HI-STAR 100
Discussion of Responses to RAIs for
Model No. HI-STAR 100 HB

Presentation to NRC
July 18, 2007
by
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## Agenda

- Introduction
- Discussion of RAIs
- Summary





Enclosure 3

## Introduction

- Topics
  - Damaged fuel definition – RAI CoC-1
  - LS-DYNA – Chapter 2 (Structural RAIs)
  - Materials (Metamic/Holtite-A) – RAI 3-3, 8-5, and 8-6
  - Chapter 7 (Operations) – Removal of Dry Cell Loading
  - Minor Clarification of RAIs – RAI 1-1, 5-10, 6-3, 6-4, and 8-1



## RAI CoC – 1

NRC - Delete the word "expected" and replace it with the word "possible" in the first sentence of the proposed definition of Damaged Fuel Assembly.

## RAI CoC – 1 (con't)

Holtec -

Current Definition of Damaged Fuel (since Rev. 2 of CoC, 2003, "Trojan" LAR):

**Damaged Fuel Assemblies** are fuel assemblies with known or suspected cladding defects, as determined by review of records, greater than pinhole leaks or hairline cracks, missing fuel rods that are not replaced with dummy fuel rods, ***missing structural components such as grid spacers, assemblies whose structural integrity have been impaired***, or those that cannot be handled by normal means. Fuel assemblies which cannot be handled by normal means due to fuel cladding damage are considered fuel debris.



## RAI CoC – 1 (con't)

Holtec - Proposed Definition, consistent with Storage CoC:

**Damaged Fuel Assemblies** are fuel assemblies with known or suspected cladding defects, as determined by *a* review of records, greater than pinhole leaks or hairline cracks, *empty* fuel rod *location*s that are not *filled* with dummy fuel rods, ***whose structural integrity haves been impaired such that geometric rearrangement of fuel or gross failure of the cladding is expected***, or that cannot be handled by normal means. Fuel assemblies *that* cannot be handled by normal means due to fuel cladding damage are considered *FUEL DEBRIS*.

## RAI CoC – 1 (con't)

Holtec - NRC is requesting change from "expected" to "possible"

- Damaged Fuel Test: "Demonstrate that geometric rearrangement of fuel or gross failure of the cladding is not possible". This is impossible to demonstrate, and goes way beyond the principle of providing "reasonable assurance". All fuel would have to be considered damaged.
- We agree with the NRC on the purpose of the classification of fuel for criticality control. However, we oppose the requested change, since in practical application it would have consequences that would go far beyond the intention.



## RAI CoC – 1 (con't)

NRC - Define those defects that are to be considered damaged and analyze them in the SAR.

Holtec -

- The defects are defined in the damaged fuel definition.
- The SAR already contains a methodology for a bounding evaluation of damaged fuel and fuel debris.

## RAI CoC – 1 (con't)

NRC - Geometric arrangements of the fuel needs to be prevented to assure the criticality safety of the package contents during all normal and hypothetical accident conditions.

Holtec - It is unclear what the purpose of this statement is. We can not prevent the rearrangement of fuel if it is damaged.



## RAI CoC – 1 (con't)

NRC - Furthermore, only pristine assemblies can be considered undamaged because the actual defects that might be considered damaged are not defined.

Holtec - The actual defects that are (not might be) considered damaged are defined, in the damaged fuel definition. These are the "impairments of structural integrity such that geometric rearrangement of fuel or gross failure of the cladding is expected". Also, note that a new term, pristine, is introduced here, but not defined.

Defining the defects that need to be considered damaged contradicts the performance based approach, and, even more important, is impractical. The appropriate approach would be to define the performance acceptance criteria, as done in the proposed definition, and then allow a case-by-case evaluation.

## Chapter 2 - Structural RAIs

RAIs 2-1, 2-2, 2-3

- HOLTEC BELIEVES ALL RAIs FOCUS ON BENCHMARKING OF LS-DYNA AND CAN BE ADDRESSED IN A SINGLE BENCHMARK PACKAGE.
- PLANNED RESPONSES ON DOCKETS FOR HI-STAR 180 AND/OR HI-STAR 60 ADDRESS ALL ISSUES INCLUDING THOSE RAISED HERE FOR HB.



## Chapter 2 - Structural RAIs (con't)

RAI 2-1

- HOLTEC BELIEVES NO SAR SUPPLEMENT MODIFICATION NEEDED.
- ¼-SCALE TEST DRAWINGS ALREADY PROVIDED IN CHAPTER 1 OF SAR.
- BENCHMARK REPORT SUBMITTAL ADDRESSES OTHER REQUESTED ITEMS IN THIS RAI.

## Chapter 2 - Structural RAIs (con't)

RAI 2-2

- HOLTEC BELIEVE'S THAT THE QUESTION PERTAINS TO THE MODELING OF THE INTERNALS IN THE ¼-SCALE TEST AND THE MODELING OF THE INTERNALS USING LS-DYNA.
- CURRENT SAR EXISTING APPENDIX 2.A (FORMELY 2.H IN EARLY APPROVED SAR) DISCUSSES THE ¼-SCALE MODEL - THE VALUES OF MASS AND OF MASS MOMENT OF INERTIA OF THE HI-STAR 100 CASK ARE APPROPRIATELY SCALED TO DEVELOP THE PROPER VALUES FOR THE ¼-SCALE MODEL.
- THE BENCHMARK SUBMITTAL ADDRESSES THE LS-DYNA MODEL OF THE INTERNALS AND WILL PROVIDE THE VALUES OF MASS AND MASS MOMENT OF INERTIA THAT LS-DYNA WOULD COMPUTE.



## Chapter 2 - Structural RAIs (con't)

RAI 2-3

- HOLTEC BELIEVES THAT THE STAFF IS REQUESTING TIME-HISTORY PLOTS IN THE APPLICATION TO DEMONSTRATE THE AGREEMENT BETWEEN MODEL TEST RESULTS AND LSDYNA ANALYSIS RESULTS.
- THIS INFORMATION IS PROVIDED IN THE BENCHMARK REPORTS.

## Chapter 2 - Structural RAIs (con't)

RAI 2-4

- HOLTEC BELIEVES THAT THE STAFF IS REQUESTING THAT STRESS INTENSITIES IN THE FUEL BASKET UNDER OBLIQUE LOADING BE PROVIDED.
- THE STRESS ANALYSIS OF THE HI-STAR HB FUEL BASKET IS BASED ON A 2-D FINITE ELEMENT ANALYSIS WITH LOADING FROM BASKET SELF-WEIGHT AND FROM THE SPENT FUEL STORED IN EACH BASKET CELL.
- UNDER OBLIQUE LOADING, AXIAL LOADING ON BASKET IS FROM SELF-WEIGHT ONLY AND IS THERFORE SMALL COMPARED TO LATERAL LOADING EXCEPT UNDER A NEAR VERTICAL DROP.
- SAR SUPPLEMENT WILL ADD TEXT TO CLARIFY WHY RESULTS OF LATERAL DROP ANALYSIS IS CONSERVATIVE.



## Benchmarking Analysis

- STAGE 2 REPORT
  - USES FE MODEL OF FULL SIZE HI-STAR 100 AND COMPARES RESULTS WITH ¼-SCALE TESTS USING SIMILARITY PRINCIPLE. DIMENSIONS SCALED, MATERIAL PROPERTIES (INCLUDING CRUSH MATERIAL) MAINTAINED
  - ALSO SCALES FE MODEL OF FULL SIZE HI-STAR 100 AND DEMONSTRATES SIMILARITY AND APPROPRIATENESS OF FE MESH
  - DEMONSTRATES AGREEMENT WITH SUCCESSFUL MODEL TESTS, BUT DOES NOT ADDRESS FAILED TESTS.

## Benchmarking Analysis (con't)

- STAGE 3 REPORT
  - LS-DYNA SIMULATION BASED ON A DIRECT MODELING OF THE ACTUAL ¼-SCALE CASK AS DESCRIBED BY SAR DRAWINGS AND ACTUAL BILL OF MATERIALS
  - SIMULATE ONE FAILED TEST (BOLT FAILURES ON BOTTOM IMPACT LIMITER IN SIDE DROP) AND FOUR SUCCESSFUL TESTS (WITH MODIFIED BOTTOM IMPACT LIMITER



## Benchmarking Analysis (con't)

Package Content

- STAGE 2 REPORT
- STAGE 3 REPORT
  - THESE TWO REPORTS ARE DISCUSSED IN DETAIL IN APPENDIX 2B OF THE HI-STAR 60 AND HI-STAR 180 SUBMITTAL
  - THE REPORTS WILL BE REFERENCEDIN THE HI-STAR HB SUPPLEMENT.
- AN ATTACHMENT TO ONE OF THE BENCHMARK REPORTS WILL CONTAIN ALL "USEFUL" DOCUMENTATION (REPORTS, DRAWINGS, TECH. PAPERS) PULLED TOGETHER IN ONE LOCATION FOR FUTURE REFERENCE.
- ALL ITEMS DISCUSSED IN HI-STAR HB, 180, 60 MTGS. WILL BE ADDRESSED IN PACKAGE.

## Materials (Metamic/Holtite-A)

RAI 3-3

NRC – Provide basis for thermal properties of Holtite-A, including aging effects from thermal or radiation degradation. Explain how any changes in the properties and HI-STAR thermal performance are considered in the thermal analysis.

Holtec - Holtite-A is qualified to withstand the effects of the elevated temperatures and high radiation exposures reached in the generic HI-STAR 100 Cask (heat loads up to 20 kW).

As the HI-STAR HB package heat loads (2 kW) are dwarfed by the generic design, much larger margins against thermal and radiation degradation are realized.

The following reports will be referenced in the RAI response:

- "Holtite A: Development History and Thermal Performance Data", Holtec Report HI-2002396, Rev. 2.
- "Holtite-A: Results of Pre-and-Post-Irradiation Tests and Measurements", Holtec Report HI-2002420, Rev. 1.



## Materials (Metamic/Holtite-A) (con't)

RAI 8-5 - Metamic

NRC – Demonstrate that sufficient B10 content is present locally considering crack formation at edges of the plates. State and justify the sample size to be used to measure the B10 content.

RAI 8-6 - Metamic

NRC – Ensure that acceptance tests will be used to justify the uniformity of the Metamic product in all materials. Justify the statements on page 8.1-7: (a) that chemical analyses will be used to establish the uniformity of the B10 in the absorber plate material and (b) that neutron attenuation test samples may be performed to quantify the actual B10 areal density.

## Materials (Metamic/Holtite-A) (con't)

Holtec -

- In 2004, Metamic was approved for all MPCs for storage in the HI-STORM (72-1014). Metamic is used in all currently manufactured MPCs.
- The initial qualification of the manufacturing process of Metamic, and the ongoing acceptance testing of the manufactured panels, is described in Chapter 8.
- The qualification testing has been successfully performed, and is documented in a Holtec Proprietary report.
- Metamic Samples from production runs are tested on an ongoing basis.



## Materials (Metamic/Holtite-A) (con't)

- By now, several hundred samples have been tested using a neutron attenuation method. Not one sample has been found to be below the minimum acceptable B-10 areal density.
- Example:
  - Average Areal Density 0.0336
  - Minimum Areal Density 0.0320
  - Standard Deviation 0.0008
  - 95/95 lower bound 0.0320
  - Minimum Required 0.0310
  - Credited in Analysis 0.0279

## Materials (Metamic/Holtite-A) (con't)

- Most neutron attenuation tests performed with a beam size of 1 inch
- Confirmatory tests with a beam size of 3/8 inch (~10mm) give practically the same results



## Materials (Metamic/Holtite-A) (con't)

- Effect of Beam Size
- The maximum keff value of the basket is a more global value.
  - Important parameters are the number and size of panels, and the overall B-10 amount.
  - Local variations of the areal density have a small if not negligible effect

## Materials (Metamic/Holtite-A) (con't)

- Case 1 – Holes in Metamic/Boral plates (in SAR)
  - A 1 inch diameter hole in ALL panels of the basket has a negligible effect on the maximum keff value
- Case 2 – local variations in areal density
  - alternating axial sections of boral / metamic with 80% and 120% of the minimum loading
  - Average maintained at (80%+120%)/2=100%
  - Axial length of the sections is varied between 0.5cm and 64 cm
  - Preliminary Results indicate that even for an axial section length of 8 cm, i.e. more than 1 inch, the effect on the maximum keff value of the system is negligible.
  - Conclusion: A beam size of 1 inch is more than sufficiently small, there is no need to use a smaller than 1 inch beam size.



## Chapter 7 - Operations

- Holtec will be removing the option for dry cell loading from the LAR submittal.
- This will be reflected in the responses to RAI 7-5, which asks for clarification in keeping dose rates ALARA while manually welding the MPC lid in a dry-cell, and 7-8 which requires modification to Chapter 7 to prevent oxidation in the fuel during loading outside a spent fuel pool as discussed in ISG-22.

## Minor Clarification of RAIs

- RAI 1-1

NRC – Explain why ten Type 2 and six Type 5 aluminum sections shown for the inner-layer honeycomb materials of the top impact limiter are not axisymmetric.

Holtec – The referenced drawing shows an already licensed design. A table has been added on sheet 1 specifically for HB for the nominal crush strength properties for the impact limiters.

This material is confined by the interior gussets and is active only in end drop. A material availability issue originally was addressed by mixing two crush strengths.

Sheet 3 of SAR drawing permits a uniform arrangement of 1420 psi crush strength material as an option for the HI-STAR 100. Sheet 3 will have an similar option for the HI-STAR HB.



## Minor Clarification of RAIs (con't)

RAI 5-10

NRC –Provide additional justification/analysis of loading design-basis damaged BWR fuel with the proposed specifications.

Holtec - We need clarification on this RAI. Gamma source terms for intact design basis fuel (Table 5.2.5) are about 2.5 times higher than gammas from the design basis damaged fuel (Table 5.2.6), even in the energy range of 1 to 1.5 MeV.

## Minor Clarification of RAIs (con't)

RAI 6-3

NRC – Show that the analysis of the MPC-HB has been performed at the optimum moderator density.

Holtec- Calculations show no optimum moderation. Would Staff prefer document details in RAI response or SAR?



## Minor Clarification of RAIs (con't)

RAI 6-4

NRC – Provide the computer code input files for the analyses used to show that a ¼ inch gap between the two neutron absorber panels in the alternate poison plate design and for the anaysis used to show that the reduced poison width is acceptable.

Holtec- Would Staff prefer the input file be submitted with the RAI response or within the SAR?

## Minor Clarification of RAIs (con't)

RAI 8-1

NRC – Revise the visual inspections section to add a provision to ensure the presence of the neutron absorber plates during the acceptance process.

Holtec - In approved Revision 12 of the SAR, in regards to neutron absorber panels, it states "Travelers and/or quality control procedures shall be in place to assure each required cell wall of the MPC basket contains a Boral panel in accordance with the drawings in Section 1.4."

The neutron absorber plates are fully encased in a stainless steel sheathing, thus a visual inspection upon delivery is not possible.

Text will be added to state that "The final quality documentation package shall be consulted to validate each required cell wall of the MPC basket contains a neutron absorber panel." We can clarify with what type of records, quality or fabrication.



## END OF PRESENTATION