FABRICATION & TESTING OF THE TN-FSV TRANSPORT CASK

G. V. Guerra

Transnuclear, Inc., Four Skyline Drive, Hawthorne, NY 10532, USA

SUMMARY

Transnuclear has designed, tested, licensed and supplied two Type B(U)F packages designated the TN-FSV transport casks. These legal weight casks were specifically developed for the transport of canistered High Temperature Gas Cooled Reactor (HTGR) spent fuel. The spent fuel is from the Fort St. Vrain Nuclear Plant and presently stored in canisters at the Public Service of Colorado (PSC) ISFSI. These casks were licensed in June 1994 by the US Nuclear Regulatory Commission and delivered to PSC in June 1995.

The cask is a right circular cylinder, fabricated from lead and stainless steel with a maximum loaded weight of 25 US tons (22.7 tonne), including wood-filled impact limiters attached at both ends of the cylindrical body. The TN-FSV is designed to accommodate a payload consisting of a fully loaded fuel storage canister containing the Fort St. Vrain fuel. The fabrication sequence and functional/acceptance testing of the casks are discussed below.

To assure that the TN-FSV meets all regulatory requirements, Transnuclear designed and implemented a comprehensive test program to complement the design and certification analyses. Static and dynamic testing were performed on one-half scale models of the impact limiters. Details of the testing are presented in this paper.

CASK DESCRIPTION

The basic components of the TN-FSV are the cask body, closure lid, and impact limiters. The overall dimensions of the cask are 247 inches (627 cm) long and 78 inches (198 cm) in diameter with the impact limiter installed. The cask is 207 inches (526 cm) long and 30.88 (78 cm) inches in diameter except at the lid end where the diameter is 31 inches (79 cm). The cask body is made of two concentric stainless steel shells welded to a forged bottom plate and a forged top closure flange. The annular space between the inner and outer shells is filled with lead. The closure lid is a stainless steel plate that is fully recessed into the cask top flange. The lid is fastened to the cask body by twelve one-inch (25 mm) diameter bolts. The lid contains double silicone O-rings for sealing, and is equipped with a leak test port between the seals. A vent port (in the lid) and a drain port (in the cask bottom) are sealed with single silicone O-rings and cover plates. The cask cavity has a length of 199 inches (505 cm). The top 7.12 inches (18 cm) of the cavity has a diameter of 20.83 inches (53 cm) and the remaining, a diameter of 18 inches 46 cm). The cask body is covered with a stainless steel thermal shield composed of a stainless steel shell over a wire wrap. Bolted to each end of the cask are impact limiters constructed from balsa wood and redwood encased in stainless steel enclosures. The cask body has two lifting sockets bolted to the cask top flange. Two rear trunnions are provided for cask rotation and tie-down. The maximum gross weight of the loaded cask is 50,000 pounds (22,686 kg) including a maximum payload of 5,000 pounds (2,269 kg). The general arrangement of the TN-FSV is depicted in Figure 1.

The payload is six HTGR fuel elements stacked vertically in a carbon steel canister. The lid of the canister contains a depleted uranium plug for shielding. The canister has metallic seals and provides a confinement function.

The fuel elements consist of graphite blocks containing fuel rods and coolant passages. The rods contain the nuclear fuel in the form of micro-spheres of either thorium/uranium carbide (fissile particles) or thorium carbide. (fertile particles). The uranium is enriched to 93% U-235. The maximum burnup per fuel element is 70,000 MWD/MTU.

FABRICATION

The cask was fabricated by procuring forgings/plates for the inner shell, outer shell, top closure flange, the bottom closure, lid plate, thermal shield shell and the trunnions. The inner and outer shell forgings were received pre-machined with extra stock at the ends for weld preparation. The following manufacturing sequence was used:

- Machine cask bottom closure including weld prep, drain hole and lead pour holes.
- Machine flange closure including weld prep.
- Machine weld preps for inner and outer shells.
- Machine trunnion cutout in outer shell and weld trunnions. Inspect welds.
- Machine trunnion cutouts for the outer shell.
- Weld outer shell to flange closure and inspect weld.
- Weld inner shell to bottom closure and inspect weld.
- Weld outer shell/flange closure assembly to inner shell/bottom closure assembly and inspect welds.
- Pour lead in annulus.
- Weld lead pour hole closure.
- Final machine cask body including flange region (bolt holes, etc.) and bottom closure.
- Final machine cask lid.
- Assemble/install lifting sockets, bolts, vent and drain port quick disconnects, port covers, impact limiters, etc.

ACCEPTANCE TESTING

In order to demonstrate that the TN-FSV cask would perform as designed, Transnuclear required the fabricator to perform a comprehensive list of acceptance tests. This testing is in addition to the NDE testing required by the ASME Code for the cask material and the welds. The following acceptance testing was performed:

Hydrostatic test. The cask cavities was hydrostatically tested in accordance with the requirements of the ASME Code to a pressure of 45 psig (3.1 bar) for a period of ten minutes. No visible leakage and no pressure drop was observed during the duration of the test.

Shielding test. The shielding integrity of the sidewalls of the casks were verified by the performance of a gamma scanning test. The results of the testing demonstrated that the sidewalls provided the minimum shielding required including the lack of significant voids in the lead filled annulus of the cask body.

Seal leakage test. The containment seals for the lid, and the vent and drain ports were leak tested in accordance with the requirements of ANSI N14.5 and an acceptance criteria of 1×10^{-3} std cc/sec air. The testing was performed using a helium mass spectrometer.

Thermal shield shell leakage test. To ensure that the thermal shield is properly seal welded to the outer shell of the cask body, the fabricator was required to perform a bubble leak test on the seal welds. The acceptance criterion was no detection of bubbles by visual examination.

Lifting socket load test. The cask is maneuvered using the lifting sockets located at the flange region of the cask. The lifting sockets were loaded tested to 1.5 times the design load of 50,000 pounds (22,686 kg) to comply with ANSI N14.6 requirements and examined for defects and permanent deformation.

Assembled cask weight test. Each cask was fully assembled and the weight recorded with impact limiters installed. The acceptance criterion was a weight limit of 44,000 pounds (19,964 kg).

Cask-canister fitup test. The fabricator was supplied with an empty fuel storage canister to perform this test. The canister was lowered into each cask and the lid installed to demonstrate that the cask cavity will accommodate the canister without interference or damage to the canister or the cask.

Cask assembly/disassembly test. The complete cycle of cask assembly and disassembly was performed to verify that the lid, impact limiters, penetration covers, and all fittings can be installed and removed without interference, damage or unusual observations.

Cask-trailer fitup test. Transnuclear supplied the fabricator with a custom built trailer for each cask. The trailer is designed to tiedown and support the cask during road transport. At the front end of the trailer is a saddle that supports the front end of the cask. At the rear end of the trailer are two pedestals that engage the rear cask trunnions and support/tiedown the cask. The fitup test consisted of lifting a cask (without impact limiters) and installing it on the trailer. Each cask was rotated from the horizontal to the vertical orientation on the rear pedestals to demonstrate cask handling on the trailer. The support/tiedown system of the trailer and cask was examined for damage and potential interference during the test.

IMPACT LIMITER TESTING

The TN-FSV casks are provided with front and rear impact limiters. Six 1.12 inch (28 mm) diameter bolts bolt the impact limiter to the cask. These impact limiters are constructed of balsa wood and redwood encased in sealed stainless steel shells. The impact limiter has steel gussets, which form compartments for containing the energy absorbing wood. The combination of the outer shell and internal gussets provide structural rigidity during normal transport and wood confinement during hypothetical drop accident conditions.

Transnuclear used a proprietary computer code, ADOC, to predict the deformation of the impact limiters, the force on the cask and the cask deceleration during hypothetical accident conditions. By analysis, the worst two orientations were selected for the impact limiter tests, the 0-15 degree side drop and the 80-degree crush angles. The 0-degree side drop has the highest transverse g loading at the center of gravity. In an impact at this orientation, each impact limiter must absorb 50% of the total kinetic energy of the drop. However, during a shallow angle (slapdown) side drop, the two limiters do not equally share the energy absorbed. Computer analysis bounded the maximum energy to be absorbed at 68% for the impact limiter hitting second in a 15-degree side drop. The 80-degree angle was selected because it had high axial g loading, and higher than expected impact limiter deformations than the end drop. A single impact limiter for the 80-degree corner drop must absorb 100% of the kinetic energy of the cask, which is very nearly a CG over corner drop.

A series of bounding static and dynamic tests were performed on half-scale models of the impact limiters to validate the force deflection curve predicted by the computer code for the impact analysis. In addition, the tests were required to demonstrate that the impact limiters do not "bottom out", verify the adequacy of the impact limiter attachment bolts, and the adequacy of the containment of the wood by the impact limiter enclosure.

Static Crush Tests

Static testing was performed at two bounding crush orientations, the side crush (0-degree) and the 80-degree crush. Two steel test fixtures (see Figures 2a and 2b) representing mock ups of the cask end were fabricated to orient the impact limiter in the required angle for each crush test. A half-scale impact limiter was installed on the test fixture using half-scale impact limiter attachment bolts. The testing was performed using a compression testing machine capable of generating much more than the required crush load. During testing the loading surface was maintained perpendicular to the direction of crushing and the test fixture was restrained from shifting during loading. The deformation of the impact limiter was measured continuously during the test using a linear potentiometer mounted to the testing machine. The crush force versus the vertical movement of the test plate was recorded continuously on an X-Y plotter.

The side crush was continued until five of the six attachment bolts failed. The point at which the bolts failed, 81% of the drop energy was absorbed by the impact limiter. This was well beyond the energy calculated for either the 30-foot (9.1 m) side drop (50% of the drop energy) or the slapdown (68% of the drop energy).

At the completion of the crush testing, one segment of the impact limiter was cut open and the wood removed and examined. It was noted that the glue joints between the individual pieces of wood in the blocks did not fail as the wood crushed.

Dynamic Drop Tests

The 30-foot (9.1 m) drop tests were performed at low temperature to demonstrate the adequacy of the impact limiter enclosure and the attachment bolts. The unyielding drop surface consisted of a two inch thick steel plate secured to the surface of a concrete pad weighting more than 250,000 pounds (113,430 kg). The test model was a solid steel half-scale mockup of the cask body with impact limiters. The steel body was designed to scale the weight and the center of gravity of the package. The drop orientations selected were the 15-degree slapdown and the 80-degree corner drop (see Figure 3a and 3b). The slapdown down orientation would put the highest stresses on the attachment bolts, and it was the orientation for which the highest impact force was expected for the side-drop orientation. The impact limiter that impacted second was chilled to –20 degrees F (-29 degrees C).

The two drop tests were performed without any unusual observations. The impact limiters contained the wood during the drop tests, and none of the attachment bolts failed. The crush depths did not result in lockup of the wood in the limiters.

REFERENCES

ASME Boiler and Pressure Vessel Code. 1989 Edition with addenda through 1991.

Leakage Tests on Packages for Shipment of Radioactive Materials. ANSI N14.5.

Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds or More. ANSI N14.6.

U.S. Nuclear Regulatory Commission Certificate of Compliance No. 9253. Docket No. 71-9253. June 15, 1994.

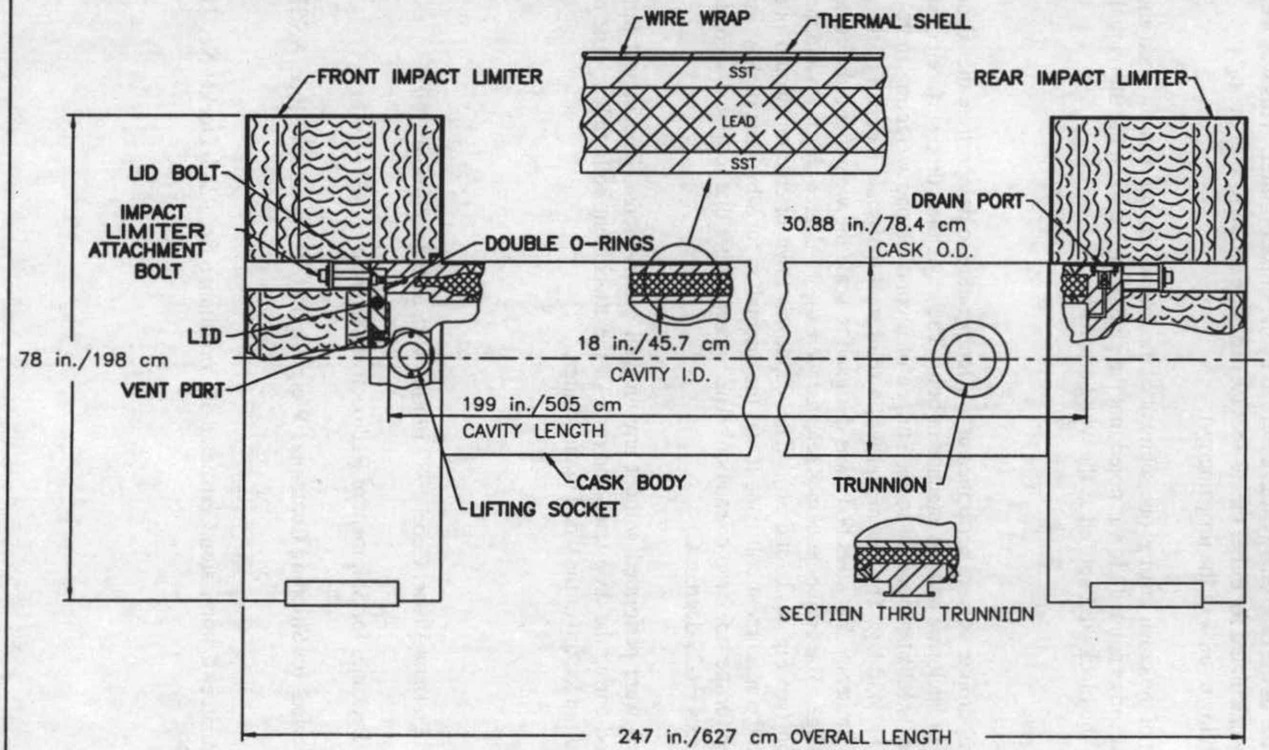
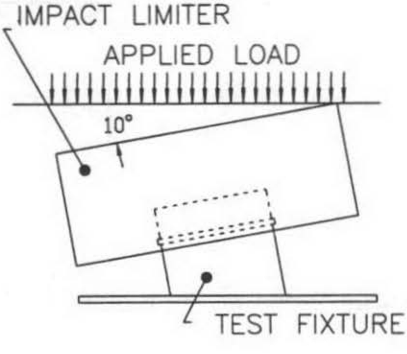
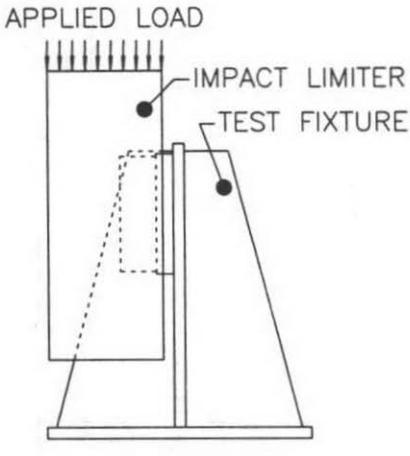


FIGURE 1 TN-FSV CASK



CORNER CRUSH TEST CONFIGURATION

(a)



SIDE CRUSH TEST CONFIGURATION

(b)

FIGURE 2 STATIC CRUSH TESTS

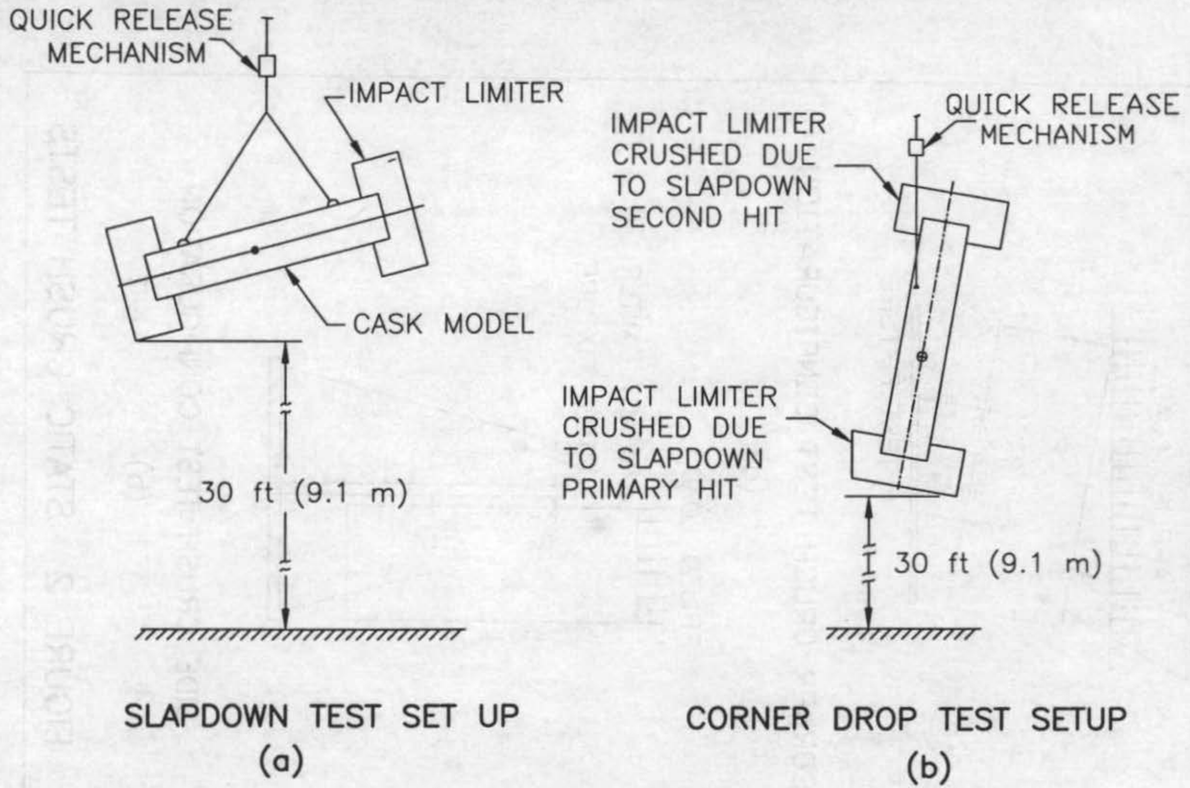


FIGURE 3 DROP TESTS

1044

SESSION 13.1

Radiation and Environmental Impact