Emergency Response Packaging: A Conceptual Outline*

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INTRODUCTION

The Packaging and Transportation Needs in the 1990's (PATN) component of the Transportation Assessment and Integration (TRAIN) program (DOE Nov. 1991) was designed to survey United States Department of Energy programs, both ongoing and planned, to identify needs for packaging and transportation services over the next decade. PATN also identified transportation elements that should be developed by the DOE Office of Environmental Restoration and Waste Management (DOE EM) Transportation Management Program (TMP). As a result of the predominant involvement of the TMP in radioactive material shipment issues and DOE EM's involvement with waste management issues, the primary focus of PATN was on waste packaging issues. However, contacts in other programs not related to waste and radioactive material shipments were also made.

Pending DOE regulations will formalize federal guidelines and regulations for transportation of hazardous and radioactive materials within the boundaries of DOE reservations and facilities. The pending requirements reflect a growing awareness of concern regarding safety environmental responsibility activities on DOE reservations. Future practices involving the transportation of radioactive material within DOE reservations will closely parallel those used for commercial and governmental transportation across the United States. This has added to the perceived need for emergency recovery packaging and emergency response features on primary packaging, for both on-site shipments and shipments between DOE facilities (off-site).

Historically, emergency response and recovery functions of packaging have not been adequately considered in packaging design and construction concepts. This paper develops the rationale for emergency response packaging, including both overpack concepts for repackaging compromised packaging and primary packaging redesign to facilitate the recovery of packages via mobile remote handling equipment. The rationale will examine concepts for determination of likely use patterns to identify types of shipments where recovery packaging may have the most favorable payoff. These concepts can lead to likely configurations of recovery packaging and their physical attributes to facilitate remote recovery and handling, as needed.

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CHARACTERISTICS OF RADIOACTIVE MATERIAL PACKAGING

According to the most recent estimate (Javitz et al., 1985), approximately 2.8 million packages of radioactive material (RAM) are transported annually in the U.S.A. The movement of RAM on this order of magnitude has been characteristic of the past several years in the U.S. The characteristics of these shipments can be evaluated in a number of ways, one of which would be from the viewpoint of what types of packaging are transported. Table 1 describes typical packages and their capabilities. Small or limited quantities, low specific activity (LSA), and Type A package shipments account for approximately 96 percent of the packages shipped in the U.S. In another view, approximately 90 percent of the commercial (non-government) packages transported contain 1 Curie or less of activity. With this information, it is possible to make a judgment that a significant number of low activity shipments are made and are made in packages that are not required to withstand the accident conditions of transport. When greater severity accidents occur, there can be releases from Type A or industrial packages. It is unlikely that such accidents can cause releases from Type B packages. Based on the analysis (Cashwell, 1992) of actual transport accidents, it has been observed that even Type A packages can withstand more than modest accident conditions in transport without releasing their contents. With this as a background, it is possible to determine that the most likely accident during which a release of radioactive contents might occur will involve a package that is not designed to resist accident conditions; in addition, if such an accident occurs, it is likely to be a small quantity of radioactive material in the package, namely less than an A1 or A2 amount. Therefore, the design of a recovery package to aid in the response to transport accidents involving radioactive materials should deal with the most likely situations to occur where radioactive material is released, namely Type A and lesser types of packaging.

TABLE 1

PACKAGING TYPES AND CHARACTERISTICS

Package Type	Package Tests	Package Uses
Industrial (Strong & Tight)	Performance tested	Limited quantities, LSA materials, radiopharmaceuticals in small amounts, instruments and articles, low-level waste
Type A	Performance tested for "normal" transport or median accident	Radiopharmaceuticals, low level waste, industrial sources
Type B	Performance tested for severe accidents	Spent fuel, TRU waste, low level waste, irradiator sources

THE CHARACTERISTICS OF U.S. SHIPMENTS OF RAM

The most recent estimate of U.S. RAM shipments stated the shipping volume as being made up of two principal components: all U.S. shipments (other than DOE shipments) and DOE shipments (Javitz et al., 1985). The U.S. shipments (other than DOE) totaled approximately 2 million annual shipments, 2.8 million packages, and involved approximately 9 million curies of RAM. The DOE shipments and packages shipped involved only a small segment of the total 5090 annual shipments and 31800 packages shipped, but the total activity transported included 27.3 million curies. This means that the total of all U.S. shipments involved approximately 36.3 million curies of RAM, and DOE accounted for approximately 75 percent of this amount. This establishes USDOE as a major transporter in the U.S. on a national basis.

During FY 1990, DOE performed approximately 23460 hazardous material shipments for all classes of hazmat (DOE May 1991). On a shipment basis, DOE performed 10681 shipments of RAM involving 116,622 tons of RAM. Other hazmat shipments involved approximately 12779 shipments and 53740 tons. This means that the total of 23460 hazmat shipments involved 170362 tons of hazmat. On a percentage basis, radioactive material accounted for 45.5 percent of the USDOE hazmat shipments and 68.4 percent of the tons of USDOE hazmat transported.

TABLE 2

U.S. DOE RAM SHIPMENTS BY CATEGORY (FY 1990)

Category	Number of Shipments	Percent of RAM Shipments
Irradiated Fuel	28	0.3
Medical Research	2014	19.1
Unirradiated Fissile Material	611	5.8
Uranium Compounds	2968	28.2
Waste	859	8.1
Reactor Core Debris	6	0.1
Empty Containers	2510	23.9
Miscellaneous	1525	14.5

Table 2 displays the categories of US DOE RAM shipments. A significant number of the shipments indicated in Table 2 could involve Type B accident resistant packages. While recovery packages could be developed to support the possibility that a Type B accident resistant packaging could be involved in a release of contents, an analysis of actual RAM transport history has shown that the most likely event where a recovery packaging is needed is not for the Type B package but for the less robust class of package, the Type A or industrial package. Table 3 displays this experience for U.S. RAM transport operations. What can be observed is that the accident resistant Type B packages perform very well and have, under accident conditions in transport, released none of their contents. A total of 2030 Type A packages have been exposed to transport accident conditions: 62 of these have been damaged without release of contents and 51 sustained such damage that they released their radioactive contents. Similar experience was noted from industrial packages where a total of 1340 packages were exposed to accident conditions: 18 of these packages sustained damage due to accident conditions, and 65 of the industrial packages received sufficient damage from the accidents that they released their contents. It should be re-emphasized that Type A (or lesser quality) packages are not designed to withstand accident conditions. The question might correctly be raised as to where the radioactive protection comes from under such circumstances. The answer is that, in general, there is a very severe restriction on the magnitude of radioactive material contained in Type A or industrial packages. This limit is the A1 or A2 amount (IAEA 1990) except for LSA materials.

The category of shipments involving LSA can result in quantities of RAM in excess of A1 or A2 being in a Type A or industrial package. This occurs because LSA is limited to a specific number of curies per gram of material. The safety concept involved for LSA is that the material is so diluted in inert material that it cannot present an inhalation/ingestion problem. An evaluation was performed of the potential consequences of a severe highway transport accident involving low specific activity waste (Ostmeyer et al., 1988). The analysis involved the development of a shipment scenario which contained unconsolidated spent ion-exchange resin from a nuclear reactor facility. The scenario assumed the overturning of a trailer carrying a shipment of LSA material with spillage of 100 percent of the material. The scenario was considered to represent a credible worst case for the shipment of LSA material. Of all the LSA wastes, spent ion-exchange from nuclear facilities contains the highest activity and is the most likely to be near the specific activity limit for LSA materials in the U.S.A. The analysis reflected current shipping practice. It should be mentioned that in actual transport accidents the likely releases of radioactive materials would be orders of magnitude less than those assumed in the analysis and further, that a 100 percent release of contents would be unlikely. From (Javitz et al., 1985) it can be determined that on a package basis, approximately 96 percent of the packages transported involve Type A or lesser magnitudes of RAM.

EMERGENCY RECOVERY OF RAM PACKAGING

A fundamental question is which segment of the shipment population would public safety benefit most from development of a recovery package. Every Member State of the IAEA has its own experience to draw upon; but based on U.S. experience as shown in Table 3, it can be seen that the package classes damaged with and without release of RAM most frequently were Type A and industrial packages. There is potential for large consequence involving the public if a Type B package is involved in a transport accident. Actual experience in the U.S.A. indicates that damage requiring control and retrieval of spilled RAM has not occurred for Type B packages involved in transport accidents.

Each country can survey its own accident experience to determine what the possibility for package recovery and clean-up is. If similar to U.S. experience, it appears that clean-up and recovery operations could involve either single or multiple Type A or lesser quality packages. Larger releases would probably come from shipments of multiple Type A packages. National assessments could evaluate the forms and radionuclides involved in the accidents, but it must be recognized that it would be difficult to generalize from historical experience to predict the potential for future recovery and clean-up operations.

RECOVERY PACKAGE NEEDS

Table 4 carries the analysis of actual transport accident experience a step further and categorizes the relative need for recovery packages. The last column indicates a qualitative judgment of the need for a recovery package which emphasizes those packages which are shipped most frequently, fail most frequently and pose significant, hazards.

TABLE 3

PACKAGE BEHAVIOR DURING TRANSPORTATION ACCIDENTS
(U.S. EXPERIENCE 1971-1990)

Package Category	No. of Accidents	No. of Packages in Accidents	No. of Packages Damaged	No. of Packages Failed
Industrial (Strong-Tight)	43	1340	18	65
Type A	159	2030	62	51
Type B	50	84	2	0
Totals	252	3454	82	116

TABLE 4

RELATIVE IMPORTANCE OF RECOVERY PACKAGES

RAM Material Type	Pkg. Type	Direct Radiation Hazard/if released	Ingestion/ Inhalation Hazard/if released	Likelihood of Pkg. Failure in Accident	No. of Shipments	Recovery package Importance
Limited Quantities	Industrial	None	Low to none	High	High	Low
Radiopharm.	Type A	Low/Mod.	Low to mod.	Medium	High	High
Industrial Use	Type A	Moderate	Low	Medium	Modest	Medium
Industrial Use	Type B	High	Low	Low	Many	Medium
LSA	Type A+	Moderate	Low	Low	Modest	Medium
Irradiators or Spent Fuel or HLW	Type B	High	High	Very low	Few	Low

CONCEPTS FOR RECOVERY PACKAGES

Based on the actual transport accident experience cited in Table 3, it appears that some simple approaches to providing a recovery package are called for. An example might be a set of nesting metal drums and bags of lead shot/polyethylene beads and packaging materials. The released RAM or damaged package could be inserted into the smallest possible interior drum, and the granular shielding material would be used to shield and pack the drum interior to meet safety requirements as required.

If able to be contact handled, the released RAM could be wrapped in a plastic wrapping such as a plastic bag and placed in the interior of the drum. Further confinement of the contents, however deformed they might be, could be accomplished by the use of lead pellets (shot) which could form a flexible shielding blanket (or polyethylene beads for neutron sources which would fill all of the interstices of the drum interior). In Table 4, a qualitative matrix of the relative importance of several radiation safety and transportation parameters is presented. The recovery package concept seems most important when hazards are high, package failure is likely, and the number of shipments (and opportunities for package use) is high.

Because of the likelihood that the released radioactive material would be able to be contact handled, the procedures outlined above would cover a large number of actual transport accident conditions. However, recovery operations would require that some regionally located stockpiles of recovery supplies and drums be established.

If remote handling should be required, it is important that recovery packages be designed such that handling lugs (or other handling attachments) be attached to facilitate the movement of the recovery package about the accident scene. Such considerations would include the loading of the radioactive material into the recovery packages in a remote manner to reduce radiation exposures to the recovery personnel.

CONCEPTS FOR RECOVERY DESIGN

For massive packages, greater than 500 kg, Type A and Type B packages are designed to maintain their shielding capabilities, and based on experience, a release of contents is unlikely. However, the handling of such a cask in the post accident condition may be difficult if the normal handling points are not accessible. To expedite the recovery and post accident handling of such packages, it is suggested that multiple sets of handling lugs be designed into the cask during packaging development. The incorporation of multiple (redundant) sets of lugs would facilitate the handling of a cask in an unorthodox position that might occur in its post accident orientation.

AUTHORIZED CONTENTS OF RECOVERY PACKAGING

The format of most national certificates of compliance is that they include a list of authorized contents to be placed in the package. One of the considerations that would have to be made in the case of recovery packaging would be whether or not the recovery package is to be a certified packaging. Since it is anticipated that there would be a limited number of recovery packaging to deal with a broad class of packaging, such as Type A or industrial packaging, that have the potential for being involved in a transport accident, some type of special arrangements would have to be agreed upon prior to recovery package development and procurement. This is because it would be very difficult to anticipate the actual contents to be placed into a recovery package and have these contents listed on the certificate of compliance in the usual manner.

Based on the experience cited above in actual transport accidents, it appears most likely that the recovery of released radioactive materials from packages involved in transport accidents will be for Type A packages. An additional possibility is for low specific activity packages involving greater than A1 or A2 amounts and, in effect, the recovery package would be an LSA package. There has been no experience dealing with the release of contents from Type B packaging due to transport accident conditions.

CONCLUDING REMARKS

The main thrust of this paper has been to put forth the idea of developing a package for the recovery and retrieval of released radioactive material contents from RAM packaging involved in transport accidents. Prior to the development of such a package, some additional studies might be performed which would confirm the general type of candidate materials which might have to be recovered. This would require a detailed inventory of U.S. packages that have released their contents due to transport accidents. The main issue is one of preparedness which would allow the U.S. Department of Energy to respond to accidents for DOE shipments and to respond nationally for shipments outside the normal jurisdiction of U.S. DOE shipments.

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