THE TN-RAM - A NEW CASK FOR SHIPPING HIGH ACTIVITY IRRADIATED HARDWARE

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INTRODUCTION

In the United States the market for transportation of irradiated spent fuel is relatively small at the present time because reprocessing is not being pursued and there is as yet no repository or central storage facility to which spent fuel can be sent. However, there is a thriving market for the transport of compacted irradiated non-fuel bearing hardware. Most of these irradiated components are shipped as low level waste from BWR power stations to Barnwell, SC or Hanford, WA for disposal. Irradiated hardware differs from most low-level waste in that it has a high activity largely as a result of Co-60 which has been produced as an activation product. Because of the high activity, a Type B packaging is needed to ship this material.

Prior to 1989 the only truck casks available in the U.S. to serve this market were two rather old Type B casks which had been originally designed for shipment of certain types of spent fuel. Neither cask was particularly efficient with regard to shielding and volume for the irradiated hardware market. Therefore, in 1988 Transnuclear entered into an agreement with WasteChem Corporation, a company which processes irradiated hardware, to design, certify, procure and operate a new and efficient cask for this market. The cask which evolved from that agreement was designated the TN-RAM. This paper provides a description of the cask, the certification process, and some information on its operational experience.

PACKAGE DESCRIPTION

Specifications for the TN-RAM were developed in conjunction with WasteChem to meet demand for a high capacity packaging to serve the irradiated hardware market. It was decided that an Over-Weight Truck (OWT) cask would be required to meet this goal. Transnuclear already operated a fleet of TN-8 and TN-9 OWT casks for spent fuel, and therefore it was decided to design the TN-RAM to mate with existing lifting equipment and auxiliary equipment to minimize the investment needed. An optimization study led to the following key design parameters:

Payload: 9500 lbs (4310 kg) including the weight of secondary liner
Heat Load: 300 watts
Source Term: 2000 times the A2 quantity for Co-60, 14,000 Curies (5.18E14 Bequerels)

With these parameters set, intensive design efforts got under way in the spring of 1988.

A schematic of the cask is shown in Figure 1. The TN-RAM transport cask has the configuration of a right circular cylinder. It is fabricated from lead and stainless steel, with wood-filled impact limiters attached at both ends. The lead and steel construction of the lid, walls, and bottom provides a shielding effectiveness of 7.1 inches (18 cm) lead equivalent. The overall dimensions of the packaging are 178.12 inches (452 cm) long and 91.75 inches (233 cm) in diameter with the impact limiters installed. The cask is 129.38 inches (329 cm) long and 52.00 inches (132 cm) in diameter. The cask cavity has a length of 111 inches (282 cm) and a diameter of 35 inches (89 cm).

The basic components of the TN-RAM packaging are the cask body, closure lid, lid bolts, and impact limiters. The cask body consists of the cylindrical shell assembly and bottom assembly. The closure lid is attached to the cask body with sixteen 1.5 inch (3.81 cm) diameter bolts. Six trunnions are welded to the cask body with four located at 90° intervals near the lid end and two located with a 180° spacing near the bottom end. Two penetrations into the containment are provided to support cask operations. One is located in the lid and one is located in the cask body near the bottom end. The maximum gross weight of the loaded package is 80,000 pounds (36,288 kg) including payload. The TN-RAM is transported horizontally on a dedicated trailer with the lid end facing the tractor. During transport, the packaging is supported in a transport cradle by two top and two bottom trunnions.

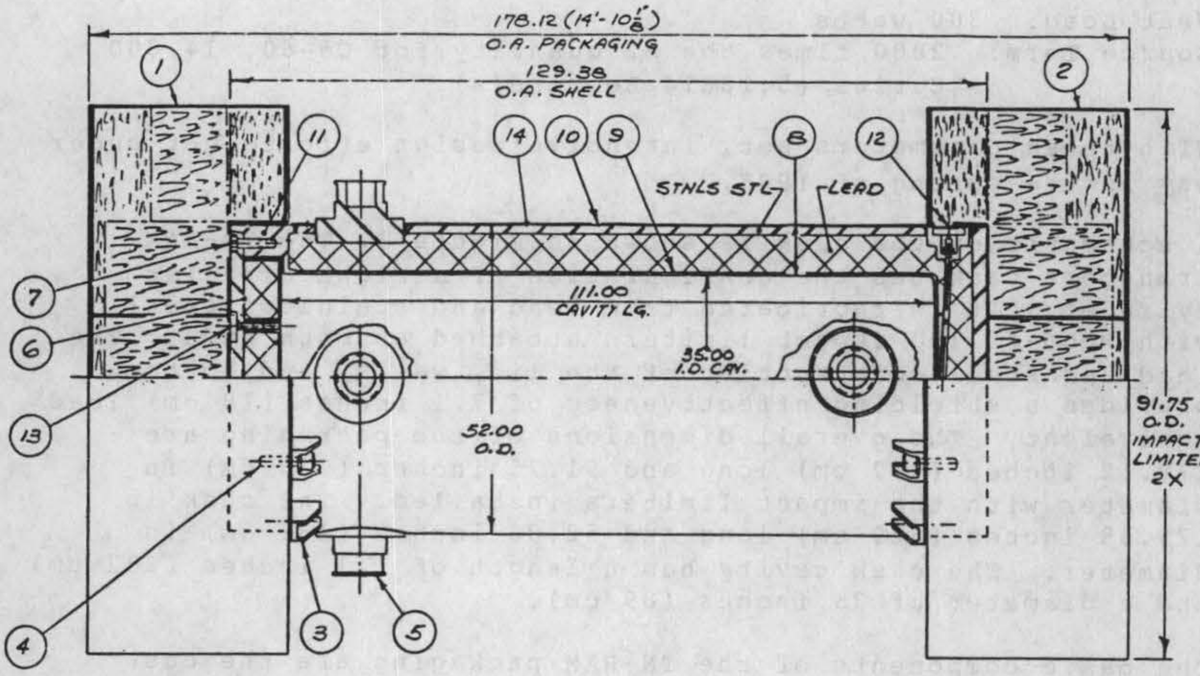
Table 1 summarizes the materials of construction used in the TN-RAM. The following sections provide a physical and functional description of each major component.

Cask Body

The cask body consists of two concentric stainless steel shells for the sidewall and two parallel stainless steel flat

FIGURE 1

TN-RAM PACKAGING



ITEM NO.	**DESCRIPTION**
1	Upper (front) Impact Limiter
2	Lower (rear) Impact Limiter
3	Impact Limiter Attachment Lugs
4	Impact Limiter Attachment Bolts
5	Lifting/Tiedown Trunnions
6	Closure Lid
7	Lid Bolts
8	Cask Body
9	Inner Shell
10	Outer Shell
11	Bolting Flange
12	Drain Port
13	Vent Port
14	Thermal Barrier

Table 1
MATERIALS OF CONSTRUCTION

COMPONENT	MATERIAL
Cask Body:	
Inner Shell	ASTM A-240, Type 304
Outer Shell	ASTM A-240, Type 304
Lead Shielding	ASTM B-29
Thermal Shield	ASTM A-240, Type 304
Bolting Flange	ASTM A-182, Type F304
Impact Limiter Attachment Lugs	ASTM A-479, Type 304
Closure Lid:	
Inner Plate	ASTM A-240, Type 304
Outer Plate	ASTM A-240, Type 304
Lead Shielding	ASTM B-29
Closure Bolts	ASTM A-564, Type 630
Impact Limiters:	
Energy Absorbing Material	Balsa and Redwood
External Shell and Structure	ASTM A-240, Type 304
Attachment Bolts	ASTM A-564, Type 630
Tiedown/Lifting Devices:	
Cask Trunnions	ASTM A-182, Grade F304

plates for the bottom, with lead between the shells and plates. A forged closure flange is welded to the lid end of the shell assembly. The outside shell is 1.50 inches (3.81 cm) thick and the outside bottom plate is 2.50 inches (6.35 cm) thick. The inner shell is 0.75 inches (1.91 cm) thick and the inner bottom plate is 0.50 inches (1.27 cm) thick.

The annular region between the inner and outer shells is filled with lead. The lead shielding thickness in the cask bottom is 6.06 inches (15.39 cm). All structural welds in the shell assembly including containment boundary welds are full penetration welds.

Attachments and subassemblies associated with the cask body include:

- Lifting and tiedown trunnions
- Impact limiter attachment lugs
- Cask body drain penetration.

Closure Lid

The closure lid consists of two parallel flat plates separated by lead shielding. The outer plate is 2.50 inches (6.35 cm) thick and the inner plate is 0.50 inches (1.27 cm) thick. The outer plate forms the lid portion of the containment boundary. The lead shielding between the two plates is 6.06 inches (15.39 cm) thick. The lid flange has 16 equally spaced holes for the closure bolts which are located on a 45 inch (114.3 cm) diameter bolt circle. The closure bolts are nominally 1.5 inch diameter. Two concentric dovetail seal grooves are machined in the underside of the lid. Silicone O-rings are installed in these seal grooves. A leak test port provides access to the region between the two seals for assembly verification leak testing conducted prior to every transport. The leak test port is closed by a threaded plug. The inner O-ring provides a containment boundary function. The outer O-ring is provided to facilitate the leak testing procedure.

Two 1.032 inch (2.62 cm) diameter holes are located at the diameter of the closure bolt circle. These holes correspond to the guide pins mounted in the closure flange of the cask body. The asymmetric location of the guide pins and lid holes ensure that the closure lid is always installed in the same orientation with respect to the cask body. Alignment marks on the lid and cask body provide positive indication to operations personnel for lid installation.

The lid is recessed into the cask body so that the outside surface of the lid is flush with the rim of the shell closure flange extending beyond the sealing surface. This recessed lid design prevents external lateral forces from acting directly on the edge of the lid. The double-step arrangement at the lid-to-body interface also provides a barrier to radiation streaming.

Impact Limiters

Top and bottom impact limiters are provided for the TN-RAM packaging during transport. Each impact limiter is attached to the cask by eight 1.75 inch (4.45 cm) diameter bolts. The bolts are attached between lugs, which are welded to the outer shell of the cask, and bolt bosses, which are integral to the impact limiter structure. The impact limiters are constructed of balsa wood and redwood, encased in hermetically sealed stainless steel shells to maintain the wood in a dry atmosphere. Each impact limiter has one cylindrical and twelve radial steel gussets which form compartments for containing the energy absorbing wood. The combination of outer shell and internal gussets provides structural rigidity during normal transport and wood confinement during crushing caused by hypothetical accident drop conditions.

Each impact limiter has nine fusible plugs which are designed to melt during a fire accident and thereby limit pressure build-up in the shell due to vaporization of moisture in the wood. Each impact limiter also has two lifting lugs for handling and two support angles for placing the impact limiters in a vertical storage position during cask loading/unloading operations. The lifting lugs and support angles are welded to the outer cylindrical steel shells. The impact limiters are installed and removed while the cask is horizontal.

Lifting and Tiedown Devices

Six single piece trunnions are welded to the outer shell of the cask body. Four of the trunnions are identical and are located near the lid end of the cask at 90° intervals around the cask body circumference. Either opposing pair or all four trunnions may be used for vertical cask lifting. One trunnion pair is sufficient for lifting the fully loaded package. The second trunnion pair may be used with redundant lifting devices. One pair of top trunnions is located on approximately the same plane as another trunnion pair attached near the bottom of the cask. In addition to the lifting function, one pair of top trunnions is used for tiedown during transport and for lifting and rotating the cask in the transport frame between horizontal and vertical. The bottom trunnions are used for rotation between horizontal and vertical and for tiedown during transport. Horizontal lifting can be accomplished by using a lift fixture attached to the bottom trunnions and the corresponding pair of top trunnions.

Thermal Shield

The outer shell of the cask body is covered by a stainless steel thermal shield. A 0.125 inch (0.32 cm) diameter wire is wrapped around the cask body. A 0.25 inch (0.64 cm) stainless steel plate is welded to the cask body over the wire wrapping. The wire and outer plate combination provide an air gap which impedes conductive heat transfer. The effect of this insulating air gap is considered in the analysis of decay heat dissipation from the payload and for the analysis of packaging heating from external sources such as insolation and the thermal accident environment. The thermal shield does not extend to the lid or bottom regions since the impact limiters serve as insulators at these locations.

Penetrations

There are two penetrations through the containment boundary which are used during loading operations. The 1.084 inch (2.75 cm) diameter straight penetration in the lid is designated as the vent port. The vent port is normally closed by a blind flange which is secured to the lid with three long socket head cap screws. The penetration cover is recessed into the outer plate of the lid so that the outer surfaces are flush. A lead-filled stainless steel tube is attached to the underside of the penetration to maintain the shielding effectiveness at the penetration location. A single silicone O-ring is mounted in a dovetail groove machined in the underside of the penetration cover. Leak testing of the penetration is accomplished using a vacuum bell.

The penetration located near the bottom of the cask body is designated as the drain port. Access to this penetration is located on the side of the cask body near the bottom plate. A double-wall stainless steel tube extends from the access location, through the lead of the bottom assembly, and through the inner bottom plate of the cask cavity. The inner tube serves a containment boundary function. The inner tube is located within an outer tube. The drain tube layout between the exterior access location and the cavity interior includes two 90° bends. The double-wall arrangement and 90° bends accommodate thermal expansion of the inner tube in the event that temperature differences develop during operations involving the drain port. The drain port permits draining of the cask cavity with the TN-RAM in a vertical orientation. A Hansen quick connect coupling is provided at this penetration. A blind flange which maintains the containment boundary at this point is secured over the drain port by three bolts. A single O-ring is located in the seal groove machined in the penetration cover. Leak testing of this penetration is also accomplished using a vacuum bell.

CASK CERTIFICATION AND FABRICATION

Because of market needs, it was decided by WasteChem and Transnuclear early in the TN-RAM project that the cask would need to be available before the end of 1989. With less than eighteen months between project initiation and the target completion date, the luxury of taking a low risk route of certification followed by fabrication was not an option. We elected to proceed on a fast track basis with fabrication carried out in parallel with NRC certification review.

This high risk strategy for fabrication necessitated a low risk approach to design and certification. The approach had two essential characteristics:

- The design must be conservative and adhere strictly to previously certified materials, concepts and safety analyses. In short, no innovation.

- Early meetings were held with the NRC staff to present design and analyses and to determine quickly where changes would be needed.

A first meeting was held with the NRC in February of 1988 to present our conceptual design. Following this meeting intensive design was initiated. A Safety Analysis Report (SAR) was completed and submitted to the NRC on November 22, 1988. In December of 1988 Transnuclear placed a contract for fabrication of the TN-RAM as designed and presented to the NRC.

Review of our design by the NRC proceeded much as we had anticipated. However, as in almost every review, at least one unpleasant surprise is encountered. In the case of the TN-RAM the surprise came in mid review after cask materials had been procured and fabrication was underway. We were informed by the NRC that the static elastic modulus of lead, which had been used by the nuclear industry worldwide for decades, would no longer be acceptable for analyzing the effects of lead slump in hypothetical drop accidents. Instead the dynamic modulus must be used, and this is two orders of magnitude below the static value. This turned out to be a costly change because it was necessary to halt fabrication, re-analyze the cask drop accidents, and change the inner shell thickness. Our efforts to redesign in order to meet the new requirement were successful, although it meant we had to scrap a partially fabricated inner shell. As bad as this was, had the change occurred several weeks later after fit up had been completed and lead poured, it would have been catastrophic - we would have had to scrap the cask and start over.

Despite the problems described above, the NRC completed its review of the cask and approved it on September 30, 1989, only ten months after the SAR was submitted. In October of 1989 the cask and its trailer were delivered to Transnuclear, and in November the first shipment was made in this new cask.

CASK OPERATIONS

There are no complex operational features associated with the TN-RAM. The packaging is designed to accomodate wet or dry vertical or horizontal operations. Cask handling can be accomplished with either pair of opposing top trunnions, or with all four top trunnions if redundancy is required. For horizontal loading/unloading operations, the cask is left in the transport cradle. Significant design features which support wet operations include self-draining bolt holes in the cask body closure flange, two penetrations for draining/drying activities, and smooth stainless steel surfaces to minimize decontamination efforts. For in-pool cask loading, cavity draining and drying is performed in order to ensure that free liquids do not remain in the package during transport.

For routine shipments of irradiated hardware, the compacted material is loaded into a special liner at a utility storage pool. This liner is then loaded into the cask underwater in a vertical orientation. When the cask is delivered to one of the low level disposal sites, it is unloaded dry in the horizontal configuration. Special lid handling equipment and a run-out tray are utilized for this dry unloading.

Since the TN-RAM was put in service, it has been utilized to make 22 shipments from seven different nuclear stations. Many more shipments are scheduled in the immediate future as utilities increasingly try to clean out their spent fuel pools in the most efficient way possible.

PACKAGING TECHNOLOGY

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