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HI-STAR 60 RAIs

Presentation to NRC

September 24, 2008

by

Holtec International

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Agenda

- Introduction
- RAI Overview
- Metamic Qualification
- Fuel-Related Questions
- Structural Questions
- Thermal Questions
- Summary

Introduction

- Holtec International submitted a licensing application for a new transportation package, the HI-STAR 60, in August 2007
- Cask is a smaller version of the HI-STAR 100 Cask, consisting of a cask body with lid and basket. There is no MPC
- Teleconference on August 8 regarding structural analyses
- RAIs were received September 3, 2008
- RAI responses will be submitted by end of October, 2008
- This meeting is used to present and discuss RAI responses in selected areas

HI-STAR 60

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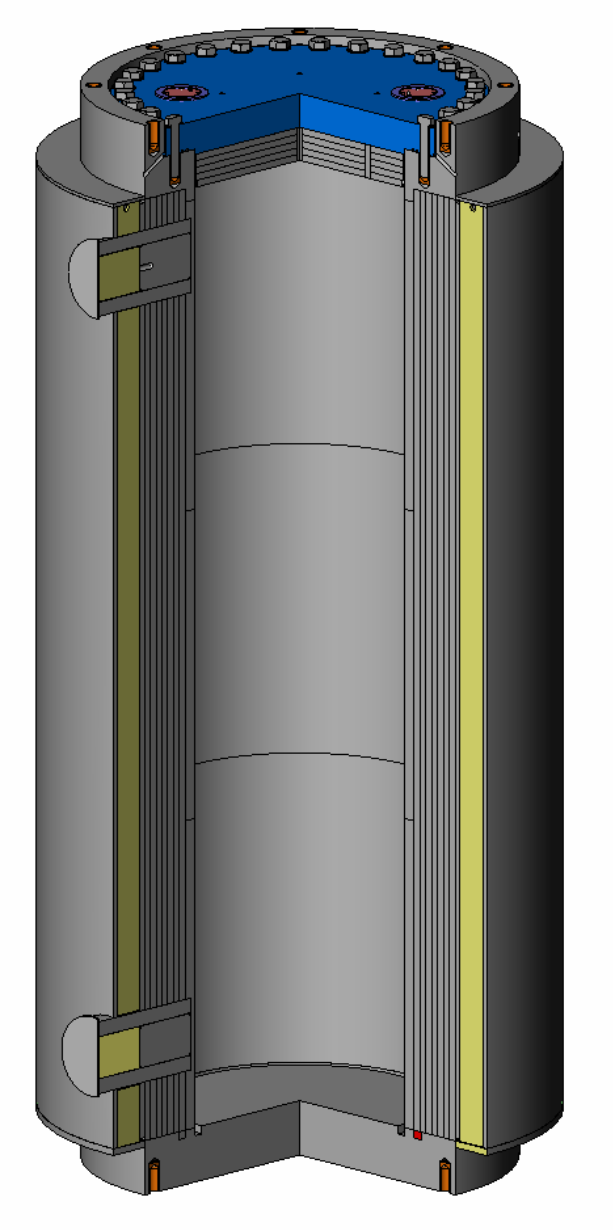

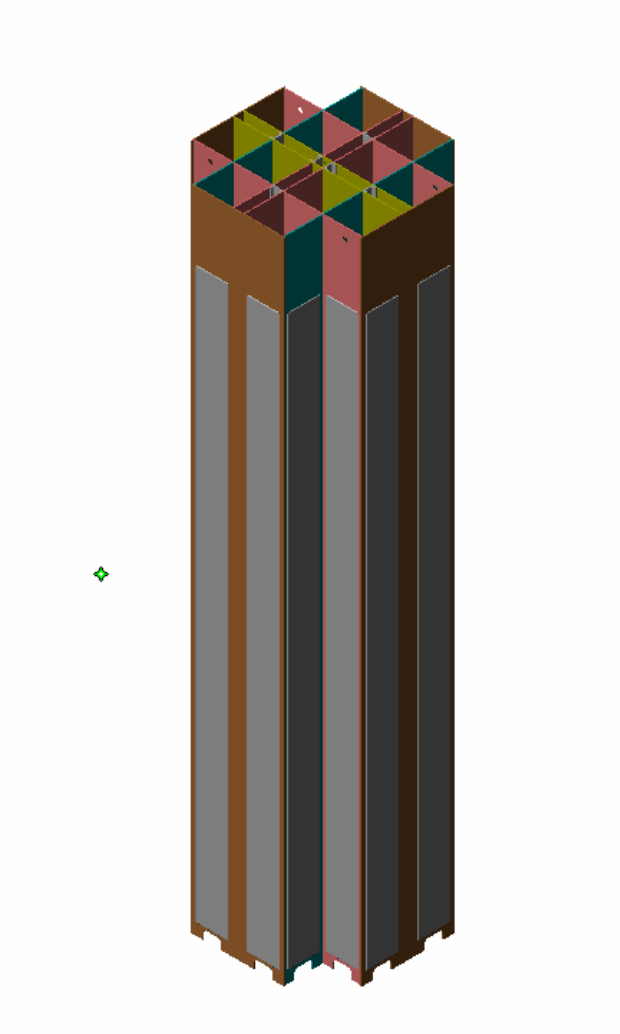

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RAI Overview

- General
  - Fuel-related questions
- Chapter 1
  - Fuel-related questions, including ISG-1
- Chapter 2
  - Revised Methodology
  - Fuel-related questions
  - Gap prior to transport accident
  - Alternative Materials
  - Impact Limiter temperature
- Chapter 3
  - Fuel-Related questions
  - Additional Analyses
- Chapter 4, 5, 6, 7
  - Clarifications, Justifications
- Chapter 8
  - Additional tests
  - ASME code clarifications
  - Metamic Qualification

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Metamic Qualification

- History
- Current use in Holtec Products
- Qualification for HI-STORM Dry Storage System
- Qualification for HI-STAR 60

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Metamic - History

- METAMIC® is a metal matrix composite (MMC) consisting of a matrix of aluminum reinforced with boron carbide. It is an isotropic, macroscopically homogeneous neutron absorber material licensed for use for spent fuel reactivity control in dry and wet storage applications.
- METAMIC® has been subjected to an extensive array of tests sponsored by the Electric Power Research Institute (EPRI) that evaluated the functional performance of the material at elevated temperatures and radiation levels (documented in an EPRI report)
- Tests by EPRI indicate that METAMIC® maintains its physical and neutron absorption properties with little variation in its properties from the unirradiated state.
- Additional tests carried out by Holtec to evaluate Metamic's suitability for wet and dry applications corroborated the conclusions reached by EPRI

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Metamic – Current Use in Holtec Products

- More than 40,000 Metamic panels have been produced for Dry Storage Casks and Spent Fuel Racks
- Since 2005, Metamic is approved in the HI-STORM Storage cask for all MPCs
- Metamic is installed in spent fuel pools in 8 Nuclear Power Plant Units in the US, and in 2 Units overseas
- Further 5 units in US and 3 units overseas are in the planning or fabrication phase
- Essentially all new MPCs and Spent Fuel Pool racks are manufactured with Metamic

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Metamic – Licensing Situation

- HI-STORM 100 Storage (72-1014)
  - All MPCs built with Metamic since 2005
- HI-STAR 100 Transport (71-9261)
  - Uses same MPCs as HI-STORM Storage
  - License Amendment Request for Metamic submitted in 2006
  - Amendment is being revised to use Metamic only in the MPC-HB
  - LAR to use Metamic in other Holtec MPCs will be resubmitted in 2009.
  - All MPCs in storage need to be transportable.
- HI-STAR 60 Transport (71-9336)
  - Four units are scheduled for manufacturing.
  - The total number of Metamic panels needed is 160.
- The path we take for the HI-STAR 60 (small number of panels), will also be the path that we take for the HI-STAR 100 (much larger number of panels).

Qualification for HI-STORM Dry Storage System

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- A two-step approach is used to qualify the panels

  1. Qualification of the manufacturing process, using coupons from the first manufactured batches

  2. Tests of the ongoing production
     - All Batches are tested for minimum B_4C content using wet chemistry and for minimum panel thickness
     - Randomly selected coupons are tested for B-10 areal density using neutron attenuation technique

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Metamic Terminology and Processing

- Lot: All material mixed from constituents (aluminum powder and B_4C) from the same source
  - 1 Lot ~ 200 batches
  - Same B-10 to B-11 ratio
- Batch: One blending of aluminum and B_4C
  - About 200 lb
  - After the blending, three samples are taken (top, middle, bottom) and analyzed for B_4C weight percent
  - 1 batch = 3 billets
  - Same B_4C Weight Percent

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Metamic Terminology and Processing (cont'd)

- Billet:
  - Each billet is isostatically pressed and thermally processed
  - Then it is extruded into one piece of bloom stock, about ¾ Inches thick
- Bloom Stock: Cut into two pieces
- Each piece is rolled out, and then sheared into typically 2 panels (MPC-32)
- Maximum 12 panels per batch (MPC-32)
- Each panel has a unique number
- For a panel length of 156 inches, the panels are sheared at 160 inches, and a piece 4x6 inches is kept, either from top or bottom of the panel. Note that since the panels are rolled from a half part of the bloom stock, the 4x6 piece comes either from the end or the center of the bloom stock

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Wet Chemistry vs. Neutron Attenuation Testing

- Wet Chemistry
  - B-10 Areal density
    = B_4C percent (measured per batch)
    times Boron Fraction in B_4C (constant)
    times B-10 fraction in Boron (from lot)
    times Density (from qualification testing)
    times Thickness (from coupon measurement)
  - Required minimum values for above parameters are set such that even if all parameters are at the their minimum value, the required B-10 areal density is still met
  - THIS APPROACH ESSENTIALLY GUARANTEES THAT ALL PANELS MEET THE B-10 AREAL DENSITY REQUIREMENTS
- Neutron Attenuation
  - Comparison of neutron transmission with transmission through reference B_4C plates with known B-10 areal density
  - This is just an independent verification to answer the question: Are we really still doing what we think we are doing?
  - Neutron count per measurement is of the order of 10^5, so statistical uncertainty of measurement is comparatively small

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Qualification Testing

- Predictability of B_4C weight percent
  - 512 samples from batches for 32 wt% B4C
  - Observed B4C content was 32.08 wt% +- 0.23 wt%
- Thickness
  - Five panels were tested at 30 location each at regular intervals.
  - Thickness variation +- 0.001 inches
- Density
  - A large number of coupons were tested, showing an average density of about 99.5% of the theoretical, and a minimum value of about 99% of the theoretical density

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Qualification Testing (cont'd)

- Wet chemistry and neutron attenuation
  - Tests comparing results from wet chemistry and neutron attenuation tests show excellent correlation
  - All values are above the required minimum B-10 areal density
- Uniformity
  - Multiple Coupons from selected panels
    - Five coupons taken from each of Five panels (one from top, one from bottom, three from side)
    - B-10 areal density variation within one panel typically +- 1%
  - Randomly selected panels
    - 40 panels tested, results were within +- 4 %
    - All values are above the required minimum B-10 areal density

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Ongoing Testing During Production Runs

- B-10 per lot; B_4C per batch; Thickness per coupon
  - This ensures that all panels meet the minimum B-10 areal density, even without calculating the actual B-10 areal density for each panel
  - Acceptance Criteria:
    - If the B_4C is not met, the batch is rejected
    - If the Thickness is not met, the panel is rejected
- Neutron attenuation testing
  - Randomly selected coupons are tested, from about 10% of the manufactured panels
  - About 40 to 100 coupons are tested at a time
  - Acceptance Criteria:
    - If a coupon does not meet the B-10 areal density, then the entire batch is rejected
  - Large number of coupons have been tested successfully

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Metamic Testing for HI-STAR 60

- Metamic for HI-STAR 60
  - Same B_4C content as standard MPCs (24, 32, 68)
  - Same thickness as Metamic for MPC-32 and MPC-68
  - Only difference is the smaller width and shorter length of the panels for the HI-STAR 60
  - Metamic panels for the HI-STAR 60 can be sheared directly from panels made for the MPC-32
- Testing
  - Same testing as for MPC-32 panels: 100% B_4C content; 100% Thickness; 10% neutron attenuation testing.
  - We will ensure that at least 10% of the panels installed in all HI-STAR 60 baskets are tested.
  - Note that thickness reduction does not an issue that must be included, since even at the minimum permitted thickness, the panels do met the B-10 areal density

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Metamic Related RAIs

- RAI 8-8 (Testing): As discussed in previous slides
  - All neutron attenuation tests from production runs
  - Coupons from end of plates
  - Thickness reduction does not need to be explicitly evaluated:
    - Panel must meet minimum thickness
    - Coupon must meet minimum thickness
    - Even at the minimum permitted thickness, the panels do meet the B-10 areal density
- RAI 8-9 (Inspection): Will be clarified
- RAI 8-10 (Wet Chemistry vs Neutron Tests)
  - By now we have performed hundreds of neutron attenuation tests, and compared the resulting B-10 areal density with the value from the wet chemistry (above). Values show excellent consistency.
- RAI 8-11 (Critical Characteristics and Procedures)
  - Will be included in Chapter 8
- RAI 8-12 (Reference Reports)
  - Appropriate documents will be referenced in Chapter 8.

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Fuel Related Issues

- ISG-1 Rev. 2
  - Will be adopted
- Indian Point 1 fuel assemblies
  - By now, all Indian Point 1 assemblies are loaded in Holtec MPCs and HI-STORMs
  - This fuel type will therefore be removed from the application
- Qinshan fuel assemblies
  - Clarification needed
  - Question G-4 appears open ended
  - ISG-11 Rev. 3 discusses cladding material, hoop stress, oxide thickness and cladding temperature effects. No explicit references to plant operating conditions.
  - Note that the HI-STAR 100, in its currently licensed condition, could be used outside the US with non-US fuel, irradiated in reactors with operational parameters not known to us.

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Structural Questions

- Alternative Materials
- Structural Methodology
- Fracture Toughness Test Criteria

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Alternative Materials

- Requests to approve alternative materials will be reduced to the minimum required for fabrication

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Structural Methodology

- Benchmarking Calculations for the Quarter-Scale HI-STAR 100 drop tests are currently being refined based on NRC comments on various licensing applications
  - Extensive work scope
  - Results look very good
- Same refinements will be applied to HI-STAR 60 Impact Limiter Runs, and rigid body decelerations will be calculated
- As an independent approach, the differential equation methodology (from HI-STAR 100) will also be used to determine rigid body deceleration values
- Cask and Basket will then be qualified using static calculations and bounding decelerations (higher of the value from LS-DYNA and Differential Equation approach)
- THE ASSUMPTIONS FOR GAPS PRIOR TO AND DURING ACCIDENT CONDITIONS NEED TO BE CLARIFIED.

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Fracture Toughness Test Criteria

- Cask Closure Lid Bolts (RAI 2-8)
  - Criteria provided in SAR Table 2.1.12 for SA193-B7 material; same criteria apply to SA564-630 and SA705-630
  - Criteria based on paragraph NB-2333 and Table NB-2333-1 of the ASME Code (2004 Edition)
  - Cv (lateral expansion) >= 25 mils at -40 deg. F
- Gamma Shield Shells (RAI 2-14)
  - Criteria provided in SAR Table 2.1.13 for “Intermediate Shells”; required Cv lateral expansion value (15 mils) will be included in table
  - Criteria taken from ASME Subsection NF for Class 3 component supports (NF-2320 thru NF-2350)
  - Criteria was previously approved in HI-STAR 100 SAR

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Thermal Questions

- Impact Limiter Temperatures
  - The Impact Limiter Temperature of 340 Deg F is for the entire structure, including crush material and support structures.
  - For the crush material, the calculated maximum temperature is lower, about 280 Deg F
  - We are trying to determine the temperature limit of the epoxy in the crush material
- Cladding Temperature during Vacuum Drying
  - The calculated cladding temperature during vacuum drying is 399 Deg C under steady-state conditions.
  - We expect to show that the hoop stress is well below 90 MPa, even at temperatures higher than the current value. With that, temperatures above 400 Deg C under loading conditions should be acceptable.
  - We will provide reasonable estimates of the uncertainties and show that even when including those uncertainties, the hoop stress of 90 MPa is not exceeded.

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Summary

- Technical Discussion on selected RAI questions, specifically Metamic Qualification and Structural Methodology
- Submittal of RAI Responses October 2008