HI-STAR PBT (TPBAR) Public Session

November 22, 2022

RSIs Affecting Impact Limiter

2-1 Provide expanded test data for the prototype impact limiter and expanded test data for the prototype foam material.

2-2 Provide expanded test data to justify the assumption that only localized damage to the impact limiter stainless steel skin seam welds will occur and that only minimal impact limiter foam material will be consumed by combustion.

RSIs Affecting Impact Limiter (cont.)

3-1 Provide justifications and additional explanations in Section 3.4.2 of the HI-STAR PBT safety analysis report (SAR) on how the four papers in Attachments A – D of the Holtec Report No. HI-2200641, Revision 0, provide an accurate representation of the material properties (e.g., thermal conductivity, density, specific heat) for the polyurethane foam, foam char, and air, as well as the quantity of foam char for the HI-STAR PBT impact limiter material during the regulatory fire and post-fire hypothetical accident conditions (HAC). Alternatively, provide HAC fire testing results of the HI-STAR PBT impact limiter with the foam that demonstrates the material assumptions in the HAC thermal model are accurate.

Holtec Response Plan

- Physical Design Enhancements to Impact Limiter
- Polyurethane Foam Component Testing
- 1/4-Scale Impact Limiter Drop Tests
- Updated Benchmark Analysis of Foam Based Impact Limiter
- Updated Thermal Analysis

Impact Limiter Testing

HOLTEC INTERNATIONAL

- Static crush tests of 2.5” x 2.5” foam specimens (unconfined)
- 9-meter drop tests of 1/4-scale impact limiter conducted at Oakridge National Lab facility
  - End drop and slapdown drop orientations
  - Package instrumented with accelerometers
  - High speed digital photography

Impact Limiter Testing (cont.)

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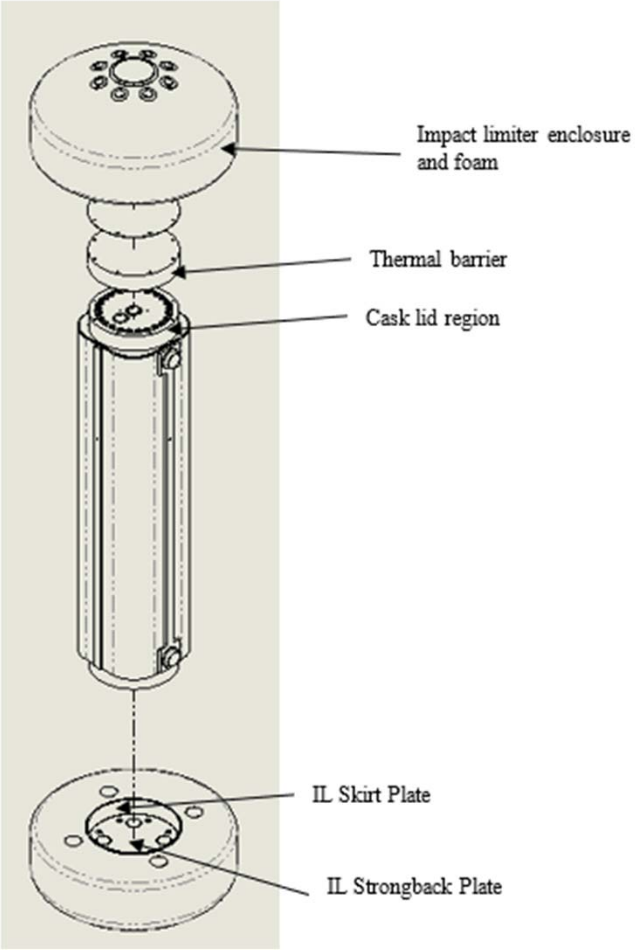
- Key objectives of impact limiter testing are:
  - ✓ To obtain design-specific test data to strengthen benchmarking of LS-DYNA simulation model
  - ✓ To confirm behavior of impact limiter skin during 9-meter drop
- Thermal barrier is not included in 1/4 scale test model since it does not affect structural response or numerical benchmarking
- Post-impact status of thermal barrier, including radial and axial gap conditions, will be determined based on full-scale LS-DYNA drop simulations using benchmarked foam material model
  - ✓ Results will be used to inform thermal analysis of fire accident event

Thermal Barrier Design and HAC Modeling

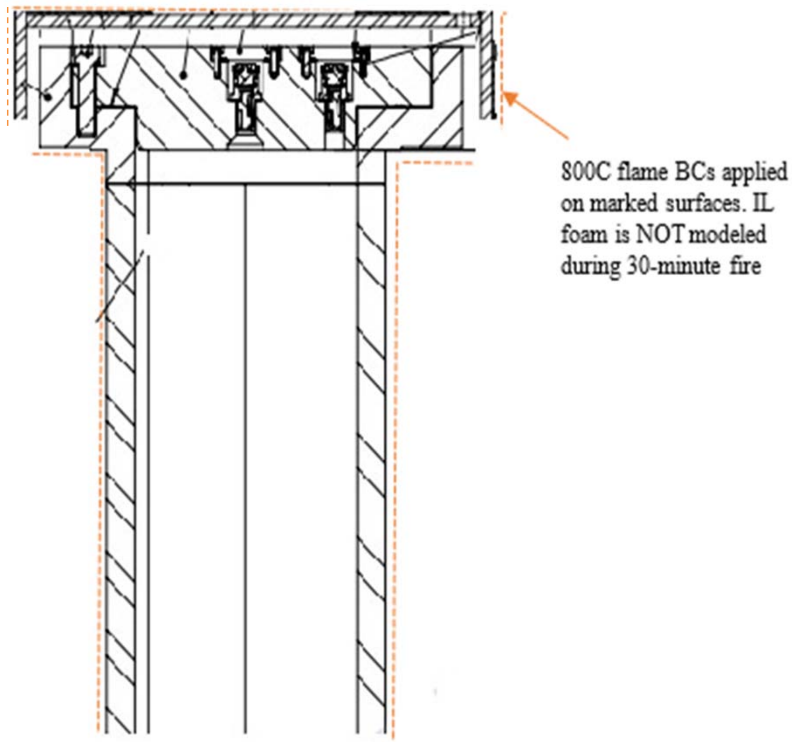
- The thermal barrier is designed to create a radial air gap around the top flange and an axial air gap above the cask lid/flange region.
- The inner surfaces of the thermal barrier are polished to minimize the radiative heat transfer into the cask during fire.
- These gaps are understated in the thermal model and are explicitly modeled.
- Radiative heat transfer across the gap is included.
- Thermal barrier not present in the bottom impact limiter.



Fire Accident Condition Modeling

- Thermal analysis of the HAC is performed in three steps:

- Thermal Model A
  - Includes entire cask, the thermal barrier and the strongback/skirt plates sections of the impact limiter.
  - Computational domain enclosed by the dashed lines in the adjoining figure.
  - Foam is not modeled.
  - 800°C flame boundary conditions applied on the outer surfaces of the strongback/skirt plates and the exposed cask surfaces.
  - ✓ This places the fire right next to the cask.

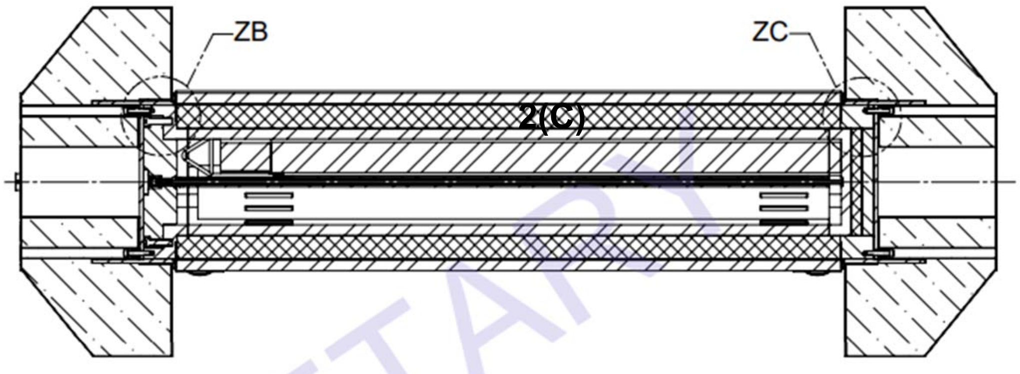


Fire Accident Condition Modeling

- During the 30-minute fire phase, the IL external surfaces are subjected to fire flame and therefore, foam absorbs thermal energy during the 30-minute fire phase.
- A separate thermal model (B) of just the impact limiter foam is constructed to compute the energy absorbed by the foam during the 30-minute fire.
- Temperature field in the foam at the end of the 30-minute fire obtained.

Hypothetical Accident Conditions Modeling

- Thermal Model C
  - IL crush material impedes rejection of the energy absorbed by the cask during postfire phase. Therefore, it is included during post-fire cooldown.
  - The two thermal models (A & B) at the end of the 30-minute fire are interfaced and the postfire phase evaluation is performed.
  - IL crush material modeled with the thermal conductivity of air to minimize heat rejection from the cask to ambient.
  - Simulation continued until all components reach their peak temperature/pressure values.



Interfaced Thermal Models A and B for Post-fire analysis. (Thermal barrier not shown)