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PROPOSED TEST PROGRAM FOR HI-STAR ATB 1T TRANSPORT PACKAGE

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Meeting Objectives

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- To present Holtec's proposed test program for the HI-STAR ATB 1T to support 10CFR71 license application
- To receive and discuss feedback from the NRC regarding the general acceptability of the proposed test program, including the test model and its numerical benchmarking

Presentation Overview

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- HI-STAR ATB 1T Package Design
- Relevant Guidance
- Holtec Approach – Benchmark Test Program
- LS-DYNA Benchmarking
- Demonstration of Leak Tightness
- Critical Structural Failure Modes
- Test Conditions
- Test Model
- Package Contents
- Test Measurements
- Acceptance Criteria for Physical Tests
- Preliminary Schedule

HI-STAR ATB 1T Package Design

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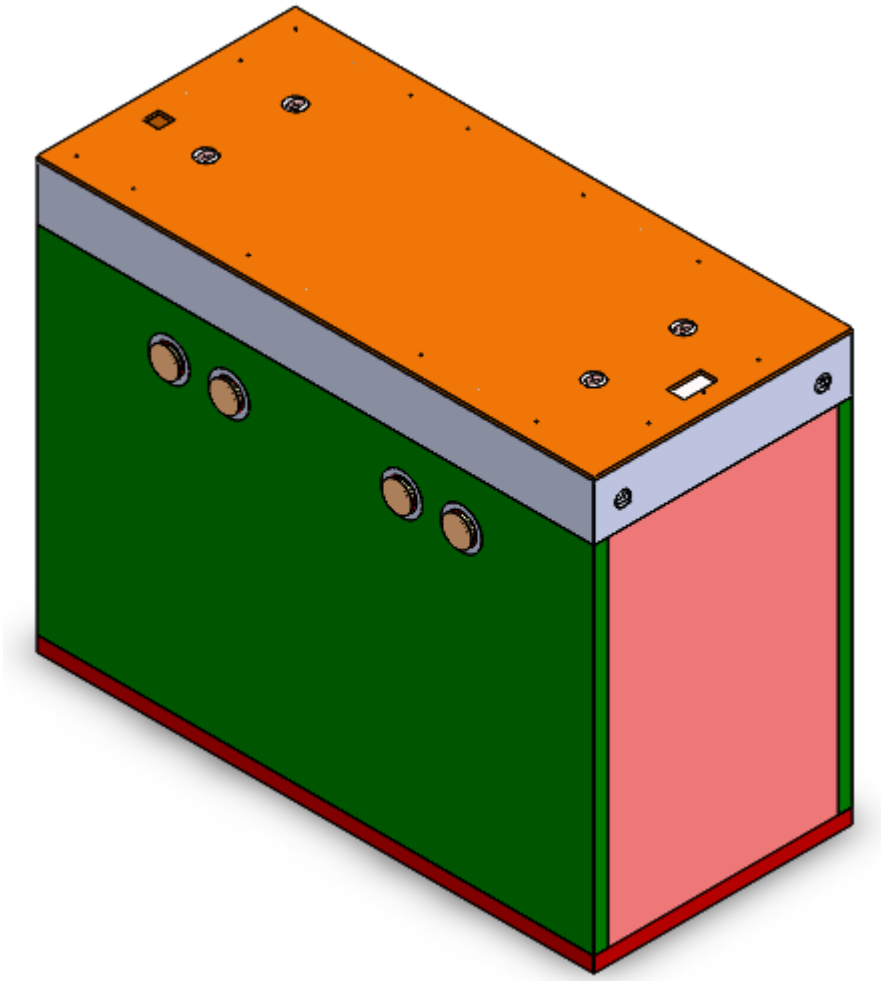

- Package design is essentially unchanged from original submittal
  - Eliminate SA-564 630 material option for closure lid locking wedges/wedge block
- Type B(U) Transport Package
- Rectangular vessel
- Stainless steel/nickel alloy containment boundary
- Unique closure lid locking mechanism
- No impact limiters

Relevant Guidance

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- NUREG-1609, “Standard Review Plan for Transportation Packages for Radioactive Material”, Subsection 4.5.3.2
  - If compliance is demonstrated by test, verify that the leakage rate of a package subjected to the tests of §71.71 does not exceed the maximum allowable leakage rate for normal conditions. Scale-model testing is not a reliable or acceptable method for quantifying the leakage rate of a full-scale package.
  - If compliance is demonstrated by analysis, verify that the structural evaluation shows that the containment boundary, seal region, and closure bolts do not undergo any inelastic deformation and that the materials of the containment system (e.g., seals) do not exceed their maximum allowable temperature limits when subjected to the conditions in §71.71.

Relevant Guidance (cont.)

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- UCRL-ID-121673, "Guidelines for Conducting Impact Tests on Shipping Packages for Radioactive Material", Section 2.1.1
  - Compliance test group
    - > The compliance test group includes all test programs intended to demonstrate, by test alone, the compliance of a package with the regulation.
  - Benchmark test group
    - > The benchmark test group includes all test programs used to justify the analysis method or model used to demonstrate the compliance of a shipping cask. Test models for these test programs need not be prototypical and can be greatly simplified; they only need to retain the design features expected to dominate the impact response of the package.

Holtec Approach – Benchmark Test Program

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- Perform limited number of physical drop tests of Scale Model Cask as a means to validate numerical model
  - Physical tests focus on critical failure modes
  - Additionally, successful drop tests give direct, positive indication of package worthiness
- Use benchmarked numerical model to demonstrate full compliance with 10CFR71 regulations
  - Consider all possible drop orientations and conditions
  - Perform sensitivity studies as needed
- In accordance with NUREG-1609 guidance, no leakage rate testing of Scale Cask Model will be performed; benchmarked numerical model will be used to demonstrate that Closure Lid Locking System (CLLS) does not experience inelastic deformation that would challenge sealing function

LS-DYNA Benchmarking

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- Benchmark model will be exact dimensional replica of Scale Model Cask
- Benchmark model will consider actual material strength properties of as-fabricated Scale Model Cask per Certified Material Test Reports (CMTR)
- Benchmark model will be able to reasonably predict (with a slight conservative bias):
  - Peak rigid body deceleration of package
  - Strain levels in containment boundary (as compared to strain gage measurements)
  - Permanent deformation of package at key measurement locations (i.e., impact point, wedge locks)
- After successful benchmarking, the full-scale package will be re-analyzed using the same modeling features (element types, material models, contact behavior, etc.) to obtain the highest quality results

Demonstration of Leak Tightness

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- HI-STAR ATB 1T cask uses elastomeric seals
  - Seating load is small in comparison to metallic seals (i.e., minimal preload is required)
  - Sealing performance is maintained provided that joint opening does not exceed the "useful" springback subsequent to the drop event
- Final analysis of full-scale cask using LS-DYNA must demonstrate that, for all analyzed drop conditions, the unloading of the top flange/closure lid joint is less than the "useful" springback specified by the seal manufacturer
- Therefore, the analysis must be able to reliably predict the component deformations in the seal region, including the top flange, closure lid, closure lid locking wedges, and wedge blocks
  - Becomes an important focus of benchmark test program

Critical Structural Failure Modes

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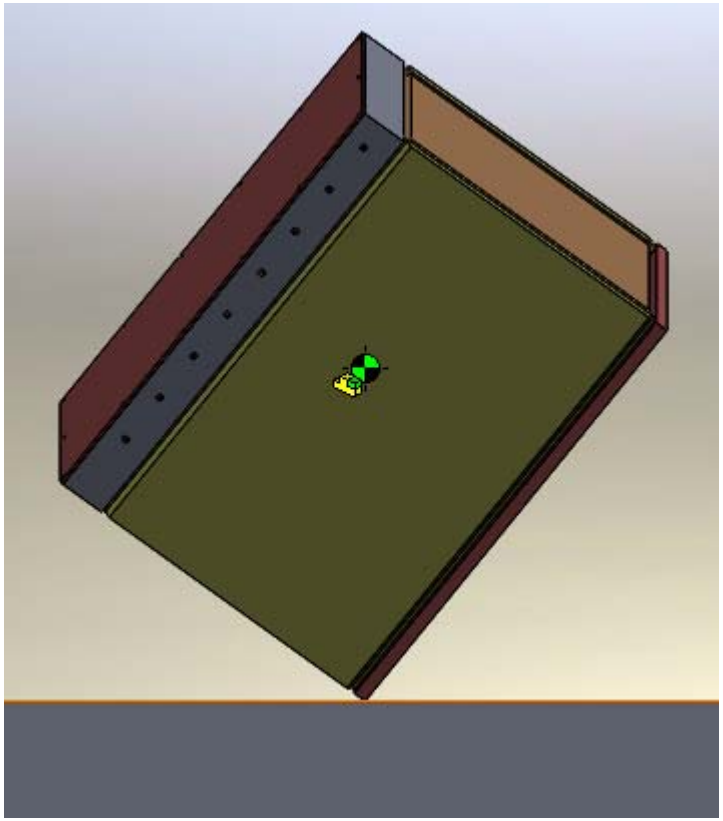
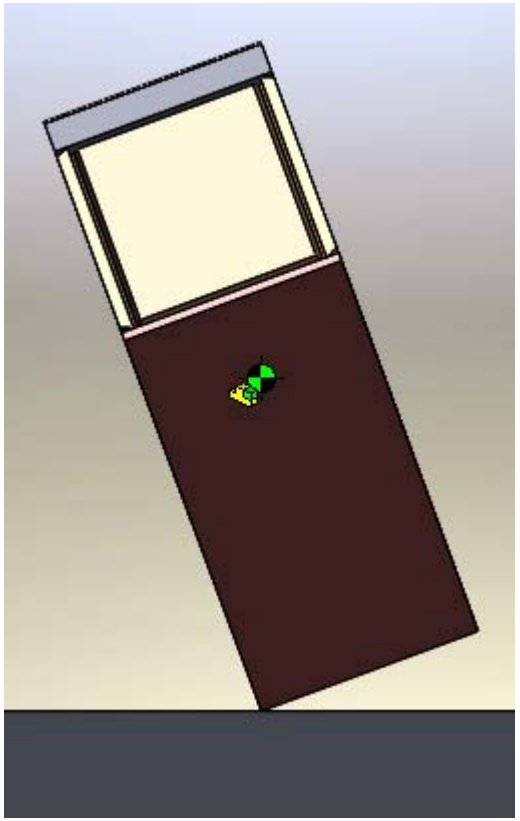
- Potential failure of weld seams (particularly at 3-D corner)
  - Perform bottom-down center-of-gravity-over-corner (CGOC) drop test





Critical Structural Failure Modes (cont.)

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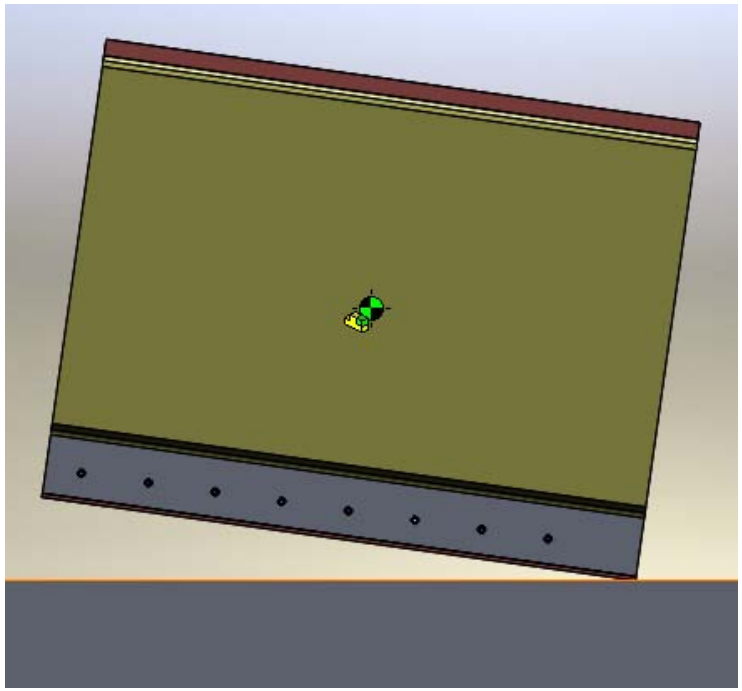
- Potential failure of Closure Lid Locking System (CLLS)
  - Perform top-down end/slapdown drop test
  - LS-DYNA will be used to determine worst-case impact angle (prior to test) so as to maximize impact load on CLLS



Test Conditions

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- Perform 2 physical drop tests using same test model
  1) Top-down end/slapdown drop test
  2) Bottom-down CGOC drop test
- Use of a single test model is justifiable because of the sequence and orientations of the drops
  - Permanent deformation due to the top-down drop will not extend anywhere near the base plate corners (as supported by the original LS-DYNA results)
  - Scale Model Cask is not expected to overturn following the top-down drop (causing a secondary impact on the base plate corner)
- Perform drop tests at national lab site (e.g., Sandia or Oak Ridge)
  - "Unyielding target surface" already qualified
  - Provide considerable expertise in drop test measurements and data analysis

Test Model

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- Use ¼ Scale Model (Type A-4 per UCRL-ID-121673)
  - Capable of capturing all response modes (wave, vibration, quasi-static deformation)
  - Gravitational similarity is not an issue since impact decelerations are dominant (> 100g's)
  - Brittle fracture resistance is not a relevant concern because of materials of construction (Type 304 stainless/SB-637 N07718/SA-193 Grade B8)
  - Convenient for fabrication (i.e., 2" thick plate → ½" thick plate)
- Scale Model Cask will be constructed using identical materials
  - Closure Lid Plate, Top Flange, Containment Boundary Walls & Dose Blocker Structure: Austenitic Stainless Steel (Type 304)
  - Closure Lid Locking Wedges/Wedge Blocks/Locking Pin: Inconel (SB-637-N07718)
  - Wedge Block Securing Bolt: Austenitic Stainless Steel (SA-193 Grade B8)

Test Model (cont.)

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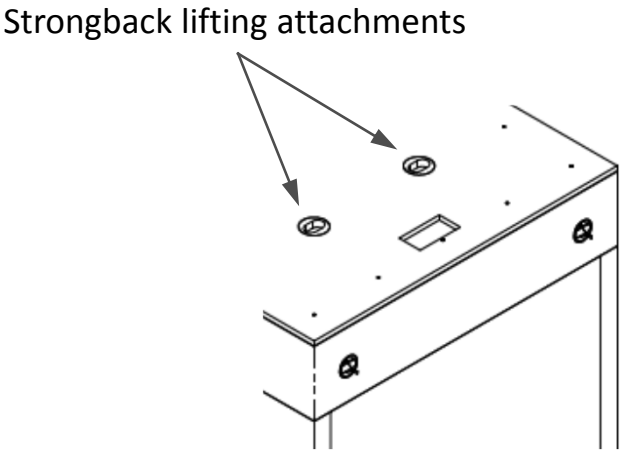
- Certain features which are not critical to the structural response will be eliminated from Scale Model Cask:
  - Collapsible lifting trunnions
  - Hydraulic system for remote lid operation
  - Leak test ports
  - Strongback lifting attachments (simplified as lid support points)



- Scale Model Cask will be fabricated using the same welding processes and weld procedures as the full-scale cask
  - Containment boundary welds will meet requirements of ASME Section III NB-4000
  - Dose blocker welds will comply with ASME Section IX requirements

Test Model (cont.)

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Item	Full Scale Prototype	1/4 Scale Test Model
Overall Cask Dimensions		
Length	3733 mm	933 mm
Width	1734 mm	434 mm
Height	2882 mm	721 mm
Package Mass		
Empty Cask	131,550 lb	2,055 lb
Loaded BFA Tank (Max.)	112,436 lb	1,757 lb
Total	243,986 lb	3,812 lb

Package Contents

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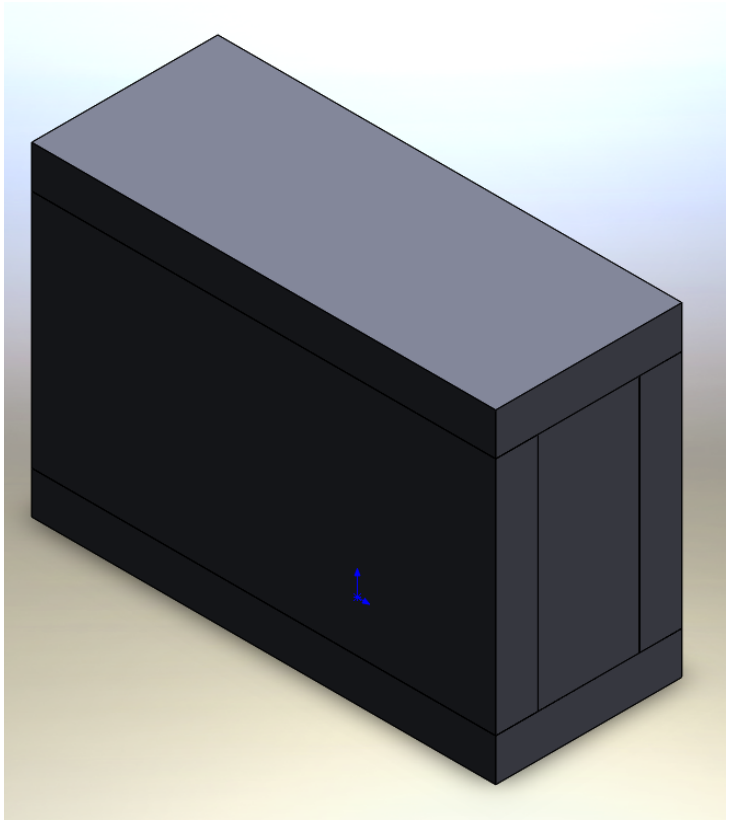
- Quarter-scale BFA Tank with simulated contents will be fabricated as a separate body and loosely placed inside the Scale Model Cask
- Mass of BFA Tank (plus contents) will correspond to heaviest loaded tank
  - All contents will be fixed inside the BFA Tank (no moving parts)
  - Center of gravity of BFA Tank (plus contents) will coincide with geometric centroid of tank
- Effects of partially/eccentrically loaded BFA Tank will be studied using benchmarked LS-DYNA numerical model



Test Measurements

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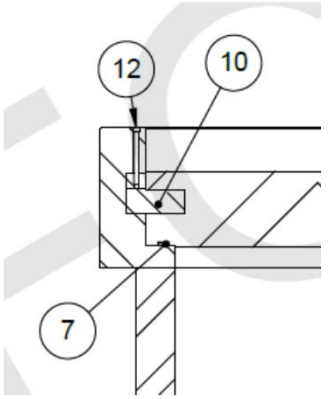
- Pre- and post-test dimensional measurements
  - Top flange opening
  - Wedge lock thickness
  - Groove height in closure lid for movable wedge locks
  - Corner geometry (for bottom-down CGOC drop test)



- Photometric measurements
  - Provide confirmation of impact velocity, impact angle, rigid body deceleration
- Accelerometers
  - Will be installed on cask body and closure lid

Test Measurements (cont.)

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- Strain gage measurements
  - Will be installed at multiple locations on the containment boundary, including closure lid, side walls, bottom plate, and closure lid locking wedges
  - Exact number and placement of strain gages to be determined in coordination with lab test engineers
- Pre- and post-test NDE examination (PT) of containment boundary welds
  - At conclusion of drop tests, Dose Blocker Structure will be removed to allow complete examination of containment boundary welds

Acceptance Criteria for Physical Tests

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- No obvious structural instability or rupture of the cask (based on visual inspections) that would prevent compliance with containment, shielding, or thermal requirements of 10CFR71
- Measured strains in containment boundary must remain below ASME Section III Appendix FF limits
- Closure lid and closure lid locking wedges must not experience inelastic deformation that would challenge sealing function
- Post-test NDE examination (PT) of containment boundary welds must not show any signs of weld cracking due to impact load

Preliminary Schedule

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- April 30, 2016: Complete fabrication of Scale Cask Model
- May 2016: Perform physical drop tests
- June 2016: Obtain final drop test report from test facility
- August 2016: Complete numerical benchmarking
- September 2016: Update and re-submit 10CFR71 license application for HI-STAR ATB 1T

Open Discussion

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End of Presentation