CONF-890631--24

An Analysis of the Consequences of Accidents Involving Shipments of Multiple Type A Radioactive Material (RAM) Packages

N. C. Finley[1], J. D. McClure[1], P. C. Reardon[2], M. Wangler[3]

[1]Sandia National Laboratories, Albuquerque, NM; [2]Gram, Inc., Albuquerque, NM; [3]U. S. Department of Transportation, Washington, DC

SAND--89-0807C

DE89 012641

INTRODUCTION

The transportation of radioactive material (RAM) packages is a routine activity in the U.S. nuclear materials industry. Several different types of packages are used to carry RAM (Low Specific Activity, Type A, Type B). Type A packages are used to transport quantities of materials that are small enough to be inherently safe, and for which only minimal amounts of shielding are required to meet regulatory requirements. The segment of the nuclear materials industry that is most prominent in shipping packages containing small amounts of RAM is radiopharmaceutical manufacturers, which ship about 500,000 packages per year in the U.S.

Multiple packages of radiopharmaceutical materials are sometimes combined into single shipments for one of four reasons:

1. A variety of radiopharmaceutical materials may have a common destination, so carriers frequently place many packages in one shipment as a cost-effective alternative to a large number of single shipments.

2. Air carrier and truck express routes are limited in the number of conveyances operated per day or week.

3. Carriers are frequently dedicated to transporting products of a single shipper, which determines what materials are loaded together.

4. Packages for a single location (e.g., a hospital or redistribution center) are often bundled (placed on a single pallet or in a plastic bag) to facilitate on-loading at the point of origin and off-loading at the destination.

*This work performed at Sandia National Laboratories, Albuquerque, New Mexico, supported by the United States Department of Energy under Contract No. DE-AC04-76DP00789.

**A United States Department of Energy Facility

Type A packages carry approximately 8% of the total curies in transport of RAM within the U.S., and make up the majority of multiple-package shipments. Typical trips involving these multiple-package shipments have a route length of approximately 1,900 km (1,200 mi) by truck on interstate highways; or a route length of approximately 1,500 km (950 mi) by cargo air.

The regulations governing the transport of Type A packages in general commerce were designed to provide adequate assurance of public health and safety. These regulations generally limit the number of packages in a single conveyance in general commerce to 50 TI (the sum of all individual package TIs). However, under sole use (or exclusive use) requirements or under a specific exemption, a greater number of packages can be transported in a single conveyance. Thus, there can be a potentially larger source term (in total curies available for release) in the event of an accident involving these shipments. This paper presents the results from an evaluation of the consequences of accidents involving such shipments and the probabilities of accident occurrences.

ACCIDENT EXPERIENCE

Multiple packages in a shipment can interact with each other and the vehicle in several potential ways in an accident. For example, a collision involving a vehicle or aircraft may not involve the shipment compartment directly (e.g., only the cab of the vehicle may be involved); however, the packages may be subject to inertial crush forces applied one to another as a result of the collision deceleration. If the shipment compartment is involved directly in the accident, the packages can be exposed not only to inertial crush forces, but can also be ejected from the transport vehicle through breaches in the cargo compartment. They can then impact on pavement or be crushed by external agents (e.g., the transport vehicle itself, a following vehicle, both). Different packages may be affected in different ways.

A third potential accident environment for multiple Type A package shipments involves fires. Vehicles transporting the materials may catch on fire, even in the absence of crush and impact forces.

The impact/crush environments discussed above can be coupled with fires. Data on a number of crush and fire environments (Clarke et al 1976) have been coupled with additional data from the Radioactive Material Incident Report (RMIR) data base to determine the transport accident history for Type A packages. The RMIR data base contains information from the U.S. Department of Transportation (DOT) incident reporting system, from the U.S. Nuclear Regulatory Commission (NRC) preliminary notification reports, and from individual state reports as they are available.

For calendar years 1971-1985, 134 transport accidents involving Type A and Strong-Tight packages occurred. Of these reported accidents, 14 involved more than one package in the shipment. Of the total number of packages in all the multiple package shipments, approximately 9% failed during accidents. Five of the multiple package accidents specifically involved radiopharmaceutical packages, where the failure rate was approximately 1%. Only two of these five reported accidents resulted in any release of RAM [one truck shipment (1 mCi I-

131 and 6 mCi Ga-67 concentrate released) and one air shipment (2 mCi Cr-51 and 6 mCi Ga-67 released)].

SHIPMENT ANALYSIS APPROACH

For the purposes of the analysis, three "generic" multiple-package shipments of radiopharmaceuticals have been developed, based on interviews with major suppliers within the U.S. These generic shipment types are referred to as the High-Activity Shipment (total shipment TI > 50), the DOT Exemption Shipment (DOT exemption restrictions for Mo-99 apply to this shipment; total shipment TI can exceed 50), and the Common Carrier Shipment (total shipment TI is 50 or less; shipment parameters are within regulatory limits for common carrier transport). The radionuclides included in the generic shipments are: H-3, C-14, P-32, S-35, Ca-45, Cr-51, Ga-67, Mo-99, I-125, I-131, Xe-133, Tl-201. The characteristics of these shipments are described in Table 1.

Table 1
Multiple Type A Package Generic Shipment Data

	Packages/ Ship.	TI[1]/ Ship.	Curies/ Ship.	Shipments/ Year
High Activity Shipment	1,250	840	1,300	400
DOT Exemption Shipment	190	110	170	3,000
Common Carrier Shipment	70	50	80	7,000

[1]TI: Transport Index, the highest dose rate at 1 m (3.3 ft) from any external package surface.

The total numbers of shipments per year are entirely hypothetical and were obtained by dividing 500,000 (the approximate yearly total of radiopharmaceutical packages shipped) by an assumed number of packages per shipment. The individual radionuclide inventory for each shipment type was divided by an estimated value for number of curies per package to obtain the number of packages per shipment. The shipment frequencies in Table 1 overestimate the total number of packages involved in each shipment category per year, because the total is shipped by a variety of modes and with widely varying numbers of packages per shipment, including individual packages. The total package quantity, however, is consistent with the annual shipment frequency.

CALCULATIONAL APPROACH

The results presented in this paper for accidents involving multiple Type A package shipments were calculated with the RADTRAN III computational system (Madsen et al 1986), by application of a method described in Neuhauser and Reardon 1986. The essential components of the RADTRAN III system are:

* a material model to define the radionuclide specific characteristics;

* a transport model to describe accident rates, traffic patterns, mode-specific shipment information;
* two geometric models, developed specifically for the multiple Type A package analysis, to accurately estimate the dose rate at the surface of a transport vehicle;
* an accident severity model to specify ranges for the seriousness of transport accidents involving RAM;
* a release fraction model to represent the portion of package contents exposed in an accident;
* a package release model to determine the expectedrelease fraction for each radionuclide in various population zones
* a population distribution model for various areas along a "generic" transport route;
* a health effects model to quantify potential health-related impacts of exposure of local populations to released radionuclides;
* an economic model to provide order-of-magnitude cost estimates for cleanup following accidents; and
* a radionuclide impact model to compute the effect of vehicular accidents in terms of level of consequence, probability of occurrence, and potential risk.

RESULTS AND DISCUSSION

Incident-free Transport

Results for the calculation of incident-free doses from generic radio-pharmaceutical shipments by truck and by cargo air are presented in Table 2. For comparison purposes, results from NUREG-0170 (USNRC 1977) are also included.

Comparison of the calculated data with USNRC 1977 results indicates the calculated incident-free doses are, for the most part, significantly lower than those reported previously. Changes from single to multiple-package shipments in modeling the exposure geometry are responsible for much of the difference observed. High TI shipments still have regulatory limits on dose rate to crew and dose rate outside the transport vehicle, resulting in RADTRAN III imposing these restrictions during the calculations. However, even with the changes in modeling, the calculations are still conservative because self-shielding and vehicle shielding are not included in the calculations. While RADTRAN I was used for USNRC 1977 and RADTRAN III was used for this study, the modeling changes in the two versions are not pertinent to the differences in the results.

Table 2

Incident-Free Population Doses from Generic Radiopharmaceutical Shipments by Truck and by Cargo Air (person-rem/year)

TOTAL POPULATION DOSE, ALL SHIPMENTS

Shipment Type	Exposed Population Group: Surrounding Population: Moving	Surrounding Population: Stopped	Persons Sharing/Vehicle: Transport Link	Crew
TRUCK				
High Activity	3	30	7	50
DOT Exemption	20	210	50	160
Common Carrier	50	510	120	200
NUREG-0170*	30	70	80	900
CARGO AIR				
High Activity	na	0.4	na	5
DOT Exemption	na	3	na	40
Common Carrier	na	7	na	90
NUREG-0170*	30	70	60**	800

---

* Data from NUREG-0170 (USNRC 1977), from Table 4-18 and Table A-8, were projected for 1985. Several of the radionuclides treated in the current analysis were not addressed explicitly in USNRC 1977. Values in the earlier tables were adjusted for a shipment level of approximately 500,000 packages per year. In USNRC 1977, packages were assumed to be shipped in quantities of one to a few packages per shipment, with no credit taken for cargo or vehicle shielding.

** It is assumed in the current analysis that for cargo air, there are no individuals sharing the transport link except the crew.

Vehicular Accidents

Table 3 presents the results for the RADTRAN III calculated exposure doses per shipment for the accident analysis. Again, comparisons with the USNRC 1977 results are included.

Table 3
RADTRAN III Results for Accidents Involving
Generic Radiopharmaceutical Shipments
by Truck and Cargo Air
(person-rem/shipment)

Shipment Type DOSE/SHIPMENT	EXPECTED VALUE OF EXPOSURE			
	High-Activity	DOT Exempt	Common Carrier	NUREG-0170 Analysis
TRUCK	1.7	1.6	1.8	13.*
CARGO AIR	.05	.05	.05	**

* For the truck case, data extracted from the USNRC 1977 accident analysis, Table 5-9, and converted to person-rem indicate that for the radionuclides Mo-99 and I-131 (1985 shipment level), the expected value of exposure dose would be approximately 2 person-rem. However, the analysis in USNRC 1977 did not include a contribution from groundshine, and only the two isotopes were considered. If the contribution from the radiopharmaceutical-like category "all others" is added to that for Mo-99 and I-131, the expected value of the exposure dose is approximately 13 person-rem.

** No comparable calculations were performed in the accident analysis for cargo air because of the significant difference in the exposure pathways used for the USNRC 1977 analysis.

Package release fractions for the baseline RADTRAN III analysis were taken directly from USNRC 1977. Compared with historical data, these release fractions are a conservative bound to what has been observed as a result of accidents. In RADTRAN III, the product of release fraction and conditional probabilities for the accident severity categories equals 10.7%. The mean failure rate for packages is approximately 8.8% based on the historical information presented earlier. Thus, the current analysis is consistent with actual accident experience.

A RAM package involved in a fire can potentially release and disperse all its contents. Fire alone occurs in transportation accidents about 1.6% of the time. The current analysis assumes complete release and aerosolization for about 5% of all accidents. Thus, the results presented in Table 3 can be considered an upper bound for transportation accidents involving fire.

CONCLUSION

Comparing the results of the RADTRAN III calculations with a normalized set of results from USNRC 1977, both for incident-free transport and vehicular accident cases, the calculated consequences in the current analysis are lower. Even for the High-Activity Shipment, the total expected population dose from either incident-free transport or vehicular accidents is small, and smaller than that estimated in USNRC 1977.

The results of the simulation in which parameters were varied randomly and independently indicate that, regardless of the input values assumed, the maximum total population dose from the High-Activity Shipment and the simultaneous occurrence of the least conservative value for each input parameter might be as high as 300 person-rem for a single shipment. The values for either of the other shipments (DOT Exemption or Common Carrier) would be significantly lower.

The potential average individual radiation doses from accidents involving multiple Type A package shipments are comparable to the increase in the normal background radiation dose of 0.09 rem/person/year (90 mrem) that an individual would receive by moving from sea level to 5,000 ft elevation. The maximum dose to an individual (one very near the accident scene) for the High Activity Shipment would be approximately 0.3 rem (300 mrem) in a maximum severity accident. This is within the individual dose guidelines outlined by NCRP (0.5 rem).

Even at the high levels postulated for multiple package shipments under DOT controlled exemptions, the potential risks to the public in terms of expected population dose in the current analysis are below those already found to be acceptable in USNRC 1977.

REFERENCES

Clarke, R. K., et al, "Severities of Transportation Accidents," SLA-74-0001, Sandia National Laboratories, Albuquerque, NM, July 1976.

Madsen, M. M., et al, "RADTRAN III," SAND84-0036, TTC-0470, Sandia National Laboratories, Albuquerque, NM, February 1986.

Neuhauser, K. S. and P. C. Reardon, "A Demonstration Sensitivity Analysis for RADTRAN III," SAND85-1001, TTC-0557, Sandia National Laboratories, Albuquerque, NM, October 1986.

U. S. Nuclear Regulatory Commission, Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes, NUREG-0170, Volumes 1 and 2, Office of Standards Development, December 1977.