LAYERED PACKAGING - A SYNERGISTIC METHOD OF TRANSPORTING RADIOACTIVE MATERIAL

Garold L. Hohmann
Idaho National Engineering Laboratory
Westinghouse Idaho Nuclear Company, Inc.

ABSTRACT

The DOE certification for a transportation cask used to ship radioactive Krypton 85 from the Idaho Chemical Processing Plant (ICPP) to the Oak Ridge National Laboratory (ORNL), was allowed to expire in 1987. The Westinghouse Idaho Nuclear Company (WINCO) was charged by DOE with modifying this cask to meet all current NRC requirements and preparing an updated Safety Analysis Report for Packaging, which would be submitted by DOE to the NRC for certification. However, an urgent need arose for ORNL to receive Krypton 85 which was in storage at the ICPP, which would not allow time to obtain certification of the modified shipping cask. WINCO elected to use a layered shipping configuration in which the gaseous Krypton 85 was placed in the uncertified, modified shipping cask to make use of its shielding and thermal insulation properties. This cask was then inserted into the Model No. 6400 (Super Tiger) packaging using a specially constructed plywood box and polyurethane foam dunnage. Structural evaluations were completed to assure the Super Tiger would provide the necessary impact, puncture, and thermal protection during maximum credible accidents. Analyses were also completed to determine the uncertified Krypton shipping cask would provide the necessary containment and shielding for up to 3.7 E + 14 Bq of Krypton 85 when packaged inside the Super Tiger. The resulting reports, based upon this layered packaging concept, were adequate to first obtain DOE certification for several restricted shipments of Krypton 85 and then NRC certification for unrestricted shipments. This methodology, which has proven successful at the Idaho National Engineering Laboratory may be used by others to alleviate shipping problems when certified casks are not available on the schedule required.

INTRODUCTION

The Department of Energy (DOE) has allowed their certifications on several transportation casks to expire over the last few years concurrent with a program to modify these casks as necessary, prepare new Safety Analysis Reports for Packaging (SARP's) and submit them for NRC certification. Such was the case for a transportation cask used to ship radioactive Krypton 85 from the Idaho Chemical Processing Plant (ICPP) to the Oak Ridge National Laboratory (ORNL). The certification for this cask expired in 1987 and the Westinghouse Idaho Nuclear Company, (WINCO) was charged with modifying the cask to meet all current NRC requirements and preparing an updated SARP. The cask was modified and a SARP prepared based on analytical evaluations and extrapolated empirical data. During preliminary reviews by DOE and their sub-contractors, it became apparent that actual testing of the modified cask to maximum probable accident conditions would be required prior to NRC certification. At the same time, an urgent need was identified by ORNL to receive Krypton 85 which was in storage at the ICPP.

Alternatives Evaluated

A trade study was conducted to evaluate three possible approaches to providing a shipping cask for the Krypton 85. The first approach was to use existing or new WINCO casks. At that time, WINCO had both a Peach Bottom cask and the Krypton 85 cask which had been modified. WINCO was also considering development of a new Krypton 85 cask designed specifically to meet all probable accident conditions. The second approach was to use a commercial cask such as the Nuclear Assurance Corporation NLI-1/2 or the GA Technologies Company, FSV-1A. The third approach was to use a government owned cask such as the Super Tiger or the Paduca Tiger.

The option of using any WINCO owned cask was infeasible as the required schedule for shipping Krypton 85 would not permit sufficient time to prepare a new SARP and obtain a Certificate of Compliance. The options of using a government owned or commercial cask were both feasible and could meet the required schedule. The final option chosen was to proceed with preparing an addition for shipping Krypton 85 to the existing SARP for the Model No. 6400 (Super-Tiger) shipping package. The Super Tiger had been previously used for shipping various radioactive materials ranging from decontaminated gloveboxes to LWBR type fuel rods.

The packaging configuration selected for analysis (1,2) was to use the existing Krypton 85 shipping cask, enclose it in a sturdy plywood box for load distribution and place the plywood box within the Super Tiger overpack. Polyurethane foam dunnage would be placed between the plywood box and the interior of the Super Tiger to provide additional impact protection and load distribution. This shipping configuration is shown in Fig. 1.

Packaging Description

The Krypton 85 is contained in a DOT 3AA cylinder equipped with a metal diaphragm valve. The cylinder has a nominal volume of 0.04 cubic meter and is authorized by DOT specification for pressures up to 13.9 mega pascal. The maximum amount of Krypton in each shipment was specified as 3.7 E + 14 Bq with an initial maximum loading pressure of 3.45 mega pascal at normal room conditions. This is approximately 1480 liters of gas at one atmosphere and 25°C. The thermal heat generation is approximately 15 watts. This cylinder is equipped with a Manifold Fabricators and Supply metal diaphragm valve rated at 6.9 mega pascal

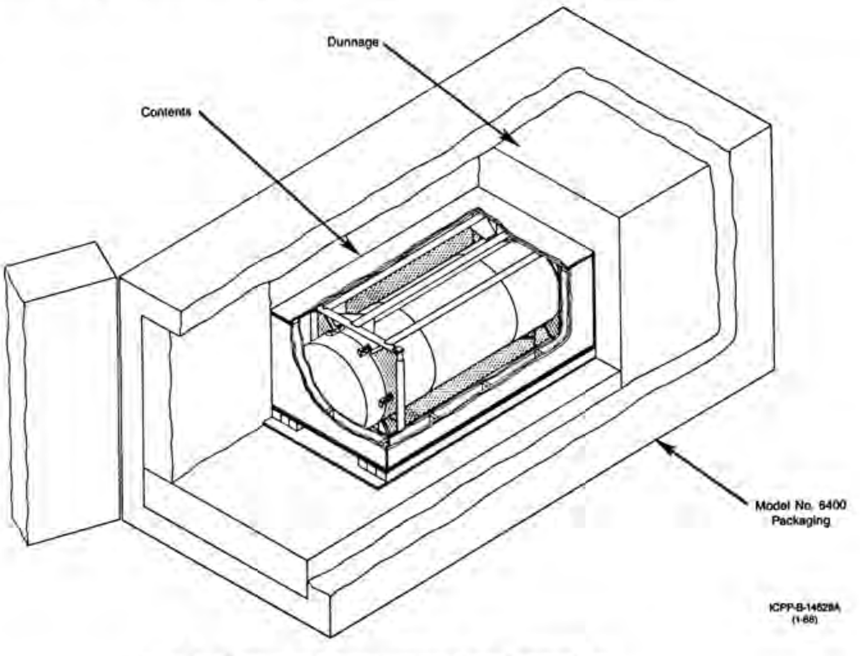

Fig. 1. Krypton-85 Shipping Configuration.

and forms the primary containment for the radioactive Krypton gas.

The primary containment cylinder is then placed in the original Krypton 85 shipping cask. Although this cask could not be conclusively shown to meet all NRC certification requirements, it does provide lead shielding, thermal insulation and an external framework which became an integral part of the final layered package. The elements of this cask are shown in Fig. 2.

Using this cask, the gas cylinder is inserted into a lead filled carbon steel shield to provide the necessary radiation shielding as shown in Fig. 3. The shield is constructed of 6.35 mm thick carbon steel with 5 cm of lead shielding on the sides and 10 cm in the top plug and the bottom base.

The shielded container is then inserted into a thermal insulation overpack. The thermal insulation is a cylindrical end-loading overpack with inner and outer casings fabricated from 16 gauge stainless steel and 7 gauge stainless steel belly bands. Four, 10 cm by 15 cm fir stringers positioned 90° apart are placed as spacers between the inner and outer casing skin and extend the entire length of the thermal insulation overpack. A 14.6 cm thick layer of Pittsburgh Corning foam-glass fills the remainder of the void between the inner and outer skins. Laminated marine plywood is used to provide end support and insulation for the closed end of the overpack. The lid uses solid fir spacers with foam-glass for insulation. Neoprene pads, 1.3 cm thick, are used in the inner shell base and in the head section to cushion the lead shield during loading and shipment.

The thermal insulation overpack is supported in a rectangular framework of 5 cm schedule 40 type 304L stainless steel pipe. This framework is welded to the bellybands of the overpack at eight locations. The framework is used as the attachment points for lifting and expanded metal mesh is tackwelded between the framework and the bellybands to assure only the appropriate lift points are used.

The Krypton 85 cask described above is snuggly enclosed in a very stout plywood box. The box is a 3.8 cm outer shell composed primarily of two 1.9 cm pieces that have been laminated together. The box encloses the contents to prevent movement and provides large flat bearing surfaces against the foam dunnage. This box is then centered within the Super Tiger cavity using foam dunnage to fill all void spaces. The foam thicknesses are 40.6 cm on the top and bottom, 29.2 cm on the sides and 93.3 cm on the ends.

The Model No. 6400 protective overpack provides physical containment, impact resistance, and thermal protection for its contents and is NRC certified. The inner shell (cavity) is approximately 1.9 meter by 1.9 meter by 4.4 meter and is constructed of 10 gauge and 4.8 mm thick mild steel. Closure of the cavity is by a 6.35 mm thick aluminum plate and silicone rubber gasket bolted to the framework of the cavity. The cavity is centered and supported in an outer 4.8 mm thick mild steel jacket by approximately 81 cm of polyurethane foam insulation at the forward end and 25 cm on the sides. A side hinged rear access door consisting of approximately 86 cm of polyurethane foam insulation encased in mild steel with a silicone rubber gasket is bolted to the main outer steel jacket during transport. The overall dimensions of the package are approximately 2.4 meter square by 6.1 meter long. Set into each corner of the outer jacket are standard steel tie down fittings.

Structural Evaluation

The Model No. 6400 packaging was designed to absorb all normal transport and hypothetical accident loads without significant deformation to the inner cavity. Impact loads are absorbed by local yielding of the ductile outer shell and the polyurethane liner material. Puncture criteria are

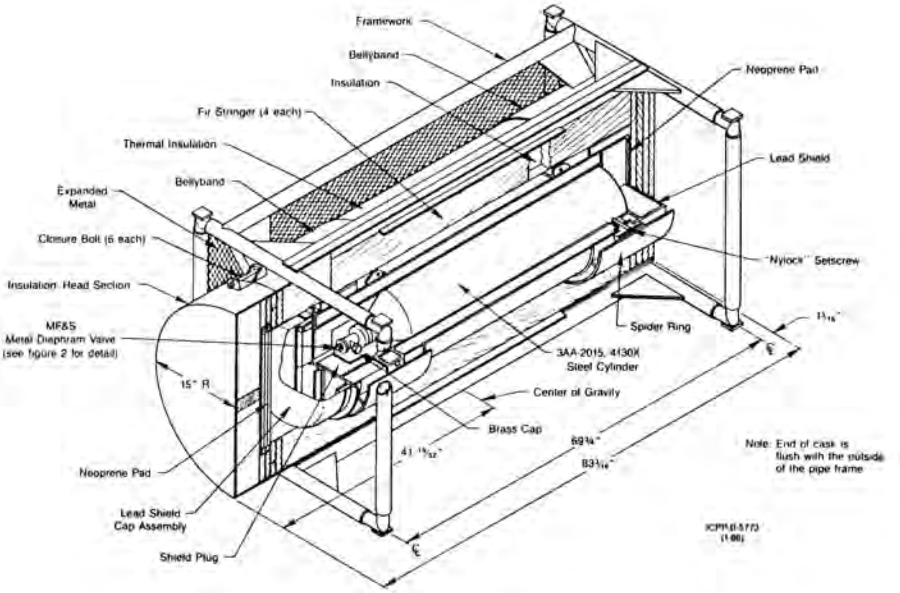

Fig. 2. Modified Krypton-85 Shipping Cask.

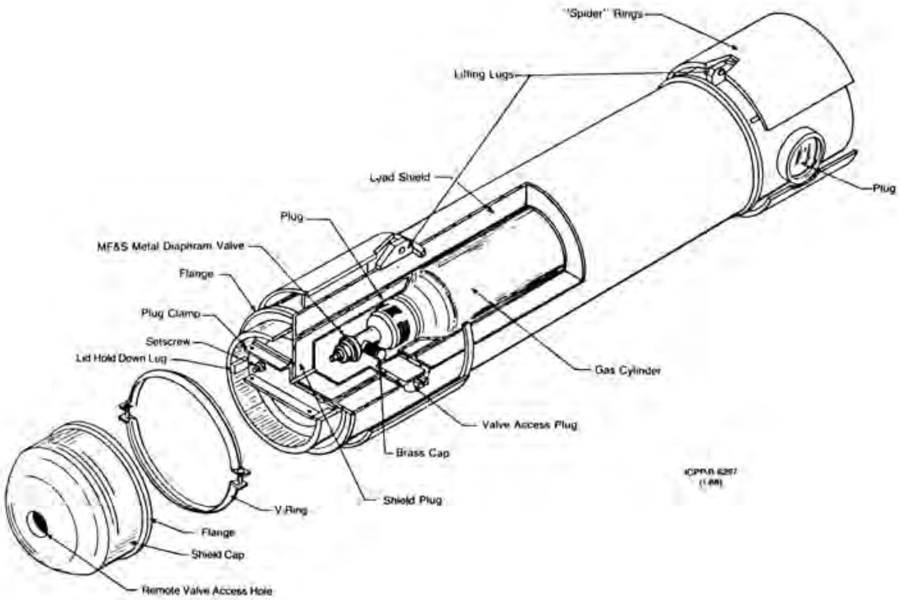

Fig. 3. Lead Shield Cutaway.

met through local ultimate failure of the outer shell and the polyurethane liner. This package has been analyzed and tested to the performance requirements of 10 CFR 71. In the Krypton 85 shipment configuration, the polyurethane foam dunnage will also absorb impact loads through compressive yield and the contents, including the plywood box, will withstand all induced impact loads without structural yield or change in geometric form. The compressive yield of the dunnage is actually sufficient to support the contents under accident induced loads such that the additional impact absorbing characteristics of the Model No. 6400 packaging chassis are not required.

For analytical purposes, the empty Model No. 6400 packaging was assumed to weigh 8,618 kg and the polyurethane foam dunnage 1,134 kg. The contents were assumed to weigh 2,948 kg for a total package weight of 12,700 kg. This is well within the allowable gross weight for the Super Tiger of 20,412 kg. However, the lighter gross weight did result in higher deceleration forces for the contents when analyzing the drop tests. The contents were loaded in the center of the Super Tiger cavity in order to maintain the same center of gravity for an empty or loaded Super Tiger.

During normal transport, the contents must survive a 0.61 meter free drop. The greatest shock load to the contents will occur during a side drop or an end drop. During these drops, the foam dunnage will be subjective to compressive yield. For an end drop, the foam dunnage will experience the maximum compression of 2.3 cm and for a bottom drop the contents will be subjected to the maximum deceleration of approximately 62g, if no credit is taken for the Model No. 6400 packaging itself.

For the hypothetical accident impact conditions, two sets of analyses were performed. The first assumed all the energy from a 9.1 meter drop test onto an unyielding surface would be absorbed by the Model No. 6400 packaging. This resulted in a maximum peak deceleration of 81g. The second assumed all the energy was absorbed by the foam dunnage. This resulted in a peak deceleration of 87g. Since the compressed gas cylinder and valve assembly has been successfully drop tested to 200g without any leaks and since the lead shield can sustain a 177g deceleration the contents can easily survive the maximum g forces imposed during the hypothetical accident condition. The puncture test will damage the exterior of the Model No. 6400 packaging, but will result in reduced deceleration forces on the contents compared to the 9.1 meter drop test.

When subjected to the hypothetical accident impact conditions, the Krypton 85 shipping configuration will sustain some damage. The Model No. 6400 packaging outer shell will deform and may rupture. The polyurethane liner will crush and possibly the inner liner will plastically deform. However, in all cases, the contents will remain protected. The lead shield will remain intact and will continue to provide radiation protection and the gas cylinder and valve will continue to provide containment for the Krypton 85 gas.

Thermal Evaluation

The thermal performance of the Krypton 85 shipping configuration was analyzed for a shipment of up to 3.7 E + 14 Bq of Krypton 85 gas contained in the DOT 3AA gas cylinder. The heat generation produced by the Krypton 85 is approximately 15 watts, which is well within the certified 30 watt limit for the Model No. 6400 packaging. The maximum temperature of the Krypton 85 gas will be about 62.2°C, and the corresponding gas pressure will be approximately 3.9 mega pascal. These are well below the Model No. 6400 design temperature of 93.3°C, and the cylinder valve limit of 6.9 mega pascal. The Super Tiger has been analyzed and experimentally tested for the required 30 minute, 802°C fire condition. The results determined that the temperature of the contents would not be raised more than 5.6°C. Therefore, the contents for the Krypton 85 shipments would be well protected without taking credit for the additional polyurethane foam used as dunnage in this configuration. This configuration was also analyzed for a low temperature shipment of -40°C, and found to be completely acceptable.

Containment

The primary containment of the Krypton 85 is a DOT 3AA-2015, 4130X steel compressed gas cylinder equipped with a Manifold Fabricators and Supply metal diaphragm valve. The cylinder is rated for 13.9 mega pascal and was tested to 15.2 mega pascal at room temperature. The valves have a pressure rating of 6.9 mega pascal and similar valves have been tested to 15.2 mega pascal. The cylinders and valves are for one-time use only and are not reused for Krypton transportation. This primary containment system has been tested to more severe conditions than for the hypothetical accident. The bare cylinder with attached valve was thermal-cycled and drop tested at a deceleration of 200 g's and remained leak tight. This is well within the 87g maximum expected during accident conditions. Likewise, the maximum pressure calculated under worst accident conditions is 4.2 mega pascal.

It should also be noted that the cylinder and valve arrangement are always contained within the lead shield when the cylinder contains Krypton. This lead shield protects the valve from any direct impacts. In addition, the primary containment will be tested for leak rate prior to shipment and must assure a leak rate less than 51.8 Bq per second.

Shielding Evaluation

A shielding evaluation was conducted using the QAD-FN point kernel shielding code. The surface of the bare cylinder was calculated to have a radiation reading of 2.3 Sv per hour. The surface of the lead shield was calculated to read 70 micro seivert per hour. This results in a reading one meter from the surface of the Super Tiger of less than 2 micro seivert per hour. These numbers are in close agreement with measured numbers for shipments of up to 2.8 E + 14 Bq of Krypton 85.

The lead shielding will maintain its configuration for loads up to 177g and 327°C. The Model No. 6400 packaging provides protection well within these limitations.

A criticality evaluation was not required since the Krypton 85 shipments will not contain any fissile material. Erroneously filling with fissile material is not possible since gaseous fissile material does not exist at the ICPP.

Operating Procedures

All activities associated with the loading, handling, and unloading of the Krypton shipments will be monitored by Operational Health Physics, Safety, and Quality Assurance personnel using established procedures and equipment to ensure personnel safety and compliance with all set requirements. The procedures for loading the gas cylinder include a helium leak test of the gas cylinder and valve a maximum of 6 months prior to loading with Krypton gas and a complete mass spectrometer analysis of the contents to identify all constituents. In addition, a leak rate test must be conducted after the cylinder is loaded to assure leak rates of less than 51.8 Bq per second.

Procedures are also prepared for installing the cylinder valve and shielding into the thermal insulation and for installing the thermal insulation into the plywood box. Additional procedures have been developed for loading the plywood box and foam dunnage into the Super Tiger and for unloading the shipment at its destination. The passive nature of the packaging, dunnage, and contents design requires no analysis of operational features since no operations during shipment are required.

Acceptance Test and Maintenance Program

A preventive maintenance program for the cylinders, valves, shielding, and thermal overpack has been developed and is monitored by Quality Assurance personnel. In addition, quality requirements have been developed which must be reviewed and attested to by Quality Assurance during the loading of Krypton 85 into the compressed gas cylinder and subsequent loading into the Model No. 6400 packaging.

CONCLUSIONS

A "Safety Analysis Report for Packaging Krypton-85 Shipment Packaging in the Super Tiger Shipping Overpack" (2), report was prepared describing and analyzing a layered packaging approach to shipment. In this approach, gaseous radioactive Krypton 85 was contained within a DOT 3AA compressed gas cylinder and valve. This cylinder was contained within a lead shield for radiation shielding. The shielded package was contained within a thermal overpack which provided thermal insulation. Initially, this entire configuration was designed to be a stand-alone shipping cask for Krypton 85. In order to expedite necessary shipments, this "Cask" was contained within a plywood box and inserted within the Model No. 6400 packaging using polyurethane foam dunnage to fill all void spaces. Based upon the descriptions and analyses presented in WIN-232, the Department of Energy was able to certify several restricted shipments of Krypton 85. The three shipments, totaling approximately 4.8 E + 14 Bq, were carried out successfully in the fall of 1987.

Early in 1988, it was determined that continued unrestricted shipments of Krypton 85 from the Idaho Chemical Processing Plant to the Oak Ridge National Laboratory would be required for the foreseeable future. A report entitled, "Evaluation of Krypton-85 Contents for Transportation in the Model No. 6400 Packaging", (1) was prepared and submitted to the Nuclear Regulatory Commission for certification of shipping Krypton 85 in a layered packaging. This certification was received on November 28, 1988 and will be used for future shipments. This methodology may be used by others to alleviate shipping problems when certified casks are not available on the schedule required. It has proven to be an expeditious means of obtaining NRC certification for radioactive shipments at the Idaho National Engineering Laboratory.

REFERENCES

1. Westinghouse Idaho Nuclear Company, Inc.,"Evaluation of Krypton-85 Contents for Transportation in the Model No. 6400 Packaging", WIN-236, Rev. 1 (March 1988).
2. Westinghouse Idaho Nuclear Company, Inc., "Safety Analysis Report for Packaging Krypton-85 Shipment Packaging in the Super Tiger Shipping Overpack", WIN-232 (1987).