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NUMERICAL SIMULATION OF HI-STAR 63 WITH POLYURETHANE FOAM IMPACT LIMITER DURING HYPOTHETICAL FIRE ACCIDENT

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ABSTRACT

The Holtec International Storage, Transport, and Repository (HI-STAR 63) package is a type B(U), radioactive package containing commercial Spent Nuclear Fuel (SNF) 63 are identical to that used
re 2 provides a pictorial of the HI-
ask is engineered with polyurethane
on each side.

METHODOLOGY

As mandated by Transport Regulations [5], the HI-STAR 63 package is subjected to a sequence of hypothetical accident conditions. The objective is to determine and assess the cumulative damage sustained by the package. The accident

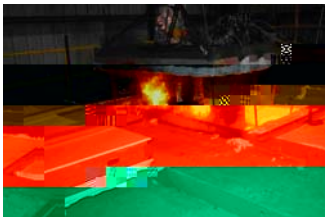
unyielding surface; (ii) a 40-inch drop onto a mild steel bar; (iii) exposure to a 30-minute fire at 800^{o}C (1472 F) and (iv) immersion under a 3 ft head of water. The initial conditions for

were spot welded to the cask body using nickel strips, the cask body was re-painted with high-temperature paint.

The furnace test was conducted at Southwest Research Institute (SwRI). The information from the test is used to determine the thermal environment the cask experienced during the test, the spatial and temporal distribution of temperatures within the cask, and the ability of the cask to maintain containment following the test. To conduct the test, the unit was first thermally conditioned by allowing it to sit in an insulated temperature conditioning box for approximately 20 hours. The temperature of the conditioning chamber was

Open furnace ready for cask

Furnace closed



Cask being removed from furnace

Cask in cool-down area

Fire from foam burning almost out

Figure 3. Sequence of High-Temperature Furnace Test

THERMAL MODEL

A thermal transient simulation model to determine the fire condition temperature response is developed on the FLUENT CFD code [6]. This model incorporates time dependent thermal loads on the exposed surfaces of the HI-STAR 63 System for determining transient responses of the 1/3 scale HI-STAR 63 cask.

Numerical simulations are carried out using FLUENT to predict the thermal behavior of the cask components during fire (furnace test) and post-fire conditions (cask cool down). The HI-STAR 63 package 1/3-scale tests are utilized to demonstrate the validity of the CFD analysis approach by comparing the FLUENT predictions against the experimentally measured test data i.e. closure lid temperatures at the elevation of the seal. Critical information such as the furnace temperature, duration of fire and ambient temperature are obtained from the tests.

The HI-STAR 63 1/3-scale package is a cylindrical container equipped with an impact limiter to simulate the scaled weight and dimensions of the HI-STAR 63 package. A geometrically accurate three-dimensional half-symmetric representation of the 1/3-scale HI-STAR 63 package was constructed using the FLUENT pre-processor GAMBIT [6]. An isometric view of the model is presented in Figure 4. The dynamic model features several conservative assumptions to bound temperature excursions during the heat up and cooldown phases of the accident. An overview of the principal features of the 3D thermal model is provided in the following:

i. The basket assembly is a hollow cylinder placed in the cask to simulate the basket mass during the tests.
ii. The 1/3 scale HI-STAR 63 containment baseplate, closure lid and containment shell are explicitly included in the 3D model.
iii. The 1/3 scale HI-STAR 63 package is heated to an initial temperature of 92^{o}C (198^{o}F). All the cask components are at 92^{o}C (198^{o}F) prior to beginning the furnace test.
iv. To evaluate the hot furnace condition, an external ambient temperature of 809^{o}C (1488^{o}F) is applied to simulate the furnace temperature during the fire test. The temperature of the furnace during the furnace test was conservatively higher than the minimum regulatory requirement of 800^{o}

test data are well within the temperature limit of 204°C (400°F). In conclusion, simulation results of the 1/3-scale HI-STAR 63 tests provide additional assurance of the capability of the CFD methodology deployed to evaluate the thermal performance of the HI-STAR 63 package.