Ontario Hydro
Radioactive Filter Transport Packages

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Ontario Hydro

INTRODUCTION

Ontario Hydro operates 18 heavy water moderated reactors generating 13.2 GW of electrical power. For purification of the heavy water used in the moderator and heat transport systems, particulate filters and IX columns are used. After the filters and IX columns are spent, they need to be transported to the Radioactive Waste Storage Site for storage until disposal some time in the future. Ontario Hydro, during maintenance and reactor rehabilitation, also produces radioactive reactor components such as pressure tubes and shut off rod segments which need to be shipped to AECL CRNL or WNRE for research and testing. Ontario Hydro has designed, developed and tested a new transportation package (the Radioactive Filter Transport Package) for such shipments. (See figure 1.)

This paper describes design details of the new package and its evolution from a previously developed transport package for transportation of tritiated heavy water. A discussion of changes and refinements in package design is presented. This is followed with a discussion on regulatory compliance. And finally, an account of the manufacturing and quality assurance programs is presented.

To streamline the design process and to provide some interchangeability, the new package is developed based on the Tritiated Heavy Water Transportation Package, (designed and licensed by Ontario Hydro for shipment of tritiated heavy water). This "next generation" package is refined to incorporate new features including separate containment and a more efficient closure system. This package is better suited for current operational requirements and is easier to operate and maintain. It also incorporates access for improved operational quality assurance including pressure test ports, etc.

The new package design has been physically tested under accident conditions using scaled models in accordance with the transport regulations. Leak tightness was demonstrated as per regulatory requirements. The package was also analyzed under impact accident conditions using the finite element analysis program DYNA3D. A verification case was run using the Ontario Hydro developed H3DMAP finite element program. The results of these analyses show very close correlation to the actual test data.

The package is licensed by the Atomic Energy Control Board of Canada as a type B(U) transport package. A fleet of three packages and road transport trailers has been procured. The packaging systems have been in-service since July 1992.

PACKAGE DESCRIPTION

The Radioactive Filter Transportation Package consists of the payload, foam dunnage, containment vessel and the overpack, as shown in figure 1. A shielded in-station flask is designated as part of the payload when carrying radioactive filters, disposable IX columns, pressure tube samples and other highly active reactor components. The overpack forms the outer packaging and houses the containment vessel, which in turn houses the dunnage and the shielded in-station flask.

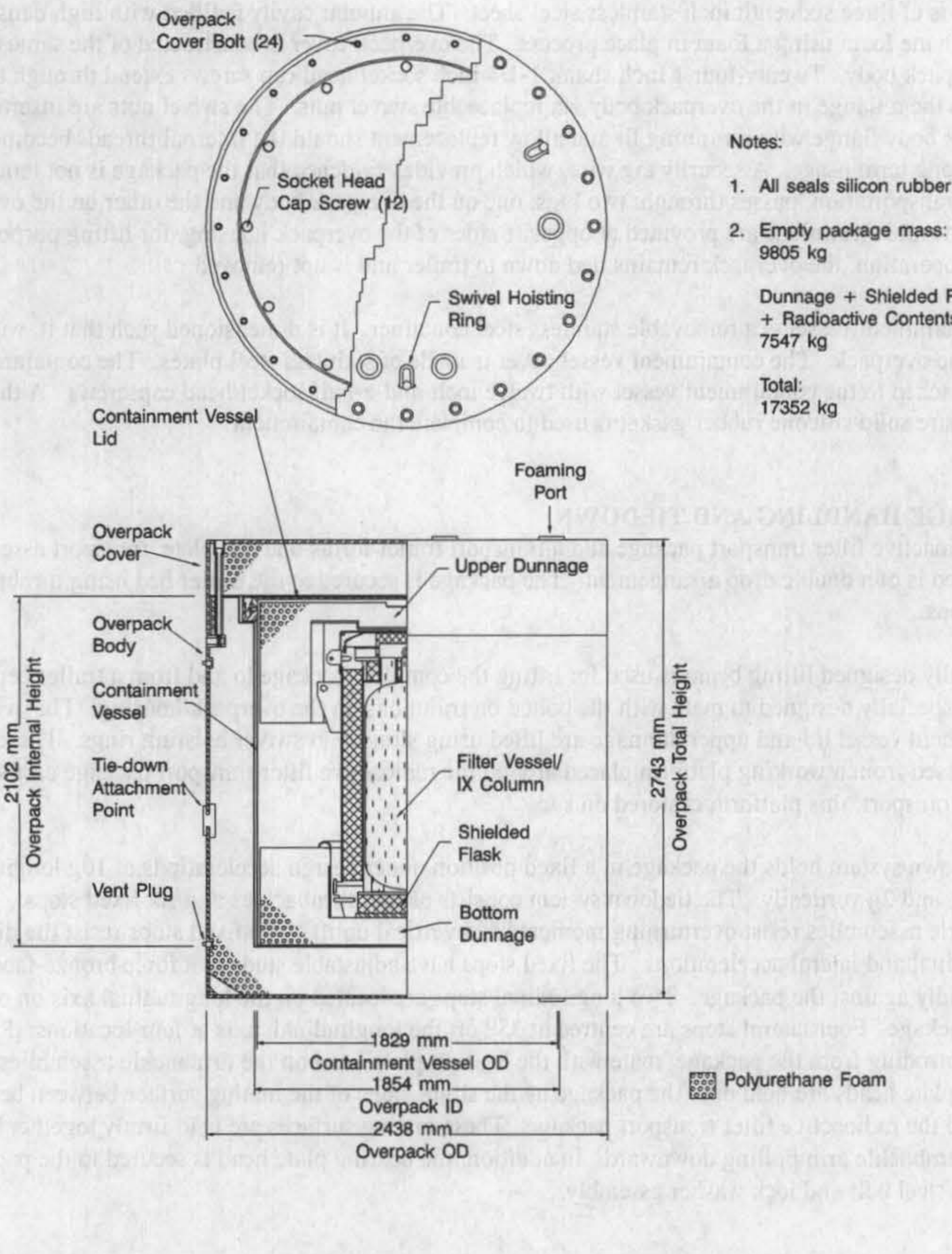

Figure 1
Radioactive Filter Transportation Package

The overpack for the Radioactive Filter Transportation Package is a stainless steel clad, polyurethane foam right cylinder. It is designed to provide thermal and impact protection for the containment vessel during normal, tested and accident conditions. The containment vessel (with its lid) provides containment for the radioactive material and will limit leakage of the radioactive contents to within the regulatory limits under tested and accident conditions of transport.

The overpack measures eight feet diameter by nine feet high with an empty weight of approximately eighteen thousand pounds. The inner cavity measures seventy-three inches diameter by eighty two and three quarter inch high. The outer housing is fabricated of three quarter inch thick stainless steel sheet and the inner housing is of three sixteenth inch stainless steel sheet. The annular cavity is filled with high density polyurethane foam using a foam in place process. The overpack cover is constructed of the same materials as the overpack body. Twenty-four 1 inch shank 1-1/4 inch socket head cap screws extend through the cover and bolt into the a flange in the overpack body via replaceable swivel nuts. The swivel nuts are inserted in the overpack body flange with a running fit and allow replacement should the internal threads become stripped during long term usage. A security tag wire, which provides evidence that the package is not tampered with during transportation, passes through two lugs; one on the overpack body and the other on the overpack cover. Two removable trunnions are provided at opposite sides of the overpack housing, for lifting purposes. During normal operation, the overpack remains tied down to trailer and is not removed.

The containment vessel is a removable stainless steel container. It is dimensioned such that it will fit snugly inside the overpack. The containment vessel cover is made of stainless steel plates. The containment vessel lid is attached to the containment vessel with twelve inch-and-a-half socket head capscrews. A three quarter inch square solid silicone rubber gasket is used to complete the containment.

PACKAGE HANDLING AND TIEDOWN

One radioactive filter transport package and a transport trailer forms one complete transport assembly. The trailer bed is of a double drop arrangement. The package is secured to the trailer bed using turnbuckles and fixed stops.

A specially designed lifting beam is used for lifting the complete package to and from a trailer bed. The lifting beam is specially designed to mate with the bolted on trunnions on the overpack housing. The overpack cover, containment vessel lid and upper dunnage are lifted using slings and swivel hoisting rings. These components are accessed from a working platform placed around the radioactive filter transport package on the trailer. During transport, this platform is stored on site.

The tiedown system holds the package in a fixed position under design accelerations of 10g longitudinally, 5g laterally, and 2g vertically. The tiedown system consists of four turnbuckles and six fixed stops. The turnbuckle assemblies resist overturning moments and vertical uplift. The fixed stops resist the direct longitudinal and lateral accelerations. The fixed stops have adjustable studs that force bronze-faced bearing pads solidly against the package. Two longitudinal stops are located on the longitudinal axis on opposite sides of the package. Four lateral stops are centred at 35^{o} off the longitudinal axis at four locations. Plates, 3/4 in. thick protruding from the package, mate with the bearing plate head on the turnbuckle assemblies. The bearing plate heads are held onto the package by the slight slope of the mating surface between bearing plate head and the radioactive filter transport package. These mating surfaces are held firmly together by the torque on the turnbuckle arm pulling downward. In addition, the bearing plate head is secured to the package with stainless steel bolt and lock washer assembly.

DESIGN CONSIDERATIONS

When the packages used for the transportation of the radioactive filters (the Modified Super Tiger Overpack) were downgraded from type B to type A transportation packages by the USNRC, Ontario Hydro was without a fully licensed transportation package for the shipment of radioactive filters and IX columns. Some shipments of the IX columns and filters were made with the Modified Super Tiger Overpack under special arrangement certificate with special precautionary measures. Other transportation packages were adapted for use for other shipments. However, it was found that a specialized package is required for efficient operations.

Ontario Hydro started by surveying the field for off-the-shelf type B transportation package for such tasks. No licensed package with suitable capacity was found. It was then decided that a transportation package would be designed in house for these purposes. As Ontario Hydro had just completed design and licensed a transportation package for the shipment of bulk tritiated heavy water and the tritiated heavy water transportation package was assessed to have suitable payload cavity size, it was decided that the radioactive filters package design would be evolved from the tritiated heavy water transportation package design. Using an existing licensed design as a basis, development and licensing were deemed to be less costly and eliminate most uncertainties.

While the detailed design for the radioactive filter transportation package was in progress, it was found that several improvements on the basic design for the tritiated heavy water package could be made. These improvements would make the package easier to operate and maintain, easier to manufacture and more versatile. The improvements were incorporated into the design of the Radioactive Filter Transportation Packages. The improvements include a cleaner outer profile for easier decontamination; easier manufacturing by elimination of thick C-channel sections of the tritiated heavy water transportation package; fewer and longer bolts for closure of the overpack; and incorporation of a unique lid/body overlap design to provide extra shear resistance during drop tests. Removable swivel nuts were incorporated for the overpack bolts which will overcome the problem of repair of stripped or worn female threads. A separated containment vessel was evolved to minimize transfer of impact strains to the containment sealing surface/closure to ensure leak tightness of the containment vessel during accident conditions.

IMPACT TESTING

To support the type B license application, scale model 9 metre drop tests were performed to demonstrate compliance of the Radioactive Filter Transportation Package during accident conditions. Two quarter scale models were built with simulated payloads. Flat end, side and C. of G. over top and bottom edges (corners) drop tests were performed at Ontario Hydro Research. Post drop leakage tests were performed to demonstrate the leak tightness of the package after the mechanical drop tests. No increase in leakage rates from the models were found after the drop tests, signifying that the Radioactive Filter Transportation Package was structurally capable of protecting its content during accident condition impact tests.

STRUCTURAL ANALYSIS

To check and validate the design of the Radioactive Filter Transportation Package and to ensure that the scale model testing would be successful, normal engineering calculations were performed during the design stage for sizing of components and to show that the package will pass all normal condition tests. Structural Impact Analysis were performed for the punch drop and 9 metre drop tests using DYNA3D and later verified by H3DMAP, an Ontario Hydro written large deflection structural finite element analysis software package.

The analytical results indicate that the structural integrity of the Radioactive Filter Transportation Package design is maintained during the 9 metre drop tests for the side drop , top end drop and the corner drops. Analysis results demonstrate that the payload is well protected and no deformation of the seal area for the containment vessel is expected thereby assuring the intactness of the sealing surfaces.

Comparison of the analysis results with experiments show excellent agreement between analytical predictions and experimental results. A corner profile plot (figure 2) of overpack from the analyses closely matched the measured deformed profile of the scale model.

Although physical tests were performed for licensing purposes, structural analyses were performed to assist in final detailing of the package design and provide assurance that the design is adequate. Analyses also provide a means of checking the stress/strain levels in various parts of the package and assist in future design refinements. The Ontario Hydro developed H3DMAP program is written in FORTRAN 77 and the latest version can be ported to PCs. Runs had been made on 386s.

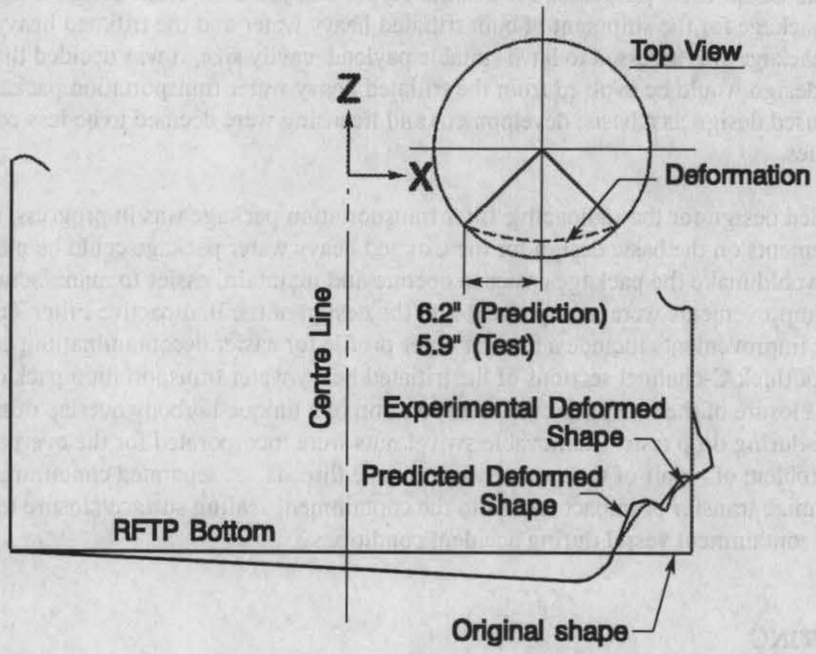

Figure 2 - Comparison of predicted and experimental RFTP Deformation

THERMAL ANALYSIS

As the Radioactive Filter Transportation Package is built with stainless steel and high density polyurethane foam, the same materials used in the tritiated heavy water transportation package and with almost identical physical dimensions, no independent testing was performed. The insulating material used (polyurethane foam) has such superb insulating properties that protecting the payload from fire is not a problem as had been demonstrated in the tritiated heavy water transportation package. As the decay heat of the radioactive filter transportation package payload is slightly higher, heat transfer calculations were performed to demonstrate that the temperature in the package will not adversely affect the package performance and will not affect the sealing capability of the containment. Assuming a maximum decay heat of 50 Watts and with the package outside with an ambient temperature at 38°C and insolation for a period of 60 days, the normal operating temperature of the payload is at approximately 120°C. The seal temperature is approximately at 115°C. Figure 3 and figure 4 show the temperature profile of the various parts of the package during the insolation test and fire test. The fire test will increase the payload and seal temperature by less than 10°C to 126°C. With silicon rubber gaskets, the sealing capability is not adversely affected by the thermal tests.

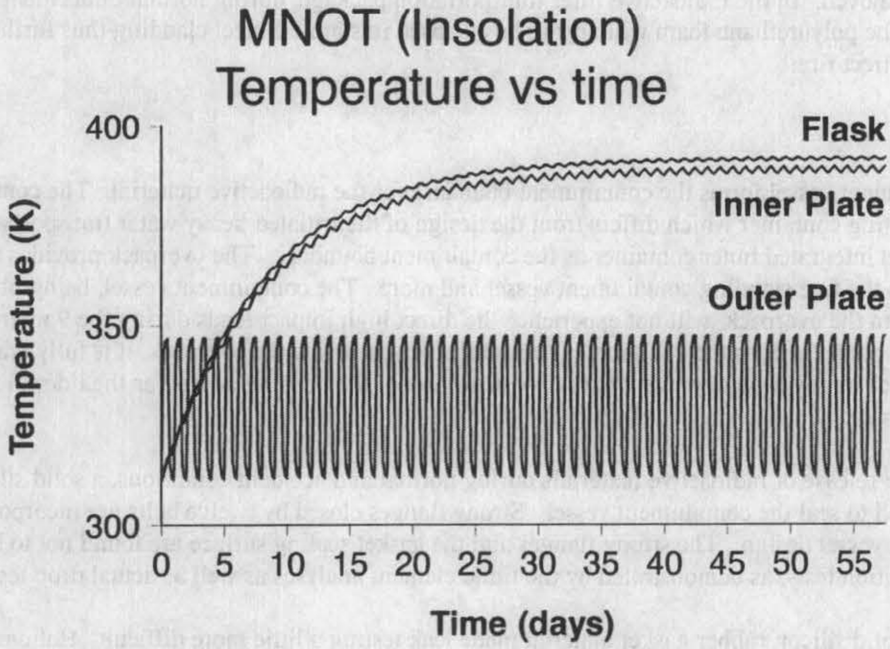

Figure 3 - Normal Operation Temperature - Insolation

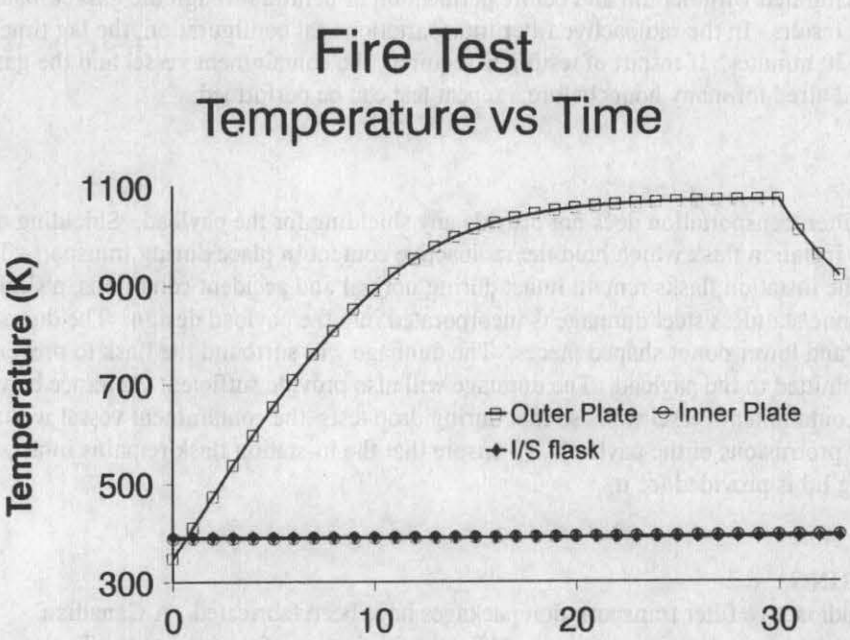

Figure 4 - Fire test

During the design and development of the tritiated heavy water transportation package, a specially formulated high density polyurethane foam was developed for specific use in the package. Fire retardants were included in the formulation to ensure extinguishing properties in the foam. Testing showed that the polyurethane foam, even when exposed directly to fire, only chars (with slow pyrolytic dissociation) and will self extinguish when the fire is removed. In the radioactive filter transportation package, during normal or accident operation conditions, the polyurethane foam will always be enclosed in stainless steel cladding thus further protecting the foam from direct fire.

SEALING

The containment vessel forms the containment boundary for the radioactive material. The containment vessel is a free floating container which differs from the design of the tritiated heavy water transportation package which has an integrated inner container as the containment boundary. The overpack provides the same kind of protection to the free standing containment vessel and more. The containment vessel, being physically detached from the overpack, will not experience the direct high impact loads during the 9 metre accident drop tests. At the same time, as the containment vessel fits snugly inside the overpack, it is fully cradled by the foam overpack at any time to prevent excessive distortion of the housing as well as the lid/seal areas due to impact stresses.

To minimize release of radioactive materials during normal and accident conditions, a solid silicon rubber gasket is used to seal the containment vessel. Strong flanges closed by twelve bolts are incorporated onto the containment vessel design. The strong flanges and the gasket sealing surface are found not to be disturbed by impact condition tests, as demonstrated by the finite element analyses as well as actual drop tests.

The use of solid silicon rubber gasket material made leak testing a little more difficult. Helium leak tests were performed to demonstrate leak tightness of the sealing surface. Unfortunately, the permeation rate of helium through silicon rubber is quite high. Thus the helium leak test must be performed quickly, before the silicon rubber gasket is saturated with helium and before permeation of helium through the gasket material started to influence the test results. In the radioactive filter transportation seal configuration, the lag time for permeation is approximately 30 minutes. If restart of testing is required, the containment vessel and the gasket have to be pumped down and aired for many hours before a repeat test can be performed.

SHIELDING

The radioactive filter transportation does not provide any shielding for the payload. Shielding of the payload is provided by an instation flask which hold the radioactive content in place during transport. To ensure that the shielding of the instation flasks remain intact during normal and accident conditions, a slightly lower density polyurethane/stainless steel dunnage is incorporated into the payload design. The dunnage is in the form of an upper and lower donut shaped pieces. The dunnage will surround the flask to prevent excessive forces being transmitted to the payload. The dunnage will also provide sufficient clearance between the payload and the containment vessel walls so that during drop tests, the containment vessel will not be punctured by any protrusions of the payload. To ensure that the in-station flask remains intact, a special newly designed shipping lid is provided for it.

MANUFACTURING

A total of three radioactive filter transportation packages have been fabricated. A Canadian (CSA Z299.2)quality assurance program was used for the fabrication of the packages. To ensure that the manufactured package closely matched specifications, an initiation meeting with all the personnel involved in the fabrication of the transport package was held before start of any work. Explanations of the design intent and the design details and the important dimensions and tolerances were carefully explained to manufacturing personnel. The end results are packages that were built closely to the approved design.

Frequent visits and progress meetings were held with the manufacturer, whenever any deviation from design was noted, as engineering evaluation were made before proceeding.

With the experience of building six tritiated heavy water transportation packages, a lot of potential manufacturing problems were avoided. The fabrication process went according to plan. No real difficulties were encountered during fabrication.

Placement of the polyurethane foam in the package is a special process that required the most attention. Prior to the actual foaming, realizing that the polyurethane foam is an extremely important ingredient of the design, special test runs were made and quality assurance procedures were established to ensure quality results. Special non-destructive testing procedures were developed to demonstrate the soundness of the pours. Special repair procedures in case voids were found were also developed prior to the actual pour.

OPERATION AND MAINTENANCE

The Radioactive Filter Transportation Packages and their respective trailers were delivered to site and commissioned in July 1992. Transportation of radioactive components has been started and proceeded without any difficulties. Prior to every shipment, a special pressure test is performed to assure that the containment seals are properly closed.

CONCLUSION

The Radioactive Filter Transportation Packages have been successfully designed and developed as a type B(U) transportation packages. The RFTPs are the newest in a fleet of type B transportation packages for Ontario Hydro for the shipment of Radioactive Filters, IX columns, and other miscellaneous highly active components including pressure tube segments, shut off rods and others. In the future, with some design modification, the RFTPs can also be transformed into a tritiated heavy water transportation packages if required. With the design and fabrication of the RFTP, Ontario Hydro has successfully built three new type B transportation package designs in the last five years. More new transportation packages for other specific and general use will be developed in the next several years.