Transportation Accidents/Incidents Involving Radioactive Materials (1971-1991)*

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INTRODUCTION

The Radioactive Materials Incident Report (RMIR) database contains information on transportation-related accidents and incidents involving radioactive materials that have occurred in the United States. The RMIR was developed at Sandia National Laboratories (SNL) to support its research and development program efforts for the U.S. Department of Energy (DOE).

This paper will address the following topics: background information on the regulations and process for reporting a hazardous materials transportation incident, overview data of radioactive materials transportation accidents and incidents, and additional information and summary data on how packagings have performed in accident conditions.

REPORTING REQUIREMENTS FOR TRANSPORTATION INCIDENTS INVOLVING RADIOACTIVE MATERIALS

The two federal agencies with primary responsibility for developing and promulgating regulations for the transport of radioactive materials in the United States are the U.S. Department of Transportation (DOT) and the U.S. Nuclear Regulatory Commission (NRC). The reporting requirements for these two agencies differ. The DOT regulations for reporting a hazardous materials incident (of which radioactive material is a subset) are specified in the Code of Federal Regulations (49 CFR 171.15). The DOT requires that a report be filed after each incident that occurs during the course of radioactive materials transportation (including loading, unloading, handling, and temporary storage) in which one of the following directly results: (1) a person dies; (2) a person is injured and requires hospitalization; (3) estimated carrier or other property damage exceeds $50,000; (4) fire, breakage, spillage, or suspected contamination involving radioactive materials; or (5) a situation that the carrier believes should be reported. The NRC regulations are also outlined in the Code of Federal Regulations (10 CFR 20.402 and 20.403) and require that the theft or loss of radioactive materials, exposure to radiation, or release of radioactive materials be reported.

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In addition to the reports received from the DOT and NRC, the RMIR contains data obtained from state radiation control offices, the DOE Unusual Occurrence Report database, and media coverage of radioactive materials transportation incidents.

ANALYSIS OF U.S. RADIOACTIVE MATERIALS TRANSPORTATION ACCIDENT/INCIDENT DATA

To evaluate the history of transporting radioactive materials, it is helpful to obtain a perspective by viewing the hazardous materials shipment record. According to the Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes (1977), it is estimated that during a given year, approximately 500 billion packages of all commodities are transported by all modes throughout the United States. Of those 500 billion packages, approximately 100 million packages are classified as hazardous materials (flammables, explosives, poisons, and radioactive materials). The most recent study of the transport of radioactive materials (Javitz, et al., 1985) indicates that approximately 2 million shipments of radioactive materials are made each year which constitutes about 2.79 million packages. Thus, radioactive materials are only 2% of the total number of hazardous materials transported each year.

When the RMIR database was established in 1981, it was designed primarily to accommodate the information on the DOT Form 5800 (Hazardous Materials Incident Report) for the recording of transportation accidents and incidents. The RMIR makes a definite distinction between an accident and a reported incident. The three kinds of reported events classified in the RMIR are defined as follows:

> **Transportation Accident:** A transportation accident is any accident that involves the vehicle which is transporting radioactive material.
>
> **Handling Accident:** Damage to a shipping container during loading, handling, or unloading operations; e.g., a forklift puncturing a package at an air terminal.
>
> **Reported Incident:** This is a very broad term which includes transportation occurrences where there is an actual or suspected release or surface contamination of radioactive materials exceeding the regulatory requirements from either the package or transport vehicle.

Table 1 tabulates the transportation accidents, handling, accidents and incidents that have occurred for the 21-year time frame of 1971 through 1991. Accidents comprise 22% of the events compiled for the United States; a slight increase over the 19% tabulated for the period 1971-1988. This percentage increase is the result of two factors: (1) the inclusion in the database of accidents that occurred in 1991 and (2) the accident information for prior years from contact with state radiation control offices. Further, 61% of all transportation occurrences tabulated in Table 1 are classified as reported transportation incidents.

TABLE 1

U.S. RADIOACTIVE MATERIALS TRANSPORTATION EVENTS (1971-1991)

Transportation Accidents	329
Handling Accidents	253
Transportation Incidents	924
TOTAL	1506

Most radioactive materials are transported on the highway; these shipments generally include industrial gauges, radioactive material used in or as a result of the nuclear fuel cycle, low-level radioactive materials or waste, and teletherapy sources. Radioactive materials that are shipped by air are generally isotopes with short half-lives that are being shipped over 500 miles from the shipper's location. Upon arrival at an airport, these radioisotopes are generally delivered to their consignees by a courier service. Radioactive materials transported by modes other than aircraft are usually those that do not require immediate delivery. Most radioactive materials traveling by highway are those involving industrial gauges, radioactive material used in or as a result of the nuclear fuel cycle, low-level radioactive materials or waste, and teletherapy sources.

Table 2 shows the RMIR breakdown for accidents, incidents, and handling accidents by transportation mode. As Table 2 illustrates, radioactive material packages transported on highways account for about 79% of all the incidents that have occurred and 88% of all accidents. Over one-half (54%) of all handling accidents recorded in the RMIR database have occurred with low-level materials at air terminals. Most of these handling accidents occurred during loading and unloading operations.

TABLE 2

TRANSPORTATION ACCIDENTS/INCIDENTS BY MODE (1971-1991)

Mode	Accidents	Incidents	Handling Accidents	Total
Air	18	150	137	305
Courier	2	4	2	8
Freight Forwarder	0	12	5	17
Highway	288	731	100	1119
Rail	20	14	2	36
Warehouse	0	3	1	4
Water	1	5	4	10
Other, unidentified	0	5	2	7
TOTALS	329	924	253	1506

PACKAGING PERFORMANCE IN TRANSPORTATION ACCIDENTS

Generally, an accident condition will be the most severe occurrence that a package will be subjected to during the course of transportation. Between the years 1971 and 1991, 3506 radioactive material packages, as documented in Table 3, were involved in transportation accidents. Of that total, only 223 (6%) were classified as having been damaged with no loss of contents or failed (package damaged with loss of radioactive contents). Industrial packages, or those that are classified as strong and tight, have been involved in 44 accidents. Of the 1342 strong and tight packages involved in those accidents, only 18 were damaged without loss of contents and 65 were damaged to the extent that they sustained loss of contents. These industrial packages are designed to withstand normal transport conditions; they are not designed nor tested to withstand accident conditions. Type A packages accounted for the majority (62%) of the package damages/failures in accident conditions. However, like industrial packages, Type A packagings are designed and tested for the rigors of normal transport conditions, not accidents.

TABLE 3

PACKAGE BEHAVIOR DURING TRANSPORTATION ACCIDENTS
(1971-1991)

Package Category	No. of Accidents	No. of Packages in Accidents	No. of Packages Damaged	No. of Packages Failed
Industrial (Strong & Tight)	44	1342	18	65
Type A	175	2079	83	55
Type B	53	85	2	0
Accidents with package category unknown[1]	62			
	334			
Accidents with 2 package types	- 5			
	329	3506	103	120

[1]These are mainly accidents that occurred in 1970's and early 1980's. Every attempt is being made to determine the package category type.

Most of the industrial and Type A packages included in the columns labeled "Damaged" and "Failed" in Table 3 were packages that were damaged without a loss of contents. For packages classified as being strong and tight, only 4.8% of those packages that were involved in accidents sustained a release. Only 2% of the Type A packages involved in accidents were damaged to the extent that there was a release, and in most of those accidents, the release was minor.

The most notable transportation accident that has occurred in the United States over the last 3 years involved the shipment of 12 containers, each of which contained 2 unirradiated nuclear fuel assemblies destined for the Vermont Yankee Nuclear Power Plant. The accident occurred on December 16, 1991, at 3:15 a.m. on Interstate 91 in downtown Springfield, Massachusetts. A car was traveling on the wrong side of the interstate, and although the truck driver swerved to avoid a collision, the car struck the tractor-trailer on the right side near the right fuel tank. The truck continued northbound and hit the center guardrail then rebounded and continued northbound striking the curb and guardrail on the opposite side of the road. After striking the outside guardrail, the truck skidded across the highway and came to rest against the center guardrail.

A fire started in the engine compartment of the tractor and spread to the entire tractor and then the trailer. The NRC's report on the accident (Carlson and Fischer, 1992) indicated that the fire burned for at least three-quarters of an hour before the cargo was affected. At that time, the entire payload was entirely intact. However, since the fire was not extinguished, the flatbed trailer and the payload also burned. The entire fire lasted approximately 3 hours.

The tractor-trailer was completely destroyed by the fire and there was significant damage to several of the Type A containers and their contents. Eight containers fell off the trailer and sustained minor damage from the impact. The wooden outer containers were burned and the inner metal containers sustained damage ranging from minor to severe.

Table 4 provides a tabulation of the 53 accidents involving Type B packages. Of these accidents, seven involved spent nuclear fuel (three of them occurred during rail transport and four occurred on the highway). There has been only one spent nuclear fuel accident which resulted in more than trivial damage to the cask. This accident, which is probably the most well known nuclear transportation accident, occurred on December 8, 1971, on U.S. 25 in Tennessee. The cask was thrown from the trailer and was embedded in the ground. The radiation surveys taken at the accident scene indicated that the structural integrity of the cask was intact and there was no release of contents. Almost one-half of the other accidents involving Type B packages have involved Iridium-192 sources.

TABLE 4

SUMMARY OF ACCIDENTS INVOLVING TYPE B PACKAGES (1971-1991)

Date of Accident	Mode	Package Description	RAM Involved	Packages Shipped/ Damaged	Accident Conditions
07/10/71	Highway	Lead container	Co-60	1/0	Collision
12/05/71	Highway	Radiography camera	Ir-192	1/0	Truck left road and overturned
12/08/71	Highway	Cask, spent fuel	Spent fuel	1/1	Truck left road; cask thrown off
03/10/74	Highway	Container	Ir-192	1/0	Trailer involved
03/29/74	Rail	Cask, spent fuel	Spent fuel	1/0	Derailment
08/09/75	Highway	Cask	U-235, U-238, Pu-239	1/0	Trailer ran off road & overturned
05/06/77	Highway	Radiography camera	Ir-192	1/0	Collision
08/11/77	Highway	Radiography camera	Ir-192	1/0	Collision with gas truck
08/25/77	Rail	Cylinders	UF6	4/0	Derailment
10/03/77	Highway	Radiography source	Ir-192	1/0	1 vehicle accident
02/09/78	Highway	Cask, spent fuel	Spent fuel	1/0	Trailer buckled from truck weight
04/10/78	Highway	Radiography camera	Ir-192	1/0	1 vehicle accident
07/07/78	Highway	Cask	Mixed fission	1/0	Collision
07/26/78	Highway	Steel cask, lead lined	Cs-137	2/0	Jeep overturned
08/13/78	Highway	Cask, spent fuel	Spent fuel, empty	1/0	Empty cask broke through trailer bed
08/27/78	Highway	Radiography camera	Ir-192	1/0	Collision
09/11/78	Highway	Radiography camera	Ir-192	1/0	Truck overturned
09/15/78	Highway	Radiography camera	Ir-192	1/0	Truck overturned
11/28/78	Highway	Radiography camera	Ir-192	1/0	Truck overturned
01/10/79	Highway	Cylinder	Ir-192	5/0	Vehicle rear-ended truck
08/12/79	Highway	Cask	Empty	2/0	Truck sideswiped
12/11/79	Highway	Cylinder	UF6	5/0	Truck jackknifed; icy roads
01/14/80	Highway	Cask, teletherapy	Co-60	1/0	Semi struck truck
01/31/80	Highway	Cask	Low level waste	2/0	Semi jackknifed
07/21/80	Highway	Source	Ir-192	1/0	Collision

TABLE 4 (Concluded)

Date of Accident	Mode	Package Description	RAM Involved	Packages Shipped/ Damaged	Accident Conditions
08/22/80	Highway	Cylinder, 30B	UF6	5/0	Truck forced-off road
09/06/80	Rail	Cylinder, 30B	UF6	8/0	Train wreck
09/29/80	Rail	Radiography source	Sr-90, Y-90	3/0	Rail accident
06/09/81	Highway	Source, shielded	Am-241/Be	1/0	Pickup accident
09/02/81	Highway	Source	Ir-192	1/0	Collision
10/26/81	Highway	Radiography camera	Ir-192	1/0	Collision & fire
11/03/82	Highway	Cask	Empty LLW	2/0	Truck overturned; cask thrown off
03/11/83	Highway	Cask	LLW	1/0	Truck sideswiped
05/10/83	Highway	Radiography source	Ir-192	1/0	Head-on collision
07/14/83	Air	Cask	Y-90, Ir-192	2/0	Plane crashed
12/09/83	Highway	Cask, spent fuel	Spent fuel	1/0	Tractor separated from trailer
07/16/84	Air	Container	Ir-192	1/0	Plane ran off runway
08/08/84	Highway	Container	Reactor waste	1/0	Trailer overturned
02/11/85	Highway	Steel drum	Ir-192	1/0	Trailer jackknifed
02/13/85	Highway	Steel drum	Ir-192	1/1	Vehicle overturned
12/04/85	Highway	Radiography camera	Ir-192	1/0	Collision
01/10/86	Highway	Source	Cs-137	1/0	Truck ran off road
08/15/86	Highway	Cylinder, 30B	UF6	3/0	Collision
03/24/87	Rail	Cask, spent fuel	Spent fuel	2/0	Train/auto wreck
10/26/87	Highway	Radiography source	Ir-192	1/0	Truck overturned
01/09/88	Rail	Cask, spent fuel	Spent fuel	1/0	Train derailed
01/23/88	Highway	Radiography camera	Ir-192	1/0	Truck ran off road
09/23/88	Highway	Radiography camera	Ir-192	1/0	Truck ran off road
03/27/89	Highway	Radiography camera	Ir-192	1/0	Collision
05/19/89	Highway	Cask	Low Level Waste	1/0	Auto struck tractor trailer
06/08/91	Highway	Radiography camera	Ir-192	1/0	Truck overturned
09/15/91	Highway	Radiography camera	Ir-192	1/0	Truck caught fire
11/03/91	Highway	Radiography camera	Ir-192	1/0	Collision

SUMMARY AND CONCLUSIONS

The data provided by the Radioactive Materials Incident Report database for this paper in part reflects the adequacy of the transportation regulations that are in effect. That is, the packages that have experienced releases are those that contain limited quantities of radioactive materials. The regulations require that Type B packagings be used for the transport of larger quantities of nuclear materials, thus posing a potentially greater consequence if the contents are released. However, the DOT regulations also specify that Type B packagings be designed and tested to withstand "hypothetical" accident conditions which are outlined in the NRC regulations (10 CFR 71). The data from RMIR indicate that Type B packages have performed extremely well in accidents. There have been two minor damages to Type B packages, but no release of radioactive materials.

Since its development in 1981, the RMIR database has evolved to become one of the most comprehensive compilations of information on transportation accidents and incidents

transportation of nuclear materials to or from such facilities.

LIABILITY DETERMINED BY STATE LAW

The Price-Anderson system leaves substantive tort law to the States (except, as discussed below, when a "nuclear incident" rises to the level of an "extraordinary nuclear occurrence"). This means that financial liability of shippers, carriers or others responsible for a nuclear packaging or transportation accident usually would be determined under applicable State law, just as it is for other types of packaging and transportation accidents in the United States.

"OMNIBUS" FEATURE

Assuming there is liability for a particular nuclear accident, financial coverage for it is different from conventional insurance when Price-Anderson applies: A unique feature of the Price-Anderson system that makes coverage under it most desirable is that, when it applies, it covers "anyone liable" (except the Federal Government) for "any legal liability arising out of or resulting from a nuclear incident". This so-called "omnibus" feature would facilitate the handling of lawsuits and reduce costs by allowing for consolidation of the defense and avoiding cross-claims among defendants (as demonstrated by the complicated litigation after the 1979 Three Mile Island accident, wherein all the defendants were able to consolidate their defense under one law firm, and emergency payments and settlements were expedited). The "omnibus" feature means there is coverage regardless of how liability of particular defendants (any one of whom might have limited assets) is allocated by tort law, a system unique to nuclear applications.

LIMITATION ON LIABILITY

The Price-Anderson Act provides that the liability of all entities covered by it is limited to the amount of coverage provided by the system. This limitation-on-liability provision was upheld unanimously by the U.S. Supreme Court in 1978 in *Duke Power Co. v. Carolina Environmental Study Group*. If the large amounts provided by the Price-Anderson system were not adequate, Congress more specifically indicated in the 1988 Price-Anderson Amendments Act it would "...take whatever action is determined to be necessary (including approval of appropriate compensation plans and appropriation of funds) to provide full and prompt compensation to the public for all public liability claims resulting from a disaster of such magnitude."

ROLES OF NRC, DOE AND NUCLEAR INSURANCE POOLS

The U.S. Nuclear Regulatory Commission (NRC) administers the portions of the Price-Anderson Act applicable to commercial nuclear facility licensees (principally section 170c). NRC indemnity agreements (under section 170c) (or U.S. Department of Energy (DOE) indemnity agreements under section 170d, as discussed below) may be the sole source of funds for public liability associated with nuclear risks where there is not insurance from private sources. Private insurance, when applicable, can furnish either underlying or exclusive coverage. It is provided by either the two nuclear insurance pools (American Nuclear Insurers, the pool of stock insurance companies, and Mutual Atomic Energy Liability Underwriters, the pool of mutual insurance companies) or the conventional insurance market. As a general rule, the pools cover nuclear fuel cycle activities, while non-fuel cycle activities (which are not considered to involve a level of risk requiring a pooling arrangement) are covered by the conventional insurance market. The pools issue two principal types of nuclear liability policies: the Facility Form (now up to $200 million), and the Supplier's and Transporter's Form (which is not part of the Price-Anderson system).

RETROSPECTIVE PREMIUMS FOR POWER PLANT OPERATORS

In the case of liability associated with NRC-licensed power plants, if the primary level of financial protection afforded by the plant's Facility Form insurance policy ($200 million for power plants) were insufficient to pay all claims, power plant operators would be assessed a "retrospective premium" per incident. The amount of this retrospective premium was raised to $63 million per power plant by the 1988 Amendments. As of September 1992, the amount of power plant coverage (and the limitation on liability) was $200 million under the Facility Form plus $7.245 billion under the Retrospective Plan (based upon 115 nuclear power plants (including Shoreham and Rancho Seco) operating as of September 1992 times $63 million each) for a total of at least $7.445 billion. (If, as their operators recently have requested, the Shoreham and Rancho Seco power plants both are removed from the NRC list of "operating" plants, the amount available under the Retrospective Plan and the power-plant limitation on liability will be reduced by $126 million.)

DOE CONTRACTOR ACTIVITIES

The other principal kind of Price-Anderson coverage is that issued by DOE under the section 170d contractor provision. That subsection, as amended in 1988, now requires DOE to provide nuclear hazards indemnity coverage to its contractors in an

amount equal to the highest amount provided for nuclear power plant licensees. (With the number of nuclear power plants decreasing for the first time and not taking into account inflation adjustments, the amount of DOE coverage is likely to remain at $7.445 billion for some time.) Coverage under a DOE nuclear hazards indemnity agreement is substantially the same as that afforded under the pools' Facility Form policy.

"EXTRAORDINARY NUCLEAR OCCURRENCE" PROVISION

An often misunderstood feature of the Price-Anderson system is the "extraordinary nuclear occurrence" (ENO) provision. The ENO provision was added to the Price-Anderson Act in 1966 for the purpose of further assuring prompt compensation to the public for serious nuclear incidents without at the same time totally displacing state laws by the creation of a "federal tort". The 1966 amendment provides that, in the event of an ENO, certain ordinarily available state law defenses are waived. Congress did not wish to make these provisions applicable to all nuclear incidents for fear of encouraging nuisance suits. Determination as to whether an incident was an ENO is made by NRC or DOE on the basis of predetermined criteria (in 10 C.F.R. Parts 140 and 840, respectively). It is not necessary that an ENO determination be made for coverage under the Price-Anderson system to apply. The only case in which an ENO determination previously has been made was the Three Mile Island accident. NRC determined that, while that event was "extra-ordinary" in ordinary parlance, it was not an ENO.

PRICE-ANDERSON AMENDMENTS ACT OF 1988

In 1988, the United States Congress extended the authority of both NRC and DOE to enter into new nuclear hazards indemnity agreements for 15 years (*i.e.*, until August 1, 2002). For nuclear power plant licensees, the principal changes brought about by the 1988 amendments relate to increased retrospective premiums (and the resulting increase in the overall limitation on liability), coverage for "precautionary evacuations", and clarification of coverage of costs for investigating, settling and defending claims. DOE contractor coverage is subject to similar changes, in addition to the fact that such coverage has become mandatory and that certain DOE "contractor accountability" provisions (new criminal and civil penalties for nuclear-safety violations) have been added. The 1988 Amendments also specifically provide that Price-Anderson coverage applies to DOE's nuclear waste activities.

For power plants, the retrospective premium was increased to $63 million per incident per plant (from $5 million), with no more that $10 million payable in any year. Additionally, the retrospective premium is made subject to inflation indexing not

less than every five years based on the Consumer Price Index, and is subject to an additional five percent surcharge for legal costs. The effect of these changes has been to increase the limitation on liability per incident to about $7.445 billion. The 1988 Amendments did not increase the $100 million coverage limit for nuclear incidents outside the United States.

The 1988 Amendments further clarify how Congress would consider "compensation plans" if the limitation on liability were exceeded. That provision requires the President to submit a comprehensive compensation plan to Congress within ninety days of a court determination that public liability for any nuclear incident may exceed the aggregate limitation. Expedited procedures for Congressional consideration are provided.

For the first time, the statute now clearly covers liability arising from a "precautionary evacuation", even if it later is determined no "nuclear incident" had occurred. This assumes that such costs constitute a "public liability" under State or other applicable law.

Certain changes also have been made in the Act's ENO provisions: First, the ENO waivers of shorter statutes of limitations are modified to eliminate the twenty-year outside limit, *i.e.* the ENO waiver now would apply to any statute shorter that a three-year-from-discovery limit. Second, the ENO provisions also are made applicable to DOE nuclear waste activities.

Federal court jurisdiction and consolidation of claims are made available for any "nuclear incident", instead of just for ENO's or where it appears the limitation on liability will be reached, as had been the case.

The new statute provides no court may award punitive damages where the Federal Government is obligated to make payments under an agreement of indemnification. Otherwise, there remains an issue whether punitive damages are covered under the Price-Anderson system and the pools' various insurance policies.

"MIXED WASTE" ISSUES

Recently, there has been growing concern about coverage for liability that might arise from handling and transportation of "mixed" waste, *i.e.* waste that contains both radioactive constituents (regulated by NRC and DOE under the Atomic Energy Act) and hazardous constituents (regulated by the U.S. Environmental Protection Agency under the Resource Conservation and Recovery Act). The Price-Anderson system covers losses arising only from "the radioactive, toxic, explosive, or other hazardous properties of source, special nuclear, or byproduct material", as those terms are defined in the Atomic Energy Act.

Price-Anderson does not cover nonnuclear, unusually hazardous activities. It may not always cover liability associated with the hazardous constituents of mixed waste.

In the past, nuclear risks generally were considered more significant than hazardous-materials risks. Today, handlers and transporters also need to be concerned about potential liabilities associated hazardous and mixed waste. The best protection now available to those engaged in hazardous and mixed waste activities for the Federal Government is that which can be provided under Public Law 85-804. Public Law 85-805 was enacted in 1958 (just a year after Price-Anderson) to authorize certain Federal agencies to indemnify contractors against "unusually hazardous or nuclear risks" when such would "facilitate the national defense".

DOE and other agencies have been considering the discretionary application of Public Law 85-804 to their mixed waste activities. More limited coverage (applicable to National Priority List sites) may be available from certain Federal agencies under section 119(c) of the Superfund Amendments and Reauthorization Act of 1986 (SARA). For non-Federal Government mixed waste, coverage may be available under conventional insurance and/or individual indemnity agreements (*e.g.*, with the shipper).

CONCLUSIONS

The 1988 statutory amendments retained the basic structure of the Price-Anderson insurance-indemnity system. A number of significant changes were advocated during the lengthy Congressional review process, but they were rejected. Thus, Price-Anderson remains an exemplary system for providing liability coverage for the risks of a potentially-hazardous nuclear activities.