Ontario Hydro Roadrunner Transportation Package System

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INTRODUCTION

Ontario Hydro operates 20 heavy water moderated CANDU (CANada Deuterium Uranium) reactors with a total generating capacity of 15 GWe. Periodically, highly active reactor components such as flux detectors, liquid zone control rods, and fuel channel assemblies are removed for replacement or research/testing purposes. These components are transported to Ontario Hydro's radioactive waste facilities for storage or Chalk River Laboratories of Atomic Energy of Canada Limited (AECL-CRL) for testing. Ontario Hydro's engineering staff has designed, developed, and tested a new transportation package named "Roadrunner" for such shipments (see Figure 1).

The Roadrunner package is designed to meet the Type B(U) requirements of the 1985 Edition of the International Atomic Energy Agency (IAEA) Regulations (IAEA 1990). The engineering approach taken was to demonstrate that the Roadrunner package meets the requirements under tested and accident conditions of transport through analysis of predicted performance of the package and by performing drop and leakage rate tests on a scale model.

PAYLOAD DESCRIPTION

The Roadrunner is currently being licensed in Canada to transport dry, solid radioactive materials contained within a specially designed liner. The maximum combined weight of the liner and its contents is 4,000 lb, with a maximum decay heat of 600 W. It is, however, conservatively assumed in the design that 1 liter of water will be hypothetically present.

DESCRIPTION OF TRANSPORTATION PACKAGE SYSTEM

The Roadrunner Transportation System consists of the container, impact limiters, tiedowns, transport trailer, and lifting beams as shown in Figure 2 . The container consists of the cask body with a shield lid and containment plate bolted at each end. The container cavity is cylindrical and houses a basket with a rectangular cavity. The customized rectangular

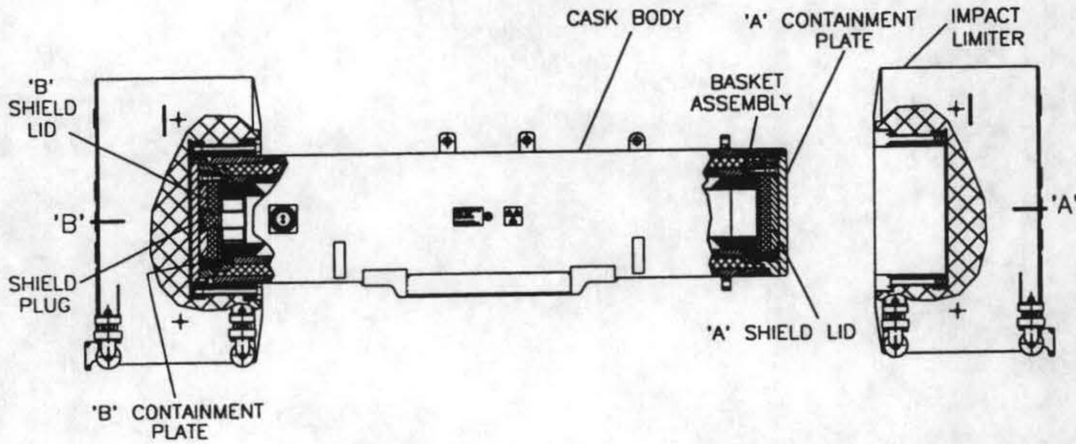

Figure 1. Roadrunner Transportation Package General Arrangement

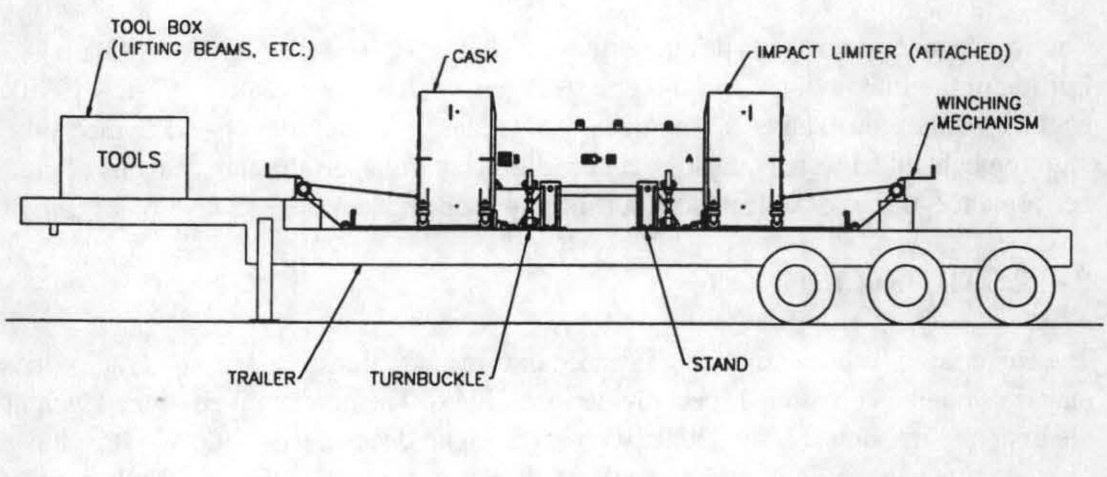

Figure 2. Roadrunner Transportation Package Trailer-tiedown arrangement

liner fits into the rectangular cavity. The gross package mass is 50,400 lb or 25 tons.

During normal operation the impact limiters will remain on the dedicated transport trailer. The container alone is removed from the trailer for loading or unloading of the radioactive contents. The cask body and the containment plates provide containment of the radioactive material and will limit radioactivity leakage to within the regulatory limits.

A dry transfer system is designed for unloading the Roadrunner at the hot cell facilities of AECL-CRL. It consists of a lead-shielded interface module mounted on a trolley and a pushing mechanism. The pushing mechanism is a pneumatically operated rodless cylinder that engages a ram to push the contents out of the Roadrunner cavity, through the interface module, and into the hot cell for further handling and testing.

The Roadrunner can also be rotated to a vertical orientation and unloaded at Ontario Hydro.'s radioactive waste storage facilities. A special adapter is used to link up the bottom of the package to the opening of an existing in-ground storage container, for the transfer of the payload.

The cask body

The Roadrunner cask body provides thermal and mechanical protection for the radioactive contents. The cask body is made of 2-inch-thick inner and outer shells of 304L stainless steel, with an outside diameter of 32 inches and an inside diameter of 18.5 inches. Between the shells are five depleted uranium castings. The mating faces of the depleted uranium castings are stepped to prevent radiation streaming. The overall length of the cask body is 147-1/4 inches.

Three lifting lugs, four tiedown lugs, and a pair of trunnions are welded/bolted to the cask body. The lifting lugs and trunnions are used for the horizontal and vertical lifting of the package, and the tiedown lugs are used for the attachment of the tiedown turnbuckles.

Shield lids

The shield lids provide the primary radiation shielding at the package ends. Each lid is composed of a 2-3/4-inch-thick depleted uranium casting within a 2-3/4-inch 304L stainless steel housing. The lid has two hollow vent/drain sleeves which provide alignment during attachment to the cask body and also facilitate draining/venting of the container cavity.

One of the shield lids is equipped with a central removable shield plug (access port plug) that provides access to the container cavity for the insertion of payload-handling tools.

Containment plates

The containment plates and seals provide supplementary shielding and prevent radioactive leakage of the payload. Two leak test ports, located on the exterior face of the containment plate, are used to test two silicone rubber o-rings, held in dovetail-type grooves on the underside of the plate flange. The volume between the containment seal (inner seal) and the outer seal can be pressurized (for a pressure-holding test) or evacuated (for a helium leak test) through the inter-seal port. For helium leak-testing, an o-ring is fitted into a circumferential groove incorporated into the lower step of the containment plate, to create a bore seal. Helium can then be introduced between the bore-seal and containment seal via the containment port. This eliminates the need to fill the entire cavity of the container with helium. All o-rings have an operating temperature range from -100^{o} to 500^{o}F.

Impact limiters

Cup-shaped impact limiters provide thermal and impact protection for the container and its contents during normal, tested, and accident conditions. The limiters are 72.0 inches in outer diameter and 42.0 inches long, with the outer shell constructed of 1/2-inch-thick 304L stainless steel plate (3/4 inches thick at the flat bottom end of the "cup"). The cavity of the "cup" is filled with rigid polyurethane foam of density = 19.6 lb/ft^3.

Each impact limiter is fastened to the container using six 16-inch-long, 1.25-7UNC Nitronic 60 cap screws. The limiters are supported by four adjustable-height v-grooved caster units that run on rails mounted on the transport trailer.

STRUCTURAL ASSESSMENT

Conventional stress calculations were performed on the Roadrunner package under normal and tested conditions. Finite element analyses and a series of 1/2 scale model drop tests were used to assess the response of the package during accident impact conditions.

The computer code H3DMAP, a general purpose three-dimensional structural analysis code developed, benchmarked, and verified at Ontario Hydro's Research Laboratories (Ontario HydroTechnologies), was used for the impact analyses.

The drop tests were performed at Ontario Hydro's Wesleyville Impact Test Facility. The unyielding target surface was constructed of a 12' x 12' x 6" steel plate, mounted to a reinforced concrete chimney foundation. A total of five drop tests were performed to test the impact response of the Roadrunner, of which three are described below:

1. (a)9-m flat side drop

The flat side drop (see Figure 3) subjected the model to a deceleration of 250 g. The impact limiters deformed upon impact to absorb some of the impact energy. The model rebounded upwards from the target plate and rotated slightly before re-impacting the target plate several times with decreasing force until it came to rest. There was no significant crushing of the sides of the impact limiters. Minor splitting of the top corner welds of the impact limiters was observed.

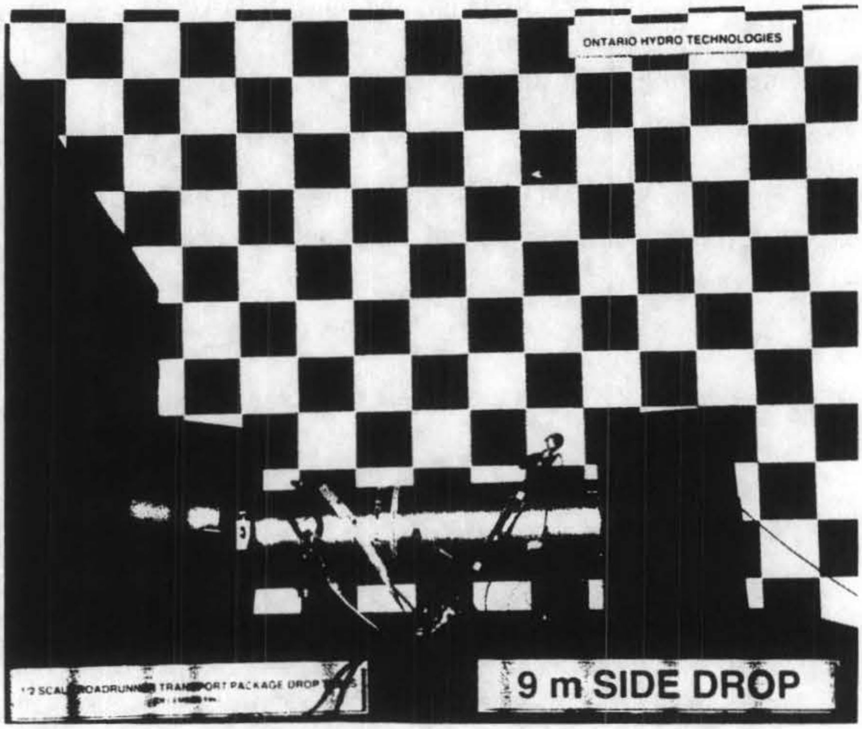

Figure 3. 9-m side drop impact test
(showing 1/2 scale model immediately following the test)

(b)9-m flat end drop

The flat end drop subjected the model to a deceleration of 275 g. The model hit the target and rebounded approximately 1 m. Some rotation of the model was observed during the rebound. Incidentally, the model came to rest in an upright position on the end of the impact limiter. There was no damage to the model, but there was a general bending downwards of the top surface of the impact limiter. Some weld tearing was found at the bottom of the recess of the impact limiter at the container-impact limiter interface.

(c)1-m flat side drop with centre of gravity over pin

The flat side drop onto the pin following the 9-m end drop subjected the model to a deceleration of 125 g. The model struck the pin squarely, rebounded, rotated slightly about its longitudinal axis, and impacted the pin a second time. The model then fell sideways off the pin and came to rest. There was only a minor surface mark on the model showing the initial impact location, and the target pin was slightly bent from the impacts.

2. Post-drop helium leakage & gamma scan tests

Helium leakage and gamma scan tests were performed on the Roadrunner model after all five impact tests were completed. Leak rates of less than 1.2×10^{-7} std cc/sec were measured, which is well below the allowable leak rate. The gamma scan test indicated that the model passed the acceptance criteria for shielding effectiveness.

3. Finite element impact simulation

The H3DMAP computer code impact response results of the 1/2 and 1/4 finite element models (see Figure 4) indicate that the structural integrity of the Roadrunner design is maintained during the drops and, in general, the simulation results agree well with the drop test results.

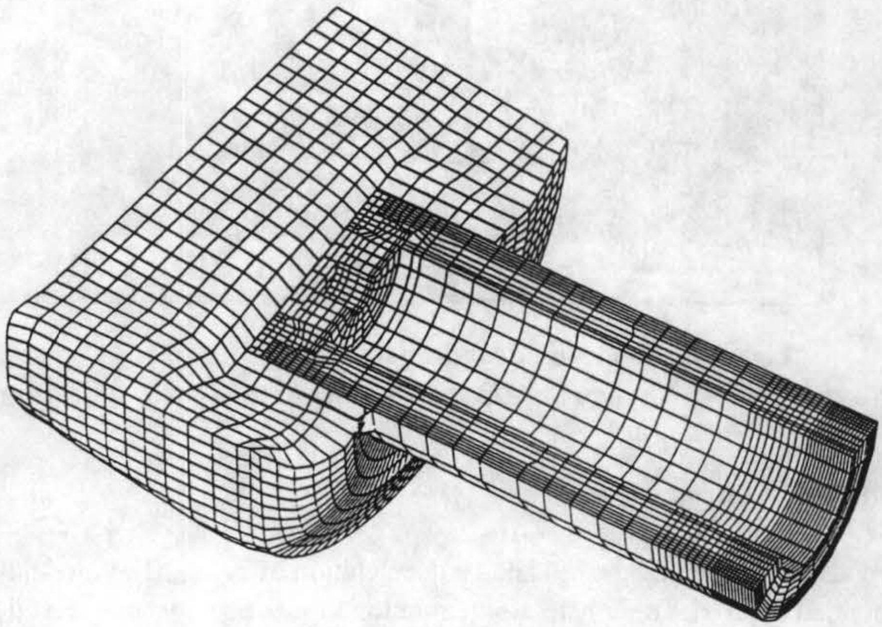

Figure 4. Deformed finite element mesh (Time = 35 ms) (simulating 9-m side drop of the Roadrunner Package)

THERMAL ANALYSIS

Thermal analyses of the Roadrunner package under normal and fire accident conditions were performed by using two in-house, 3-D, finite element/difference computer codes, i.e., H3DTAP and FD-HEAT. The analysis results are shown in Table 1 below and indicate that the maximum temperatures reached during normal and accident conditions are well within the working temperature of the stainless steel, depleted uranium, and solid silicon rubber used in the construction of the Roadrunner package.

The thermal stresses on the package were calculated using the H3DMAP program. The maximum thermal stresses occurred at the outer surface of the cask body near the end of the half-hour fire, with a maximum von Mises stress of 102 ksi (702 MPa). These stresses are considered self-limiting due to localized yielding. Thermal distortions of the containment lid area appear to be negligible, hence the sealing integrity of the package will be maintained throughout the postulated half-hour fire.

TABLE 1. Thermal Analysis Results

	Normal Conditions	Accident Conditions	Cooldown Analysis
Max Seal Temperature (^{0}F)	226	228	293
Max Containment Cavity (Air) Temp. (^{0}F)	311	477	543
Max Temperature of DU Castings (^{0}F)	360	651	500
Max Container Outer Surface Temp. (^{0}F)	194	1182	484
Outer Surface Temp of Impact Limiter (^{0}F)	194	1472	354

RADIATION LEVELS/SHIELDING

The maximum external dose rates on contact and at 3 feet (1 m) during normal conditions have been calculated to be 176 and 3.2 mrem/hr, respectively. During accident conditions at 3 feet (1 m), it is 3.2 mrem/hr. The finite element analyses of the package response to accident conditions, combined with the results of the scale model testing, confirm that the integrity of the shielding will not be compromised under accident conditions.

MANUFACTURING

Fabrication of the Roadrunner package started in March 1994 and completion was expected by December 1994. The production schedule was delayed significantly, primarily due to unforeseen difficulties encountered by the depleted uranium casting supplier. The latest estimated in-service date is April 1996.

REFERENCES

Regulations for the Safe Transport of Radioactive Material 1985 Edition (As Amended 1990), IAEA, Safety Series 6, Vienna, 1990.