appendix P Table P.1), it’s expected that the weld areas mentioned above in items A, B, and C may have temperatures higher than 309°F when liquid penetrant examinations are performed during loading operations.

Given that liquid penetrant examination is applicable for the weld surface temperatures below 250°F, the applicant should provide the weld surface temperatures at/near MPC lid, vent port, drain port and MPC cover plate when liquid penetrating test is performed at loading operations, as described in item A, B and C, to ensure weld integrity and confinement effectiveness.

This information is needed to determine compliance with 10 CFR 72.236(e) and (f).

4-11 Provide justification for the proposed new standard methodology for calculating decay heats and identify any conservatisms included in the proposed methodology.

The proposed FSAR Section 5.2.5.3 describes a new methodology to calculate heat loads for zircaloy clad fuel. The applicant relies on comparisons of its method to RG 3.54 and an assessment of RG 3.54 to a limited set of measurements. While the applicant's assessment suggests the proposed methodology yields conservative results, the applicant has not provided information to justify the stated conservatism. The proposed FSAR states that "(T)his conservatism is sufficient to offset the 1 to 3% difference between RG 3.54 and the methodology proposed here." It is not clear whether 1 to 3% would be conservative and whether any safety factor has been considered in the applicant's methodology. The applicant's justification appears only to be based on comparisons to a limited set of assembly measurements, and it is not clear how the applicant's approach handles additional uncertainties when the method extends beyond the measured data range. For example, is there any consideration for assemblies with longer cooling times, such as beyond 30 years? In addition, there is no discussion of the actual methodology in the attachment, thus, the NRC staff would not be able to evaluate the applicant's analysis beyond the comparisons cited.

Lastly, justify why the proposed methodology does not include uncertainty for assembly burnup.

This information is needed to determine compliance with 10 CFR 72.236(f).

Chapter 8 - Materials Evaluation

8-1 Revise Table 3-1 of Appendix B, List of ASME Code Alternatives for HI-STORM 100 Cask System, to identify ASME Code Case N-635-1 for the use of duplex stainless steel UNS S31803 for MPC NB-2121.

The current text is consistent with the initial amendment application (prior to RSI), which listed a duplex stainless steel that was not included in a NRC-approved ASME Code Case.

This information is necessary to assure compliance with 10 CFR 72.236(b).

8-2 Revise FSAR sections that call out "Alloy X" for the MPC basket.

It is apparent from the proposed FSAR Section 1.A.1 that duplex stainless steels were intended for the MPC shell and not the MPC basket. As such, the following changes are needed:

a) Revise SAR Section 1.2.1.1, Multi-Purpose Canisters: "Any steel part in an MPC may be fabricated from any of the acceptable Alloy X materials listed below, except that the steel pieces comprising the MPC shell (i.e., the 1/2" thick cylinder) must be fabricated from the same Alloy X stainless steel type."
b) Revise materials for the MPC Basket and internal components included in SAR Table 2.2.6;
c) Revise SAR Section 3.1.2.3, "Brittle Fracture," to address the use of duplex stainless steels;
d) Revise SAR Section 3.3.1.1, "Alloy X";

e) Revise tables in SAR Chapter 3, as necessary;
f) Revise description of basket materials and tables in SAR Chapter 4;
g) Revise SAR Tables 7.1.1 and 7.1.4

This information is necessary to assure compliance with 10 CFR 72.236(b).

8-3 Justify the 650°F allowable temperature for duplex stainless steel S31803 in the proposed FSAR Table 1.A.6.

ASME Code Case N-635-1 states that the maximum permissible temperature for duplex stainless steel S31803 is 600°F. Similarly, ASME Code, Section II, Part D, Table 1A (applicable to ASME Section III, Class 2 systems) also lists the maximum use temperature of 600°F for UNS S31803 (Page 126 of 2015 version).

This information is necessary to assure compliance with 10 CFR 72.236(b).

8-4 Provide technical justification for not requiring an engineering evaluation and a recovery plan for MPC shells constructed using duplex stainless steel S31803 after a 100% Air Inlets Blockage Accident, where the MPC shell temperature may exceed the maximum permissible temperature of 600°F specified in ASME Code Case N-635-1.

The proposed FSAR Table 4.III.7, "Maximum Temperatures and Pressures Under 32-Hour 100% Air Inlets Blockage Accident," indicates that the MPC shell temperature may reach 639°F. While the time at temperatures above 600°F may be too short for any significant embrittlement for a single incident, the blocked vent accident conditions could potentially occur multiple times during ISFSI operation.

This information is necessary to assure compliance with 10 CFR 72.236(b) and 10 CFR 72.236(g).

8-5 Provide a justification for the overpack inner shell maximum temperature during normal storage with a MPC-68M (proposed FSAR Table 4.III.3b) which exceeds the long-term normal design temperature limits in FSAR, Rev. 13, Table 2.2.3.

This information is necessary to assure compliance with 10 CFR 72.236(b).

8-6 Provide an analysis to support the local maximum concrete temperature (355°F) under normal long-term storage in Table P.1 of the thermal calculation package in Holtec Report HI-2043317. The maximum concrete temperature exceeds the both the normal and accident temperature limits for concrete listed in ACI-349-85.

Note also that ACI 349-85 Appendix A Section A.4 - Concrete temperatures states:

> *A.4.1- The following temperature limitations are for normal operation or any other long term period. The temperatures shall not exceed 150°F except for local areas, such as around penetrations, which are allowed to have increased temperatures not to exceed 200°F.*

A.4.2 - The following temperature limitations are for accident or any other short term period, The temperatures shall not exceed 350°F for the surface. However, local areas are allowed to reach 650°F from steam or water jets in the event of a pipe failure.

This information is necessary to assure compliance with 10 CFR 72.236(b).

8-7 Provide a justification or analysis to support the off-normal and accident temperatures for concrete in the proposed FSAR Tables 4.III.7, 4.III.15, and 4.III.17 that exceed the maximum accident temperature limits for concrete listed in ACI-349-85. In addition, clarify the required recovery plan for the overpack following the off-normal and accident conditions where the concrete temperatures exceed the maximum accident temperature limits in ACI-349-85.

NUREG/CR-6900 (NRC, 2006) includes a summary of the potential concrete degradation mechanisms that occur at elevated temperatures. The analysis should include an assessment of these degradation mechanisms and their effects on the safety function of the concrete in the HI-STORM overpack.

This information is necessary to assure compliance with 10 CFR 72.236(b).

8-8 Revise the notes for the MPC basket drawings.

It is apparent from the proposed FSAR Section 1.A.1 that duplex stainless steels were intended for the MPC shell and not the MPC basket. As such, the following changes are needed:

a) Update notes on Drawing 3923 MPC shell to include duplex stainless steels as Alloy X materials.
b) Clarify or update notes on Drawing 3925 (MPC-24E/24EF basket) to be consistent with the proposed use of duplex SS as 'Alloy X' material.
c) Clarify or update notes on Drawing 3926 (MPC-24 basket) to be consistent with the proposed use of duplex SS as 'Alloy X' materials.
d) Clarify or update notes on Drawing 3927 (MPC-32 basket) to be consistent with the proposed use of duplex SS as 'Alloy X' materials.
e) Clarify or update notes on Drawing 3928 (MPC-68/68F/68FF basket) to be consistent with the proposed use of duplex SS as 'Alloy X' materials.

This information is necessary to assure compliance with 10 CFR 72.236(b).

8-9 Revise Position Paper DS-213 to be consistent with required acceptance criteria for duplex stainless steel welds.

SAR Appendix 1.A, Section 1.A.1 (as revised in the RSI response) states:

Holtec will implement a test program to insure that the weldments are tested for the absence of detrimental intermetallic phases. The test program will comply with ASTM A923 and will use metallographic examination, impact testing and corrosion testing to demonstrate the absence of such detrimental phases.

ASTM A923-14, Table 2 (ASTM International, 2015) identifies an acceptance criteria of 25 ft-lb for UNS 31803 welds and 40 ft-lb for the UNS S31803 base metal and weld heat affected zones.

The calculation of fracture toughness from the Charpy values in Holtec position paper DS-213 uses a relationship developed for ferritic steels applicable to the upper shelf temperature range (Roberts and Newton, 1981). Originally, Holtec position paper DS-213 only addressed austenitic stainless steels which do not have an observed ductile-to-brittle transition temperature. For austenitic stainless steels, the use of a correlation equation that is applicable to the upper shelf temperature range should yield conservative values of fracture toughness from Charpy data. However, duplex stainless steels have a microstructure with both austenitic and ferritic phases and previous testing has shown that duplex stainless steels and their welds can undergo a ductile-to-brittle transition around −40°C [−40°F] (Sieurin and Sandstrom, 2006). The duplex stainless steel MPCs may be exposed to a range of operating environments and temperatures. A fracture toughness correlation developed for ferritic steels that is limited to the upper shelf temperature range is unlikely to be appropriate for estimating the low temperatures behavior of duplex stainless steels with a microstructure having approximately 50% ferritic phase.

Holtec Positon Paper DS-213 should be revised to include the following:

a) Actual specified minimum fracture toughness value for the duplex stainless steel welds that are consistent with the acceptance criteria in the referenced ASTM standard.
b) Provide information to justify the use of a fracture toughness correlation based on Charpy data for duplex stainless steels that demonstrated the calculated values of fracture toughness bound the contribution from the ferritic phase at low temperatures.

This information is necessary to assure compliance with 10 CFR 72.236(b) and 10 CFR 72.236(g).

8-10 Revise Attachment 2 for Holtec Letter 5014812, “Structural Calculation Package for MPC,” (Holtec Report HI-2012787) and provide the following:

a) Fracture toughness estimations for Metamic-HT as a function of temperature using the mechanical properties reported in “Metamic-HT Qualification Sourcebook,” (Holtec Report HI-2084122 Revision 10) to support the calculation of a minimum flaw size for crack propagation.
b) Additional information with respect to the composition of Metamic-HT including the minimum and maximum boron carbide and aluminum oxide loading to allow a comparison of the estimated fracture toughness values for Metamic-HT to measured fracture toughness values of particle reinforced aluminum metal matrix composites.

In applicant’s structural calculation analysis, the Metamic-HT fracture toughness value provided was stated to be based on an estimate by NRC staff using Charpy impact data and a correlation between Charpy data and fracture toughness based on pressure vessel steels. The applicant stated that: “[…] *Based on CVE correlations for steels, the critical stress intensity factor of Metamic-HT basket was estimated by the NRC reviewer [1] to be* K_{IC} *= 30 ksi* $in^{1/2}$ […].” The applicant further stated that the estimated value of fracture was comparable to the range of fracture toughness for aluminum alloys, which tend to be in the range of 18.2 to 45.5 ksi $in^{1/2}$. Based on the estimated fracture toughness value, the applicant calculated a minimum flaw size for crack propagation, α, using the equation for the stress intensity for a plate with an edge crack (Holman and Langland, 1981) to be 1.275 inches or more than 20× greater than the allowable or detection flaw size stated by the applicant to be 1/16" (0.0625").

The staff reviewed the applicant's analysis and determined that the statement claiming that NRC staff estimated a value for the Metamic-HT critical stress intensity factor is not accurate. A review of the conversation record (ML092330054 and ML092440495) show that the NRC staff at the time were questioning the fracture toughness of Metamic-HT. The NRC staff estimation of the fracture toughness of an aluminum metal matrix composite (MMC) using a correlation developed for pressure vessel steels was understood to be an estimate. In addition, the staff note that estimating the fracture toughness for aluminum MMCs using data for aluminum alloys is not an established practice. Fracture toughness of aluminum alloys is dependent on a number of factors, including composition and condition for aluminum alloys that can be age hardened (ASM, 1998).

The Metamic-HT Qualification Sourcebook (Holtec Report HI-2084122 Revision 10) includes mechanical properties of Metamic-HT over a wide range of temperatures. Although fracture toughness is not directly measured, the Metamic-HT Qualification Sourcebook Attachment E includes: (1) calculation of the required fracture toughness as a function of peak stress and crack size and (2) a correlation equation developed for structural steels that can be used to calculate fracture toughness using the Charpy V-Notch (C_v) data and Young's Modulus (E) data.

The staff notes that the estimation of fracture toughness for Metamic-HT using a correlation equation developed for structural steel is not an established practice. Estimated values of fracture toughness for Metamic-HT can be compared to measured values of fracture toughness for particle reinforced aluminum metal matrix composites if the composition of Metamic-HT including the minimum and maximum boron carbide and aluminum oxide loading are provided. This is necessary to show that the use of the correlation equation for pressure vessel steels provides similar values of fracture toughness compared to reported fracture toughness values for analogous particle reinforced aluminum metal matric composites. The staff reviewed the available literature on fracture toughness measurements for aluminum metal matrix composites (Flom et al., 1989; Flom and Arsenault, 1989; Lewandowski, 2000; Miserez, 2003; Rabiei et al., 2008). Numerous aluminum MMCs exist which utilize a variety of aluminum alloys and ceramic particle compositions. Commonly used particle compositions include SIC, Al_2O_3, and B_4C. Based on the available information on fracture toughness of aluminum MMCs, the range of fracture toughness values spans from 8 to 30 ksi·$in^{1/2}$. Several factors can influence the fracture toughness of aluminum metal matrix composites including: (1) particle composition, (2) particle size, (3) particle loading, (4) particle distribution or clustering, (5) alloy composition and, (6) alloy condition for aluminum alloys that can be age hardened. The applicant should consider whether technical information in addition to the Metamic-HT composition should be provided to support a comparison of the fracture toughness values for Metamic-HT.

This information is necessary to assure compliance with 10 CFR 72.236(b).

8-11. Provide information on potential strength degradation of aluminum basket shims by thermal over-aging of precipitation-hardened microstructure.

The application addressed the use of aluminum alloy basket shims primarily in thermal performance. The applicant assumes aluminum alloy to be effective for the short duration dynamic loading from the tip-over accident. Aluminum alloy, such as Alloy 2219, used by Holtec is precipitation-hardened alloy. The application shows the shims temperature could be as high as 295˚C (563°F) under normal conditions (FSAR Table 3.III.3 and Table 4.III.3b). Literature data shows that over-aging and accompanying strength degradation could occur at 210 – 240 ˚C in a few hours (for Alloy 2219 in Rafi Raza et al., 2011).

It is unclear to the staff whether the structural analysis adequately accounts for potential degradation of strength of aluminum alloy for prolonged conditions including normal conditions as discussed in HI-STAR SAR Section 2.2 (Holtec International, 2017). The staff requests that the applicant (i) provide justification that the current tip-over analysis in the design basis is valid, (ii) revise the analysis to adequately account for the degradation of aluminum alloy strength, or (iii) state that the type of Alloy 2219 (e.g., 2219-O) is in the annealed conditions which would not be subject to degradation of strength due to over-aging.

This information is needed to determine compliance with 10 CFR 72.236(b).

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