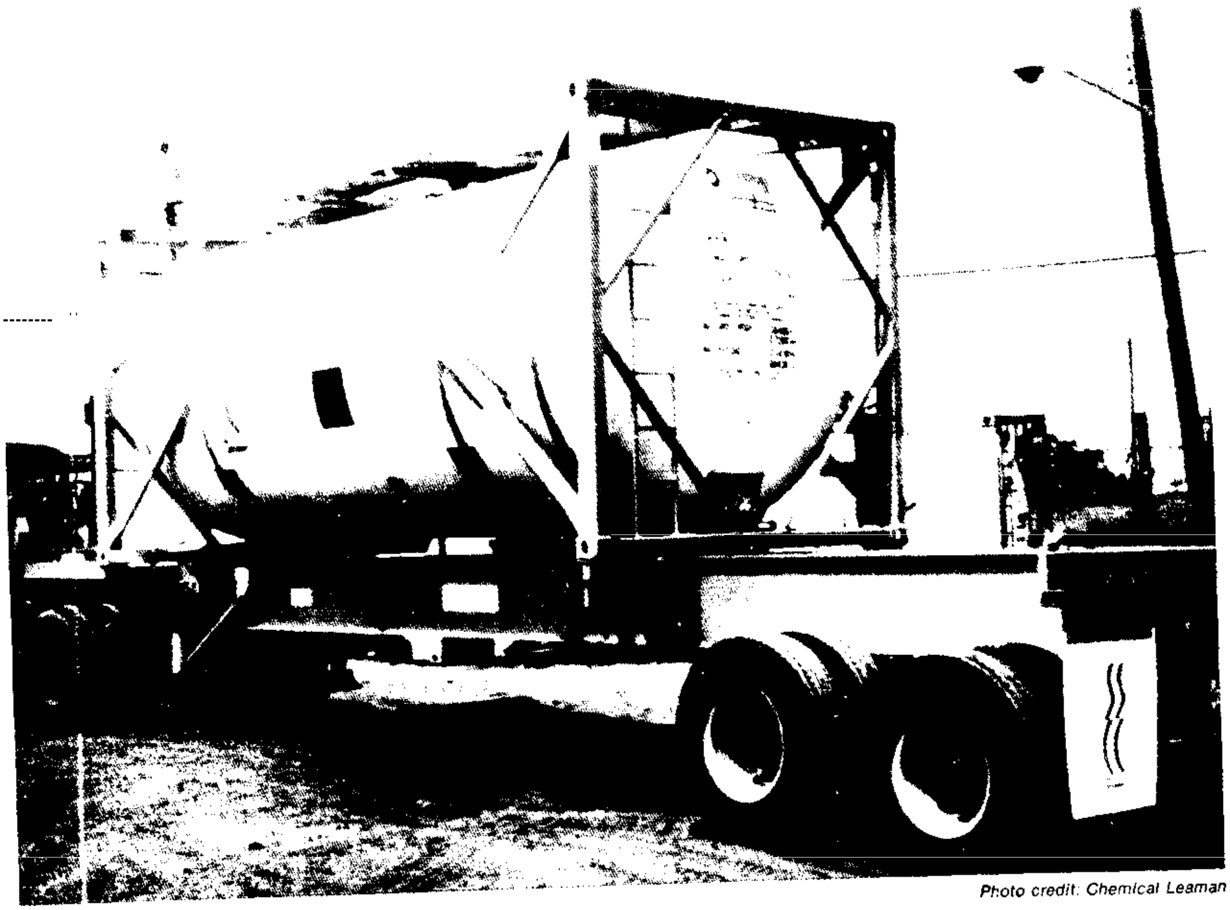
Chapter 3

Containers for Hazardous Materials Transportation



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INTRODUCTION

Ensuring the safe transportation of hazardous materials is a complex activity. If accidentally released, hazardous materials pose risks to human safety, property, and the environment. Consequently, the containers or packaging used for shipping most of these materials are required by regulation to be adequate to contain their contents during normal transport. However, standards for containers for highly radioactive materials are set differently and require that the packages withstand severe accident conditions without a dangerous radioactive release.

Over 30,000 different hazardous materials must be shipped under U.S. Department of Transportation (DOT) regulations. Among the classes of materials regulated are explosives, flammables, corrosives, combustibles, poisons, radioactive materials, and etiologic (disease-causing) agents. These materials, essential to the business and industrial economy of the United States, are shipped by air, highway, railroad, and water under regulations that reflect the history and different operating characteristics of the various modes. Hazardous products are transported in bulk by vessels, tank cars, tank trucks, intermodal portable tanks; and in smaller containers such as cylinders, drums, barrels, cans, boxes, bottles, and casks. Widely varying packaging have been developed by industry to match the strength and integrity of the containers to the characteristics and hazards of the materials they must contain.

Packaging for hazardous materials during transportation is a major element of DOT's regulatory system. The Department, through its Research and Special Programs Administration and other branches, establishes technical standards for the design and testing of packages and associated transportation equipment for all hazardous materials and small quantities of radioactive materials. The Nuclear Regulatory Commission (NRC) sets standards for the design and performance of packages to carry highly radioactive materials.* Private shipping companies and container manufacturers, DOT, NRC, and the Department of Energy (DOE), all are exploring new technologies and possible design changes for the shipping containers used for hazardous materials and wastes, including spent nuclear fuel. Packaging issues that repeatedly confront Federal agencies include:

- the types and severity of tests necessary for determining the level of protection provided by the packaging,
- the development of new materials for packaging,
- the influence of international commerce and standards on U.S. packaging designs, and
- the impact of accident and spill frequency and consequences on container regulation.

This chapter examines a wide range of issues concerning hazardous materials packaging technology, including the development of design and testing standards and their relationship to the transportation system. Part I examines the unique container issues associated with the transportation of radioactive materials, including those related to shipment of high-level radioactive wastes, such as spent nuclear fuel. Part 11 deals with packaging for other hazardous materials commonly used, such as chemicals, petroleum products, explosives, and poisons. h discusses:

- the present spectrum of bulk equipment and small packages for shipping hazardous materials and wastes, and
- the impact of Federal regulation on transportation safety and container technology.

*Highly radioactive materials include fissile and greater than A_1 and A_2 limits of radioactive materials. Fissile material is that containing one or more fissile radionuclides—Plutonium 238, Plutonium 239, Plutonium 241, Uranium 233, and Uranium 235. Neither natural nor depleted uranium is fissile material. A_1 and A_2 quantity limits are defined in 10 CFR 71.4 and table A-1 thereto.

PART 1: CONTAINERS FOR TRANSPORTING RADIOACTIVE MATERIALS

Radioactive materials are employed extensively in modern society. In addition to their role in generating electric power, radioactive materials are used for research, manufacturing, and a wide range of industrial processes. They are also often indispensable for medical diagnosis and therapy. The pervasive use of these materials means that they and any waste products must be regularly transported. In total, some 2.8 million packages of radioactive materials are transported in about 2 million shipments each year in the United States by truck, rail, and air, out of 100 million shipments of all types of hazardous materials. Box 3A defines terms used throughout this chapter.

Almost two-thirds of radioactive shipments are for medical purposes, with the balance for use in the nuclear fuel cycle to generate electricity, for industrial and research activities, and waste.* (See table 3-l.) About 7 percent of all shipments are classified as wastes (see box 3A), with the vast majority being low-level wastes.[1] The total volume of low-level wastes shipped each year is about 2.7 million cubic feet, or enough to cover a football field with a pile 52 feet high. Between 100 and 300 shipments of high-level wastes and spent fuel, from electric utilities, and DOE and U.S. Department of Defense (DOD) research or training facilities, are made annually by truck and rail. See tables 3-2 and 3-3 for histories of commercial reactor and low-level waste shipments, respectively, and table 3-4 for the volumes and types of shipments associated with the nuclear fuel cycle. Reactor operation and the fuel cycle are summarized in box 3B.

Box 3A.—Forms of Radioactive Wastes

Spent fuel.—Irradiated fuel discharged from a nuclear reactor. Contains fission products, unused uranium and plutonium, and various transuranic (TRU) elements.

High-level wastes.*—Highly radioactive materials resulting from chemical processing of spent fuel to recover usable uranium and plutonium. Contains fission products, traces of uranium and plutonium, and other TRU elements.

Transuranic wastes.—Materials contaminated with enough TRU elements to require the same sort of long-term isolation as high-level radioactive wastes. TRU elements are radioactive and have long half-lives; examples include plutonium and americium.

Mill tailings.—Slightly radioactive materials left over from extraction of uranium from ore.

Low-level wastes (LLW).—All radioactive wastes not classified as high-level radioactive wastes, TRU wastes, mill tailings, or byproduct materials as defined in Public Law 96-73. Fuel cycle LLW is generated from the conversion of yellowcake to UF_6, as well as reactor operations. LLW also is generated by institutions and industries engaged in research and various industrial and medical activities. While most LLWs are relatively short-lived and have low radioactivity, some may present a significant radiation hazard.

*The U.S. Nuclear Regulatory Commission is developing a definition of high-level waste that would include other material of such a highly radioactive and long-lived nature that it requires placement in the permanent repository.

Although medical and industrial shipments of radioactive materials are by far the most numerous, it is shipments of low- and high-level wastes and spent fuel that cause the greatest public concern and controversy. Federal regulations governing these shipments are extensive, yet in the absence of widespread public confidence in Federal safety activities, over 650 additional State and local laws have been enacted attempting to control and even ban the movement of radioactive wastes.[2]

The public is understandably apprehensive about the movement of highly radioactive materials. Even though such operations are not new here or abroad,

*A third category, radioactive materials for the defense industry—research, propulsion, and weapons-is not considered here, although problems related to shipments of hazardous materials by the U.S. Department of Defense are discussed briefly in ch. 5 in the enforcement training section.

[1]Harold S. Javits, et al., "Transport of Radioactive Material in the United Stares, SAND84-7174 (Albuquerque, NM: Sandia National Laboratories, April 1985); and EG&G Idaho, Inc., *The 1984 State-by-State Assessment of Low-Level Wastes Shipped to Commercial Disposal Sites*, DOE/LLW-50T (Washington, DC: U.S. Department of Energy, December 1985), p. 6.

[2]N.P. Knox, et al., "Nuclear Waste Programs," *Transportation of Radioactive and Hazardous Materials: A Summary of State and Local Legislative Requirements for the Period Ending December 31, 1985, ORNL/TM-9985* (Oak Ridge, TN: Oak Ridge National Laboratory for the U.S. Department of Energy, April 1986), p. v.

Table 3-1.—Summary of Unclassified Radioactive Materials Shipments by the Nuclear Regulatory Commission (NRC) Licensees and the Department of Energy (DOE) Licensees

Sector	Number of packages/year: NRC licensees	Number of packages/year: DOE licensees	Percent of total packages
Medical	1,730,000	16	61.5
Industrial	213,300	—	7.6
Nuclear fuel cycle	114,000	6,246	4.2
Waste (all sectors)	181,000	1,146	6.5
R&D and academic	17,100	1,802	0.7
Other	526,500	22,580	19.5
Total	2,781,900	31,790	100.0

SOURCE: Harold S. Javits, et al., *Transport of Radioactive Material in the United States*, SAN D84-7174 (Albuquerque, NM: Sandia National Laboratories, April 1985), pp. 16 and 28.

Table 3.2.—History of Domestic Commercial Spent Fuel Shipments

Year	Method	Number of shipments[a]	Number of assemblies
1973	Truck	83	185
	Rail	6	72
1974	Truck	222	333
	Rail	1	13
1975	Truck	166	198
	Rail	4	64
1976	Truck	291	291
	Rail	18	324
1977	Truck	444	444
	Rail	27	407
1978	Truck	230	230
	Rail	24	256
1979	Truck	79	83
	Rail	15	105
1980	Truck	22	22
	Rail	5	32
1981	Truck	81	242
	Rail	2	13
1982	Truck	100	297
	Rail	—	—
1983	Truck	b	
	Rail		
1984	Truck	132	571
	Rail	50	883
1985	Truck	30	153
	Rail	50	883

[a]For 1976 to 1985, the number of shipments was derived from the number of fuel assemblies of either the boiling water reactor (BWR) or pressurized water reactor (PWR) type sent by each mode. It was assumed that: all rail casks held 18 BWR assemblies or 7 PWR assemblies; legal weight truck casks were used up through 1980 (with a capacity of 2 BWR or 1 PWR assemblies); and overweight truck casks were used from 1981 to 1985 (with a capacity of 7 BWR or 3 PWR assemblies).
[b]Some of the shipments credited to 1982 actually occurred in 1983. D.F. Newman, Battelle Pacific Northwest Laboratories, personal communication, April 1986.

SOURCE: Science Concepts, Inc., "Containers for Transporting Radioactive Materials," OTA contractor report, September 1985, p. 5 (1973 to 1975 data); and D.F. Newman, Battelle Pacific Northwest Laboratories, written communication, April 1986 (1976 to 1985 data),

they are complex and potentially dangerous. Concerns have been voiced that the packaging may be inadequate, packaging test criteria do not reflect realistic accident conditions, industry does not always follow safety procedures, localities cannot exercise sufficient control over routing, and the consequences of an accident could be far more severe than government and industry reports indicate.[3]

Unless substantial progress on resolution of issues is made, controversy over the transportation of high-level radioactive materials will increase as greater quantities of spent fuel must be moved from reactor sites that have exhausted their onsite storage capacities. As many as 22 reactors are expected to have no more spent fuel pool capacity available between 1987 and 1993, unless alternatives now being actively explored, such as reracking, rod consolidation, or dry cask storage, can be implemented.[4] The Nuclear Waste Policy Act of 1982 (NWPA) requires that, starting in 1998, DOE take title to spent nuclear fuel at commercial reactor sites and, when necessary, transport it to a repository. A permanent waste repository may not be available by that date,

[3]Marvin Resnikoff, *The Next Nuclear Gamble* (New York, NY: Council on Economic Priorities, 1983); Stephen N. Salomon, *State Surveillance of Radioactive Material Transportation*, NUREG-1015 (Washington, DC: U.S. Nuclear Regulatory Commission, 1984); and Joseph Strohl and Lindsay Audin in U.S. Congress, Office of Technology Assessment, "Proceedings of OTA Workshop on Nuclear Materials Packaging Technology," unpublished typescript, Feb. 8, 1985.
[4]U.S. Department of Energy, *Spent-Fuel Storage Requirements*, DOE/RL-84-1 (Washington, DC: U.S. Government Printing Office, May 1984); and Marvin Smith, Supervisor, Nuclear Engineering, Virginia Electric Power Co., personal communication, April 1986.

Table 3-3.—Quantities of Low. Level Radioactive Waste Shipped and Buried in 1984

Disposal site	Volume (m^3)	Percent total	Radioactivity (curies)	Percent of total
Barnwell, SC	34,879	47	383,079	64
Beatty, NV	2,069	3	544	
Richland, WA	38,481	51	215,286	36:
Total quantity	75,429	100	600,909	100

SOURCE: EG&G Idaho, Inc., "The 1984 State-By-State Assessment of Low-Level Radioactive Wastes Shipped to Commercial Disposal Sites," DOE/LLW-50T, prepared for the U.S. Department of Energy, December 1985.

Table 3=4.-Radioactive Material Shipments Associated With the Nuclear Fuel Cycle (annual shipments per 1,000 megawatt reactor)

Material	From	To	Quantity[a]	Activity (Ci)	Shipments[b]
U ore	mine	mill	$3.4(10)^5$ MT	1 .4(10)3	6,300
Yellowcake	mill	refinery	307 MT	360	20
UF_6	refinery	enrichment	266 MTU	360	22
Enriched UF_6	enrichment	fuel preparation	43 MTU	62	6
UO_2	fuel preparation	fuel fabrication	43 MTU	62	12
New fuel assembly	fuel fabrication	reactor	43 MTU	62	7
Spent fuel assembly[c]	reactor	storage	16 MTU	7.6(10)'	13
			24 MTU	1 .1(10)'	8[d]
Low-level waste	refinery	burial site	280 m^3		25-38
Low-level waste	fuel fabrication	burial site	180 m^3		19-25
Low-level waste	reactor	burial site	100-1.000 m^3		=60

[a] MT is metric tons, MTU is metric tons Of uranium.
[b] All shipments are byoverweight truck using current generation of casks except where noted.
[c] 1 000 MWe reactors of different design may discharge different amounts of spent fuel annually. This table is based on an international study. U.S. reactors, however, discharge 28 to 32 MTU per year.
[d] Rail shipments using current generation Of rail casks.

SOURCE: Essam El-Hinnawi, "Environmental Impacts of Production and Use of Energy, " *Transport of Radioactive Materials* (New York: United Nations Environment Program, 1981).

and DOE has proposed moving much of the stored spent fuel to a monitored retrievable storage facility. In the meantime, shipments of spent fuel will continue in connection with intra-utility transfer and storage plans and DOE research and development.

For these reasons, Congress asked OTA to study the issues surrounding shipments of radioactive materials, especially spent nuclear fuel and high-level wastes. The focus of this first part of chapter 3 is specifically on the containers used for spent fuel, their integrity, and the procedures surrounding their use in transportation. The technical issues related to the containers will be evaluated as will the institutional, legal, jurisdictional, and public policy issues surrounding spent fuel shipments. These latter are as important and as difficult to assess as the technical issues. In particular, this section will address these questions:

- Are current technical standards and safety analysis methods for spent nuclear fuel containers adequate?
- How safe is the transport of spent reactor fuel, and what may be the consequences of an accident?
- What improvements are necessary in the safety procedures for container manufacture, transportation, and container and vehicle inspections?
- What public concerns must be addressed as the country prepares for increased spent fuel shipments under NWPA?
- What can be done to resolve legal and jurisdictional concerns regarding the choice of safe shipping routes and other operational restrictions?
- Is the public understanding of technical issues adequate to provide a basis for resolution of contentious issues? If not, what should or can be done to improve this?

Box 3B.—Reactor Operation and Spent Fuel Production

The light-water reactor (LWR) is the principal reactor type in commercial use in the United States.* Fuel for nuclear reactors consists of fuel rods in the form of 12- to 13-foot long, zircalloy tubes about ½ inch in diameter, filled with ceramic uranium oxide pellets. These rods are bundled together to form fuel assemblies. In the LWR, the fuel assemblies are immersed collectively in a coolant (water), where they form the reactor core. The control rods interspersed among the fuel rods control the rate of fission in the reactor fuel. Heat from fission and, to a much lesser extent, from the decay of fission products is used to heat water to steam, which is used to generate electricity.

After about 3 years, the buildup of fission products in a fuel assembly impedes the efficiency of the chain reaction. When the concentration of U^{235} in the fuel is around 1 percent, the assembly, considered spent fuel, is removed and replaced with fresh fuel. LWRs discharge between 60 and 175 assemblies, or a total of about 28 to 32 metric tons of uranium** of spent fuel, each year.

Because of the decay of the fission products and transuranic elements, spent fuel is highly radioactive when it is initially discharged from the reactor. For this reason spent fuel units are stored in water basins to provide the cooling and radiation shielding that they require. After 6 to 12 months in the storage pools, the radioactivity decays enough to allow shipment.***

The heat output and radioactivity of spent fuel decay rapidly in the first year after discharge. The approximately 10 kilowatt (kW) of heat emitted per tonne after 1 year equates to that of one hundred 100-watt light bulbs. The radioactivity decays less rapidly after the first year; the 10 kW at the end of the first year is reduced to about 1 kW by the end of 10 years after discharge.

*Seventy-three of the 74 U.S. commercial powerplants are light-water reactors (LWRs). The one high-temperature gas-cooled reactor at Fort St. Vrain, CO, operates like an LWR but uses helium gas for its coolant.

**Note that only the mass of the initial uranium is considered in the measurement of fuel amounts and not the mass of the rest of the assembly. A metric ton, or tonne, is equivalent to 1,000 kilograms, or about 2,205 pounds. The estimate of 60 assemblies per year is for a pressurized water reactor and the estimate of 175 assemblies per year is for a boiling water reactor.

***Many spent fuel casks are licensed to transport fuel that has been cooled for 150 days. Although commercial utilities typically ship only fuel at least several years old, shipments of 150-day-old fuel by the U.S. Department of Energy and the U.S. Department of Defense are not unusual.

Photo credit: U.S. Department of Energy

Spent fuel storage basin at a commercial nuclear powerplant.

The information in this chapter is derived from technical literature, interviews with technical experts and concerned citizens, and from an OTA workshop on nuclear materials packaging.[5]

Regulatory Framework

While the primary Federal regulatory responsibility for shipments of radioactive materials lies with DOT, NRC and DOE also have specific responsibilities. Under its authority, DOT has issued regulations covering all aspects of transporting radioactive materials, including requirements for the containers, the mechanical condition of the transportation vehicles, and the training of personnel, as well as the routing requirements, package labels, vehicle placards, and shipping papers associated with shipments of radioactive materials. DOT also conducts carrier equipment inspections.

Under a Memorandum of Understanding, NRC and DOT cooperate closely to regulate containers for radioactive materials. NRC, under its own legislative authority, is responsible for regulating, review-

[5]U.S. Congress, op. cit.

ing, and certifying the packaging and certain transportation operations for shipments of fissile and highly radioactive materials that must be packaged very securely in Type B containers (described below) when such shipments involve NRC licensees.[6]

DOE also has authority, granted by DOT regulations,' to approve the packaging and certain operational aspects of its research, defense, and contractor-related transportation of fissile and highly radioactive materials. Although DOE is required to use standards and procedures equivalent to those of NRC in the container certification process, when DOE has chosen to exercise its own authority to use casks and procedures other than NRC-approved, substantial conflict between DOE and States and concerned citizens has arisen. Officials from New York and New Jersey were outraged to learn in July 1985 that DOE had planned to use a cask that had been refused NRC certification for nuclear waste shipments from Brookhaven National Laboratories on Long Island. Tennessee officials were similarly infuriated when they were told by DOE that a spent fuel shipment to be used for research would be moving through the State sometime in the next few months. Tennessee insisted on and received more specific information from DOE and assurances that the State procedures and requirements would be met.[8]

DOE has established the Office of Civilian Radioactive Waste Management to plan and establish specific regulatory and procedural guidelines for spent fuel shipments under NWPA. A more complete discussion of issues related to NWPA shipments may be found on page 106. DOD has authority similar to DOE's to use equipment and procedures equivalent to NRC'S,

DOT sets regulations for all other packaging for radioactive materials in consultation with NRC. NRC approval is required of routes for shipments needing physical protection during transport to prevent theft or sabotage, but the routes chosen must be compatible with DOT regulations described in chapter 4.

Guidelines for public radiation protection are established by the U.S. Environmental Protection Agency and follow international criteria established by the International Commission on Radiological Protection and the National Commission on Radiation Protection. DOT and NRC regulations are based on these guidelines, which establish upper limits on radiation levels around containers.

U.S. regulations for containers used for radioactive materials transportation are based on internationally accepted performance standards. International regulations and standards divide the materials to be shipped into three categories based on their radioactivity levels:*

1. low hazard or very low levels of radioactivity requiring "strong tight" containers,"
2. somewhat higher levels of radioactivity requiring secure containers called "Type A" packages, and
3. fissile materials and those with very high levels of radioactivity requiring exceptionally durable containers called "Type B" packages.

Federal regulations limiting the radioactive contents for the commonly used strong tight and Type A containers are based on the assumption that the containers might break open in an accident and release some of the contents. In contrast, Type B packages, frequently called casks, are required to be sufficiently strong to withstand severe accident conditions, thus providing for safety largely independent of procedural and other controls on the shipment. To assure that Type B packages are designed, constructed, handled, and loaded in a fashion that protects public health and safety, NRC must approve and certify container designs and make certain that quality assurance procedures are implemented for manufacturing, operating, and maintaining the casks.

While the philosophy is to use Type B containers as the first and most important device for public protection, there are additional regulations and requirements for their transportation to reduce potential radiological hazards. First, the movement of high-

[6]10 CFR 71.4; also, "Transportation of Radioactive Materials: Memorandum of Understanding," *Federal Register, vol. 44, No. 128,* July 2, 1979. Among the 22,000 Nuclear Regulatory Commission and Agreement State licensees are manufacturers and users of radiopharmaceuticals, oil exploration companies, 127 nuclear powerplants, and 90 nonpower reactors and their supply industries.

[7]49 CFR 173.7.

[8]Personal communications from DOE and State officials and congressional staff, August to October 1985.

*International Atomic Energy Agency Safety Series 6,1985, now contains a fourth category called "surface contaminated object," which is under consideration to become a U.S. category.

level radioactive materials involves a much greater degree of scrutiny by NRC and DOT than do shipments of low-level materials. NRC monitors the quality assurance programs of its licensees for the construction and operation of spent fuel shipping casks and requires operational checks, such as leak tests, for the casks prior to each use. NRC also conducts routine checks for compliance with regulations at its licensees' facilities. To increase the number of inspections without overtaxing the agency, NRC has transferred authority for inspection of certain activities, including shipment of byproduct, source, and less than critical quantities of special nuclear materials to "Agreement" States.[9]

However, authority for activities related to commercial spent fuel shipments remains with NRC, and its inspectors are on hand at licensees' facilities to monitor the beginning of any spent fuel shipping campaign. In the period July 1983 to June 1985, NRC conducted more than 300 inspections of spent fuel shipments at origins and destinations.[10] As an added precaution, some States through which spent fuel shipments pass may require inspection of shipments by State personnel as well.

NRC also requires that the Governors of affected States be notified in advance of commercial shipments of spent fuel and certain other highly radioactive materials. The information provided must include the name, address, and telephone number of the shipping organization, as well as a description of the material and estimates of times of arrival at State boundaries. DOE notification procedures are much less explicit, creating friction with many States. Moreover, certain shipments that involve national security are exempt from this requirement, although **DOT** requires postnotification of many shipments of highly radioactive materials.

Both DOT and NRC have the authority to impose fines for violations of regulations. However, the enforcement efforts of both agencies have been the subject of severe criticism. NRC has had "too much of a closeness with industry . . ." according to NRC Commissioner, James K. Asselstine.[11] The adequacy of DOT's relatively small inspection forces has been questioned for monitoring the millions of shipments of radioactive materials that do not involve spent fuel.[12] For further details on inspection levels see chapter 5.

Containers

Packaging regulations and standards for shipping radioactive materials were first established in 1946 by the Interstate Commerce Commission, based on recommendations by the National Academy of Sciences. The standards were subsequently adopted by the International Atomic Energy Agency (IAEA) and 53 nations. As part of an ongoing international evaluation of the standards, there have been several updates, including provision in 1967 for Type A and Type B packaging standards. The United States recently revised its regulations slightly to make them consistent with 1973 IAEA guidelines.[13]

The need for technical improvements to the packages is examined as an ongoing part of research and development, and Type B packages have been a focus of DOE-funded research over the years. An international meeting of experts in this area, Packaging and Transportation of Radioactive Materials, is held periodically, about every 3 years, providing a forum for the exchange of information.

Procedures to ensure safe packaging for transporting radioactive materials include:

- categorizing the materials according to their levels of radioactivity and form, and
- requiring the preparation and use of packaging appropriate for the type and quantity of material.

[9]E.L. Emerson and J.D. McClure, *Radioactive Material (RAM) Accident/Incident Data Analysis Program,* SAND 82-2156 (Albuquerque, NM: Sandia National Laboratories, March 1985), p. 7. As of 1986, 28 States are Agreement States and responsible for regulating their 13,000 licensees. NRC is still responsible for regulating its 9,000 material licensees and its some 200 reactor (power and nonpower) licensees, even if they are physically located in an Agreement State. Stephen Salomon, Office of State Programs, U.S. Nuclear Regulatory Commission, personal communication, February 1986.

[10]Alfred W. Grella, Office of Inspection and Enforcement, U.S. Nuclear Regulatory Commission, "NRC Inspection Activities on Recent Shipments of Spent Fuel 1983 to Present," unpublished manuscript of speech presented at the Spent Nuclear Fuel Transportation Seminar, Chicago, IL, Aug. 1, 1985.

[11]Howard Kurtz, "NRC Officials Avoid Pursuit of Wrongdoing, Critics *Say," Washington Post*, Apr. 8, 1986, p. A-1.

[12]Paul Rothberg, Science Policy Research Division, Congressional Research Service, "Hazardous Materials Transportation: Laws, Regulations, and Policy," Issue Brief IB76026, Mar. 11, 1986, p. 5.

[13]10 CFR 71, *Federal Register*, Aug. 5, 1983; International Atomic Energy Agency standards adopted in 1985 require a 200 meter submergence test to allow for transport over coastal ocean depths. Because no U.S. shipments now travel by sea, the United *States* has not yet considered adoption of this new requirement.

The choice of packages is based on the form and quantity* of the material shipped. There are two forms: normal-form and special-form. Most materials are classified as normal-form. They are not highly radioactive, and although they constitute about 87 percent of all radioactive packages shipped annually, they include only 10 percent of the curies. Special-form materials are generally encapsulated solids that present a hazard due to direct external radiation if they escape from the package; although they constitute only about 13 percent of all radioactive packages, they include 90 percent of all the curies shipped annually.[14] However, special-form solid material is not readily dispersible and has high physical integrity, and thus poses relatively little risk from inhalation or ingestion. The quantity of radioactivity in the material is indicated by four subdivisions: excepted or limited quantity, low specific activity, Type A, and Type B.

Excepted *material* is that which is so low in radioactivity that the hazards are negligible, and the materials can be shipped without special packages, shipping papers, or labels. Examples of such materials include smoke detectors, static elimination brushes, lantern mantles, luminous watch dials, and luminous exit signs. Excepted materials are regulated by DOT.

Low specific activity (LSA) material is that in which the specific radioactivity is sufficiently low that the radiological hazard presented by inhalation or ingestion of the material is very small. LSA materials include such things as uranium mill tailings, uranium ore, natural uranium hexafluoride, some low-level wastes, and most laboratory and medical wastes. LSA materials must be contained in strong and tight packages which permit no leakage of radioactive material under normal transportation conditions. Wooden boxes, 55 gallon drums, and special tank trailers fit this criteria. Containers for LSA materials are regulated by DOT in consultation with NRC. Some LSA materials, such as spent resins from reactors, are required to be packaged in NRC-certified Type A packages,

Type *A packaging* is intended to prevent the loss or dispersal of its contents when subjected to a specified set of "normal" transportation conditions. The conditions are actually more severe than the "normal" label implies, as is shown in box 3C. Most radiopharmaceuticals for medical uses are packaged in Type A containers, as are radioassay materials used in research and medicine, and some wastes associated with reactor operation. Type A containers are regulated by DOT in consultation with NRC.

Type B *packaging* requirements are the most stringent. Type B containers are employed for the larger

Box 3C.—Type A Tests: Normal Conditions of Transport* (general description)

Heat.—Direct sunlight at an ambient temperature of 100° F in still air.

Cold.—An ambient temperature of −40° F in still air and shade.

Pressure.—Reduced external pressure of 3.5 pounds per square inch (psi) absolute and increased external pressure of 20.0 psi absolute.

Vibration.—Vibration normally incident to transportation.

Water spray.—Sufficiently heavy to simulate rainfall of 2 inches per hour for 1 hour.

Free drop.—Onto a flat unyielding horizontal surface, striking in a position expected to do the most damage, through the distance specified (note: defined by table from 1 to 4 feet based on package weight).

Corner drop.—Onto each corner in succession (or each quarter of a cylindrical rim) from a height of 1 foot onto a flat unyielding surface (for all fissile Class II packagings . . . and packagings weighing less than 110 lbs).

Penetration.—Impact of the hemispherical end of a vertical steel cylinder 1¼ inches in diameter and weighing 13 lbs, dropped from a height of 40 inches and striking perpendicular to the surface at a point on the package which is expected to be the most vulnerable to puncture.

Compression.—For 24 hours, a load of either five times the weight of the package, or 2 psi times the maximum horizontal cross section of the package, whichever is greater, will be applied against the top and bottom of the packaging in the position in which the package would normally be transported. (For packages less than 10,000 lbs only.)

*From 10 CFR 71.71.

*Quantity refers here to the degree of radioactivity.

[14]Javits, op. cit., p. ii.

Photo credit: Research and Special Programs Administration, DOT

Marking for radioactive materials, required by Federal regulations.

quantities and high-level radioactive materials. Type B packages are required for most fissile materials, spent fuel, highly radioactive waste, irradiated components, radioactive sources for medical therapy, industrial radiography sources, highly contaminated equipment, and power sources for pacemakers. Type B "overpacks" are frequently used for shipping many Type A packages when additional protection is required. NRC regulations contain the standards for Type B containers and certifies the designs used in their construction. The Type B test sequence—drop, puncture, and exposure to heat and water immersion—is described on page 100. DOT regulations allow the use of either DOE- or NRC-certified Type B and fissile packages in commerce.

Type B Containers for Spent Fuel

Underlying the Type B packaging standards is the assumption that the possibility of an accident can never be eliminated and that the package must be able to survive severe accident conditions without a dangerous release of its contents. Thus, NRC regulations provide a set of performance criteria for the containers, rather than specific design requirements. The intent is to remove the need to predict specific accident events and circumstances and to provide a set of engineering test specifications for impact, puncture, temperature, immersion, and leak tightness that encompass the types of conditions that could occur in an accident.

The basic criteria for Type B cask design are virtually the same in every nation with a commercial nuclear program. The most widely recognized Type B containers are the casks for transporting highly radioactive spent reactor fuel from commercial nuclear powerplants. The casks are 10 to over 20 feet long and are constructed of two concentric, welded, stainless steel shells typically 1 to 2 inches thick each, enclosing a gamma radiation shield of lead or depleted uranium metal and a water or other hydrogenous material neutron radiation shield. These casks were designed to contain and ship for reprocessing spent fuel that had been removed from the reactor 4 to 5 months previously and that was still relatively radioactive. However, since no reprocessing of commercial fuel is being carried out in the United States, no utilities are currently shipping fuel less than 10 years old.* A general description of the current generation of U.S. casks is as follows:[15]

- Truck casks (legal weight):
  —weigh less than 25 tons,
  —contain one to two fuel assemblies, and
  —can be unloaded in less than 12 hours.
- Truck casks (overweight):
  —weigh up to 40 tons and are restricted in movement,
  —contain three to seven fuel assemblies, and
  —can be unloaded in less than 16 hours.
- Rail casks:
  —weigh up to 100 tons,
  —contain between 7 and 24 fuel assemblies, and
  —can be unloaded in 28 to 36 hours.

Specific descriptions of spent fuel casks in use in the United States today may be found in table 3-5.**

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*The U.S. Department of Energy and the U.S. Department of Defense routinely make such shipments, however, for research purposes and nuclear submarine maintenance.

[15]U.S. Department of Energy, *Spent Fuel Storage Fact Book*, DOE/NE-0005 (Washington, DC: April 1980), p. 54.

**Monolithic, all-steel casks and nodular cast iron casks are already used in Europe and Japan. Prototypes of such casks have been submitted to the Nuclear Regulatory Commission (NRC) for testing, but none has yet been certified. In the case of nodular cast iron casks, a highly ductile cast iron is required to prevent brittle fractures, which have been a problem in casks tested to date, according to NRC.

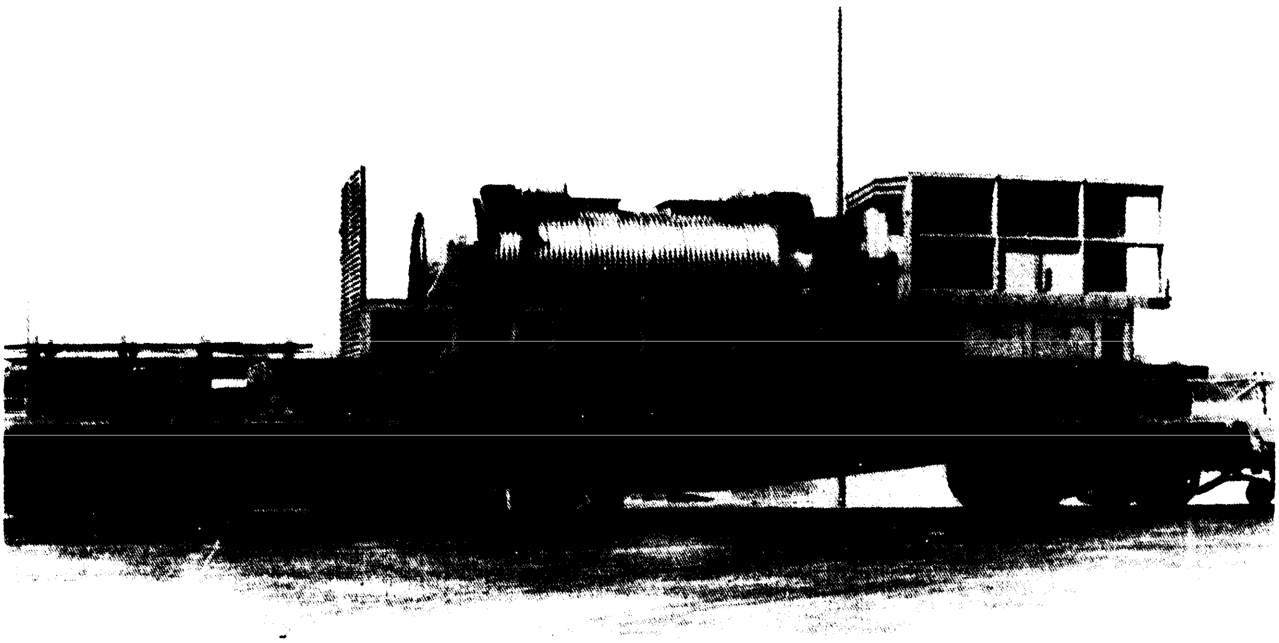


Photo credit: General Electric

Rail cask mounted and secured on a railcar.

Table 3-5.—Characteristics of the Current Generation of Nuclear Regulatory Commission Certified Light Water Reactor Spent Fuel Casks

	Nuclear Assurance Corp. Norcross, GA			General Electric Morris, IL	Transnuclear, Inc. White Plains, NY	
Cask name	NAC-1/NFS-4[a]	NL1-1/2	NL1-10/24	IF-300	TN8	TN9
Transport mode[b]	LWT	LWT	Rail	OWT/Rail	OWT	OWT
PWR/BWR assemblies/cask[c]	1/2	1/2	10/24	7118	3/0	0/7
Loaded weight (tons)	22.5	24	95	63.5 to 70	38	38
Gamma shield	lead	lead/U	lead/U	uranium	lead	lead
Neutron shield	berated water	water-glycol	water-glycol	water-glycol	resin	resin
Cavity coolant	inert gas	helium	helium	inert gas	inert gas	inert gas
Exterior surface	smooth	smooth	stainless steel fins	corrugated	copper spines	copper spines
Units operating	5[d]	5	2[e]	4[f]	4[g]	2[h]

[a]Not currently licensed to transport spent fuel from power reactors.
[b]LWT—legal weight truck; OWT—overweight truck.
[c]PWR—pressurized water reactor; BWR—boiling water reactor.
[d]One unit owned by Duke Power (for transporting spent fuel onsite only).
[e]Cask has never been in service.
[f]One unit owned by Carolina Power & Light
9T[wo] certified units operating in Europe.
[h]One unit owned by Commonwealth Edison.

SOURCE: Sandia National Laboratories, Commercial Experience *Involving* the *Transportation of* Spent *Fuel* and *High Level* Waste *in the* United States, TTC/009 (Albuquerque, NM: May 1981),

Accident Conditions and Test Standards

The hazards associated with highly radioactive materials require the use of special, exceptionally durable packages for transportation. Establishing standards for the design and construction of such packages requires that the types and severity of conditions that could be experienced in an accident be understood and defined.

The Federal approach to ensuring container safety includes:

- **Performance standards** that are specified by NRC and converted by the cask designer to specific design requirements for the container.
- **Engineering test conditions** that are established to encompass real accident conditions. The test conditions may be satisfied by computer analyses, model testing, full-scale tests, or a combination of all three methods.

Performance standards specify how a container must perform under specified conditions, tests, and environments. The infinite number of possible accident variables precludes development of a standard worst-case accident. Consequently, a set of engineering test conditions, based on evaluations of actual accidents, have been chosen to encompass and generally exceed the types of actual accident conditions. Having specific test criteria makes it possible to duplicate tests and compare consequences with different designs and at different times and achieve consistent results. This approach to engineering safety is the basis for current engineering practices, whether for bridges, skyscrapers, or aircraft.

To evaluate whether a cask design conforms to the regulations, NRC requires detailed structural, thermal, and nuclear safety analyses, computer modeling, and scale-model or full-scale tests. The evolution of both computers and modeling techniques has led to reliable ways to establish the adequacy of container designs without destructive testing,[16] and many studies have examined the validity of computer modeling and scale-model tests of casks in accident environments. Where parameters are not known with sufficient precision, assumptions are used that will overestimate damage to a cask.

Full-scale tests have shown that the mathematical analyses, computer models, and scale-model tests accurately predict the behavior of full-scale casks.[17] In a series of tests, a spent-fuel cask was dropped onto several kinds of surfaces at an impact speed of 45 mph.[18] For this velocity, analyses based on the regulatory requirement of impact with an "unyielding" surface predicted a deceleration (or measurement of the amount of energy absorbed by the cask and causing damage) of 1,200 gs. (A "g" is a unit of force equivalent to the force due to gravity.) The full-scale test produced 1,000 gs. For impact onto concrete, the analysis predicted 900 gs; the actual test produced 600 gs. While the models do not precisely predict the actual conditions, the difference is always conservative, predicting higher than actual impact energies. Further studies are being conducted to improve the accuracy of the computer models and to establish extremely severe accident condition bounds.[19] Similar results and confidence exist in the computer models for evaluating scale-model tests.[20]

The engineering tests established to encompass accident conditions for Type B packages can be summarized as follows.[21] The conditions are to be ap-

[16] M. Huerta, *Analytical and Scale Modeling Techniques for Predicting the Response of Spent-Nuclear Fuel Shipping Systems in High-Velocity Impacts Against a Rigid Barrier, SAND77-0270* (Albuquerque, NM: Sandia National Laboratories, April 1978); see also, M. Huerta and H.R. Yoshimura, *A Study and Full-Scale Test of a High-Velocity Grade-Crossing Simulated Acciden. of a Locomotive and a Nuclear-Spent-Fuel Shipping Cask,* SAND79-2291 (Albuquerque, NM: Sandia National Laboratories, February 1983).

[17] J.D. McClure, et al., "Relative Response of Type B Packaging co Regulatory and Other Impact Test Environments," *Proceedings of the 6rh International Symposium on Packaging and Transportation of Radioactive Materials (PA TRAM),* vol. II, held in Berlin, Federal Republic of Germany (Springfield, VA: National Technical Information Service, November 1980), pp. 1247-1252.

[18] W.E. Wowak, Research *and* Development *at the Transportation Technology Center*, SAND TTC-0484 (Albuquerque, NM: Sandia National Laboratories, 1984); presented at the Packaging and Transportation of Radioactive Materials Seminar, Washington, DC, April 1984.

[19] A.A. Trujillo, et al., "Thermal and Structural Code Evaluation," *Proceedings of the 7th International Symposium on Packaging and Transportation of Radioactive Materials (PA TRAM),* held in New Orleans, LA (Springfield, VA: National Technical Information Service, May 1983). The Nuclear Regulatory Commission is currently sponsoring research at the Lawrence Livermore Laboratories into the engineering conditions that have resulted from very severe transportation accidents.

[20] W.E. Baker, "Scaling and Prediction of Impact Puncture of Shipping Casks for Radioactive Materials," *The Shock and Vibration Bulletin,* Bulletin *48* (Washington, DC: Naval Research Laboratory, September 1978); see also, B. Evason, "Impact Modeling and Reduced-Scale Tests," *The Urban Transport of Irradiated Fuel* (London: Macmillan Press, 1984), p. 233.

[21] 10 CFR 71.73.

plied sequentially to determine the cumulative effect on a package:

- Free drop.–A free drop of 9 meters onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected.
- Puncture.–A free drop of 1 meter, striking in a fashion for which maximum damage is expected, the top end of a vertical, cylindrical, mild steel bar mounted on an essentially unyielding, horizontal surface. The bar is 15 centimeters in diameter, with the top horizontal and its edge rounded to a radius of not more than 6 millimeters, and such a length as to cause maximum damage to the package, but not less than 20 centimeters long. The long axis of the bar is perpendicular to the unyielding, horizontal surface.
- Thermal test.–Exposure to a thermal test in which the heat input to the package is not less than that which would result from exposure of the whole package to a radiation environment of 800° C for 30 minutes, with an emissivity coefficient of 0.9. The package may not be cooled artificially.
- Water immersion (for fissile material packages only) .—Immersion in water to the extent that all portions of the package are under at least 15 meters of water for a period of not less than 8 hours.

Familiarity with the engineering principles involved is critical to understanding the safety provided by the casks. These four conditions have been widely described, in simplified form, in popular literature on the subject of the transportation of spent fuel.[22] However, simplified descriptions often cannot accurately represent the technical criteria, and at least two of these are often misunderstood—the free drop and thermal test conditions.

The free drop, or drop test *criterion* of 9 meters, about 30 feet, may appear substantially inadequate considering that the maximum reported falling distance for a rail accident was 76 feet and for a truck accident, 89 feet.[23] In addition, concern has been voiced over the chance of an accident in which a cask falls from a bridge 300 feet above water.[24] The critical engineering condition in the criterion is the use of an *unyielding* surface, meaning that all of the energy resulting from impact is absorbed by the cask. Such a surface provides a worst-case and consistent basis for testing and engineering design purposes. Sandia National Laboratories have conducted tests and analyses of casks on conventional common surfaces to compare damages inflicted on casks after impact with an *unyielding* surface.

However, virtually no natural surface or manmade structure encountered in the transportation environment would be *unyielding.* Almost all surfaces will yield, thus absorbing some of the impact energy that would otherwise go into damaging the cask. The 30-foot drop test results in a cask velocity of 30 mph on impact. To produce the same damage as a 30-mph collision with an unyielding surface, a cask velocity of 65 to 90 mph is required. Sandia also dropped a smaller Type B test container 2,000 feet onto hard, undisturbed earth.[25] The cask hit the ground at 235 mph and buried itself some 41/2 feet into the ground. The cask suffered no damage other than paint abrasion, although dropping a similar cask 30 feet onto an unyielding surface at an impact velocity of 30 mph produced visible damage. See box 3D for a description of the Sandia National Laboratories full-scale cask tests.

A British Central Electricity Generating Board demonstration in 1984, in which a locomotive crashed into a cast steel cask* at 100 mph, while dramatic, caused little damage to the cask. More to the point, the energy imparted to the cask on impact was about

[22] International Atomic Energy Agency, *Safe Transport of Radioactive Material* (Vienna, Austria: May 1982); George Russ, *Nuclear Waste Disposal: Closing the Gap* (Bethesda, MD: Atomic Industrial Forum, June 1984), p. 21; Resnikoff, op. cit., p. 20.

[23] Ridihalgh, Eggers, & Associates, Inc., *Definition of Bounding Physical Tests Representative of Transport Accidents—Rail and Truck," vol.* 1 (Washington, DC: U.S. Nuclear Regulatory Commission, Aug. 30, 1982), p. 98.

[24] Joseph Strohl, in U.S. Congress, op. cit.

[25] I Waddoups, *Air Drop Test of Shielding Radioactive Material Containers, SAND75-0276* (Albuquerque, NM: Sandia National Laboratories, September 1975).

*Cast steel casks do not have the weldments that have proven to be troublesome in some current casks. Although they are widely used in Europe, no cast steel casks have yet been licensed for use in the United States.

Box 3D.—Full-Scale Spent Fuel Cask Crash Tests

In 1976 and 1977, a series of full-scale tests were undertaken for the U.S. Department of Energy by Sandia National Laboratories. Obsolete casks containing nonirradiated stainless steel clad fuel were used in the tests, since the intent was not to certify the integrity of a specific operational cask, but to compare predictions to actual events involving a cask accident.

The primary purpose of the tests was to validate the computer models used to design and evaluate spent fuel shipping casks. The tests also provided other information. These were the first full-scale accident simulations conducted on a spent fuel cask. The tests allowed full instrumentation to be utilized in order to assess the magnitude of the forces and other stresses encountered in a number of accident cases. By using these measurements it was possible to validate the use of "lumped parameter" models to predict accident environments over the entire range of possibilities. The test program also included sub-scale tests (one-eighth and one-fourth scale) to evaluate the accuracy of reduced scale testing.

The program began with the development of "lumped parameter" models which were used to predict the accident environment which the spent fuel casks would encounter. Calculations were made to determine the tiedown strengths, structural crush-up, and structural failure, all of which were translated into time v. velocity predictions for the cask. These calculations, for example, predicted that in the 60 mph truck accident the tiedowns would not fail until very late in the event resulting in the cask impacting the wall at about 30 mph. Actual impact velocity was 27 mph. Using the same analytical tools it was predicted that in the 80 mph impact, the tiedowns would fail early and the resulting impact velocity would be about 65 mph. Actual impact was 65 mph. The results of these "lumped parameter" calculations were then applied in determining the effect on the shipping cask. Calculations using the widely accepted technique known as finite element analysis predicted cask deformations in each case under study. Engineers then used these analytical predictions to estimate the extent of cask failure, if any, that would be produced by the test. Scale models were built and tested to evaluate the analytical results and the scale-model testing techniques themselves.

Cracks occurred both in the bodies of the casks and in some of the weldments, and, in one fire test, the lead radiation shield began to vaporize. Nonetheless, the actual accident damage to the cask was the same as or less severe than the predictions. The predictions were in good agreement with the results even where they overestimated damage. Any additional stresses that might have occurred had irradiated, zircalloy fuel rods (currently used throughout the nuclear fuel industry) been used or damaged in the casks were not addressed by the tests and deserve further study.

one-sixth that which would have been imparted by a 30-foot drop test onto an unyielding surface.[26]

The thermal test specifies a temperature of 800° C (1,475° F) and may appear to understate real fire conditions, since typical flame temperatures for burning fuels are 1,850° to 2,200° F. The criterion requires a "radiation environment" for the whole package of 800° C, *not* a flame temperature of 800° C, and further specifies that an emissivity coefficient of the source of at least 0.9 and an absorptivity of the cask of at least 0.8 must be assumed for calculations. Producing a thermal "radiation environment" equivalent to 800° C requires a flame temperature higher than 800°. The emissivity coefficient refers to the amount of heat that the flames are assumed to radiate (90 percent) compared to the maximum theoretical amount, 100 percent, that could be radiated by ideal flame sources. The cask absorptivity coefficient is specified as 0.8, or 80 percent of the theoretical maximum heat absorption. These technical specifications require that the cask be completely enveloped in the thermal environment so that the cask absorbs virtually all of the heat, with little of it being radiated or conducted away. A stainless steel cask may have an initial absorptivity of about 0.2 and a fire about 0.5 to 0.6. The net result is that the heat absorbed by the cask

[26]Richard Cunningham, U.S. Nuclear Regulatory Commission, in U.S. Congress, Office of Technology Assessment, "Transcript of Proceedings—OTA Advisory Panel Meeting on Hazardous Materials Transportation," unpublished typescript, June 27, 1985, p. 250.

in the test environment is greater than it would be in a real fire.

Sandia National Laboratories conducted an experiment in which a spent fuel cask, designed to withstand a 60-minute fire, was suspended over a pit filled with burning jet fuel. However, the fuel was cut off after 100 minutes, because due to defects in cask manufacture, heat caused the outer shell of the cask to crack and the lead shielding began to vaporize. Regulations specify a 30-minute exposure to a 1,4750 F thermal environment; jet fuel burns at about 1,8000 F. Nonetheless, under these conditions, instruments showed that the thermal environment was less severe than the casks are required to meet.[27] A number of technical organizations have conducted tests confirming that a 1,475° F temperature is a realistic *thermal environment* associated with fires as hot as 1,850° F.[28]

Such results are consistent with the fact that in a real fire, the temperature is not uniform and the cask is not totally enveloped. A fully engulfing fire, as regulations specify, is difficult to imagine since the cask will be resting on a vehicle or the ground, and will thus be partially protected from heat—and a means will exist for conducting some heat away. Natural and many accidental fires have varied temperature profiles with peak flame temperatures of about 1,850° F. However, some railroad fires burn at higher temperatures, and the fire in the enclosed environment of the Caldecott tunnel in Oakland, California, created a thermal environment that approached that of the regulatory standards. The Federal Railway Administration is considering testing casks to determine whether internal cask temperatures remain at safe levels under extreme fire conditions.[29]

Flame emissivities are strongly associated with flame thickness–the greater the flame thickness, the higher the effective emissivity. However, increasing flame thickness for open fires also reduces ventilation, and if a fire were to engulf a cask, it would reduce ventilation for the flames surrounding the cask, and thus tend to lower flame temperatures.[30] Finally, the very high theoretical flame temperatures for certain chemical fires can be achieved only under ideal conditions, often requiring a direct air supply to the fuel.

A third test, the puncture test, is generally well understood. However, new equations and analytical methods have been developed since the current cask designs were certified[31] that will increase the accuracy of future tests.

The four criteria set out are intended to result in a cask design sufficiently robust to withstand different types of accidents and do not specifically include all types of accident events. For example, there is no requirement for the cask to withstand a torch-like flame that may be created in a tank car accident; nevertheless,” tests have been conducted on shipping casks to observe and measure the effect of a torch. Test results show that because the torch introduces heat to a limited area of the cask, and the large cask has a high heat capacity and is an effective thermal conductor, the torch flame produces conditions less severe than the all engulfing fire condition.[32]

A crushing force is another accident condition not directly specified by the regulatory criteria. An NRC-sponsored study of this condition concluded that casks that meet the impact and puncture criteria are at least equally resistant to crushing forces.[33] Another study concluded that the crushing load of an entire locomotive on the (spent fuel) packages that meet the requirements will not exceed the packages' capability, based on bounding crush

[27]R Pope, et al., *An Assessment of Accident Thermal Testing and Analysis Procedures for Radioactive Materials Shipping Packages, 80-HT-38* (Washington, DC: American Society of Mechanical Engineers, April 1981).

[28]Ibid.

[29]Claire L. Orth, Office of Safety Analysis, Federal Railroad Administration, U.S. Department of Transportation, personal communication, March 1986.

[30]W Dircks, Nuclear Regulatory Commission, Washington, DC, “Staff Memorandum, Feb. 10. 1982.” unpublished typescript.

[31]Charles E MacDonald, Certification Division, Nuclear Regulatory Commission,” personal communication, May 1986.

[32]M.G. Vigil, et al., *HNPF Spent Fuel Cask Temperature Response: Torch Impinging on Water Filled Neutron Shield, SAND82-0702* (Albuquerque, NM: Sandia National Laboratories, March 1982); Philip E. Eggers, et al., “Thermal Response of HNPF Spent Fuel Shipping Container in Torch Environments,” *Proceedings of the 6th International Symposium on Packaging and Transportation of Radioactive Materials—1980* (Springfield, VA: National Technical Information Service, November 1982).

[33]U.S. Nuclear Regulatory Commission, *Potential* Crush Loading *of* Radioactive *Material* Packages in Highway, Rail, *and Marine Accidents,* NUREG/CR-1588 (Washington, DC: October 1980).

loads of half of the 400,000 pound weight of the locomotive resting on the package.[14]

OTA performed independent calculations that satisfactorily verified these analytical results.[35] Box 3E provides answers to some commonly raised questions about the casks,

The NRC cask certification process is of necessity painstaking and time-consuming. The safety record of NRC-certified casks, however, provides a degree of public confidence in the casks. The regulatory system governing the movement of radioactive materials has worked well. There have been no releases of radioactivity from the accidents involving spent nuclear fuel containers currently certified for transportation. Of the 2,552 packages for low-level radioactivity materials involved in accidents between 1971 and March 1985, only 67 were sufficiently damaged to cause releases. These packages are not required to contain the material in the event of an accident, and all releases involved low levels of activity that posed little threat to public health. (See table 3-6.)

Risk—Accident Probabilities and Consequences

An assessment of overall public risk must combine estimates of probability and consequence. Moreover, estimates of accident probabilities must include two factors: 1) the probability that any given vehicle carrying spent fuel will be in an accident, and 2) the probability that the spent fuel shipping cask will release any of its contents. The first of these is relatively easy to assess since a large amount of actuarial data about accident rates have been developed. Bureau of Motor Carrier Safety statistics show that accidents involving trucks occur once every 400,000 miles of travel, while rail statistics from the Federal Railroad Administration show that a rail accident occurs every 139,000 miles of travel. This translates into a probability of 2.5 X 10^{-6} truck accidents and 7.2 ^{x6} rail accidents per vehicle-mile.[36]

For the second factor, likelihood of release, estimates must be used, since there is *no* significant actuarial record. A report from the Transportation Technology Center at Sandia National Laboratories estimates that fewer than 1 in 100 accidents would involve conditions severe enough to cause concern over a release of some contents of the cask.[37] This estimate appears consistent with analyses of the stresses involved in numerous actual highway and rail accidents of all types. The analyses show that real accident stresses do not exceed the test conditions in the regulatory standards in 99.5 and 99.9 percent of truck accidents involving impact and fire, respectively; as well as 99.6 and 99,9 percent of rail accidents involving impact and fire, respectively.[38] Thus, the overall probability of a truck or rail shipment of spent fuel being involved in an accident where conditions are sufficiently severe to cause some release of radioactive materials is less than 2.5 X 10^{-8} per vehicle-mile—or less than once for every 40 million miles of transport.

Table 3-7 shows estimates based on an OTA analysis of truck and rail accident rates in the year 2000. Current DOE estimates indicate that there are likely to be about 1,000 annual shipments from commercial reactors to a storage site.[39]

The consequences of a spent fuel cask accident involving radioactive material releases are proportional to the quantities of radioactivity released, the estimated health effects of the specific radioactive materials released, and the exposure of individuals or population groups to the materials. Related variables include:

- **The age of the spent fuel-Older spent fuel—out of the reactor for 5 or more years—is much cooler than recently discharged fuel both in thermal and radiological terms. If more spent fuel is carried in each cask to reduce the number of necessary trips, the amount of thermal activity in the cask will increase. The radioactivity available for release and the heat available to raise the temperature of the spent fuel**

[34] Philip E. Eggers, Severe *Rail and Truck Accidents: Toward a Definition of Bounding Environments for Transportation Packages,* NUREG/CR3499 (Washington, DC: Nuclear Regulatory Commission, October 1983), p. 69.

[35] OTA background analysis, June 1985.

[36] Edward W. Sheperd, *Transportation Technology Center Quick Reference File,* Item TTC/012, SAND79-2101 (Albuquerque, NM: Sandia National Laboratories, May 1981).

[37] Ibid.

[38] T. Wolff, *The Transportation of Nuclear Materials,* SAND84-0062 (Albuquerque, NM: Sandia National Laboratories, December 1984).

[39] U.S. Department of Energy, "Environmental Assessment for a Monitored Retrievable Storage Facility," *Monitored Retrievable Storage Submission to Congress, vol. 2,* RW0035, review copy, unpublished typescript, December 1985, p. 2.23.

Box 3E.—Brief Answers to Common Questions

A wide range of public concerns has been raised regarding the transportation of spent reactor fuel. Many of the concerns surround three general areas:

1. What happens if a spent fuel cask is in an accident that causes it to leak?
2. Can the fire test standards really be adequate if they specify a temperature lower than that at which many substances burn?
3. What is the worst that can happen?

Facts pertinent to the questions:

1. What happens if a spent fuel cask is in an accident that causes it to leak?
   - The shipping casks are 10 to over 20 feet long, weigh 20 to 100 tons and are constructed of two concentric stainless steel shells, typically 1 to 2 inches thick enclosing a radiation shield of lead. A broken cask would be one in which, for example, the lid (itself weighing several tons) or a valve on the cask were to leak.
   - Spent fuel is a solid ceramic-like material. It has a melting point higher than any fire temperature and cannot explode.
   - In the event of an accident with a large fire, the heat might cause release of small amounts of volatile radioactive elements in the spent fuel. These would disperse rapidly, and health effects would be minimal.
   - The principal radiation risk is from the possibility of inhaling any radioactive materials released in the accident. Only people at the immediate scene are likely to be affected.
   - The amounts of radiation exposure likely to be associated with such an accident are lower than those associated with radiation exposure from many natural sources.[1]
   - State and local emergency response personnel must be trained properly to deal with the accident by sealing off the accident area and notifying appropriate response experts. Federal technical assistance is available from both the Nuclear Regulatory Commission and the U.S. Department of Energy.*
2. Can the fire test standards really be adequate if they specify a temperature lower than that at which many substances burn?
   - Yes, spent fuel shipping casks are required to meet certain overall thermal requirements, which include but are not limited to, fire temperatures.
3. What is the worst that can happen?
   - No one can be certain what the worst might be, since there has never been an accident with any significant release. A series of events, including poor quality control during cask manufacture or improper preparation for shipping, would have to transpire before any release at all would occur. Another series of events would have to take place related to the accident before the release would be more than negligible. However, fatalities due to the nonradiological consequences of an accident are far more likely than any due to radiation. Environmental and property damage and long-term health impacts are more difficult to assess.
   - The worst event is often considered sabotage. Sandia National Laboratories have conducted experiments with explosives to measure the quantity of radioactive material that could be released—they discovered that 0.0006 percent could be released, an amount too small to be significant.[2]

*See chapter 5 for additional information on emergency response training.

[1]See for example R.R. Fullwood, "Risks Associated With Nuclear Material Recovery and Waste Preparation," *Nuclear Safety*, vol. 25, September-October 1984, p. 665; and U.S. Congress, Office of Technology Assessment, *Managing the Nation's Commercial High-Level Radioactive Waste*, OTA-O-171 (Washington, DC: U.S. Government Printing Office, March 1985), p. 46, which shows 3,000 to 4,000 latent cancer fatalities per year due to natural background radiation.

[2]R.M. Jefferson, *Shipping Cask Sabotage Source Term Investigation*, NUREG/CR-2472 (Washington, DC: Nuclear Regulatory Commission, 1982).

must thus be carefully analyzed. High temperatures are necessary for volatile materials to be released.

- The **types of material released.—Radioactive material released from a damaged spent fuel assembly will not necessarily escape from the shipping cask. Small amounts of radioactive gases, mainly the inert gas Krypton 85, could escape readily from the assembly, but will dissipate relatively harmlessly in the open air. Other more critical radioactive materials, such as volatile cesium and rubidium isotopes, will tend** to plate

Table 3-&- Radioactive Materials Involved in Transportation Accidents (January 1971 to March 1985)

Packaging category contents	Number of packages involved	Number of packages failing	Number of packages releasing contents
Strong tight industrial and miscellaneous unclassified	596	62	56
Type A	1,956	28	11
Type B:			
Spent fuel (see box B)	4	0	0
Medical sources	24	0	0
Uranium hexafluoride	3	0	0
Radiography and well logging	8	0	0
Other Type B	11	0	0
Total Type B	50	0	0

SOURCE: J.D. McClure and A. Tyron-Hopko, Radioactive *Material Transportation* Accident Analysis, SAN D85-1016 (Albuquerque, NM: Sandia National Laboratories, July 1985).

Table 3=7.—Estimated Occurrences of Accidents During the Transport of Spent Fuel

Mode	MTUs[a] per shipment	Miles per shipment	Total number of shipments per year	Accidents[b] per year	Years between accidents where stresses approach performance test
With MRS[d]					
Trucks to MRS	1.0	700	725	1.27	158
Rail to MRS	7.0	700	250	1.26	159
Rail, MRS to repository	112.5	2,400	22	0.38	526
Without MRS:					
Truck	1.0	2,400	725	4.35	46
Rail	7.0	2,400	250	4.32	46

[a]MTU—metric ton of uranium.
[b]Assumes one accident per 400,000 miles for truck (BMCS data) and one accident every 139,000 train miles for rail (FRA data)
[c]Assumes that 99.5 percent of highway and rail accidents are less severe than the performance tests (Robert M, Jefferson, Sandia Report SAN D64-2128, TTC-0528, January 198S)
[d]MRS—monitored retrievable Storage
[e]Assumes MRS is in Tennessee, Assumes the repository is in Nevada.

NOTE: Shipments will begin in the year an MRS is opened

SOURCE: Office of Technology Assessment

out on the surfaces of the cask, making them less likely to reach the environment.'"

- The location (in a rural or urban area) of an accident.

Estimates have been made of the combined risks to the public based on the probability of an accident and using the consequences of the releases. Sandia National Laboratories estimates that the probability of an accident involving spent fuel causing five or more fatalities over time is low—5 X 10^{-6} a year. No more than five early fatalities were considered possible under worst--case accident conditions in a heavily populated urban area.[41] Another estimate puts the risk in slightly different terms: 1 X 10^{-8} latent cancers per 1,000 MW(e)* powerplant for six trips transporting spent fuel 1,000 miles.

However, the environmental and/or economic effects of a transportation-related release require thorough examination.[42] Not considered heretofore has been the extent of public injury or loss of life that

[40]W. Dircks, *Fission Product Release From Highly Irradiated Fuel*, NUREG/CR-0722 (Oak Ridge, TN': Oak Ridge National Laboratory, 1980). A series of experiments on irradiated fuel found a fractional release of 0.3 percent for cesium from the fuel elements—not from the cask. Such a release was estimated to produce no early fatalities.

[41]U.S. Nuclear Regulatory Commission, *Transportation of Radionuclides in Urban Environs: Draft Environmental Assessment*, NUREG/CR-0743 (Washington, DC: July *1980)*, p. 66.

*Megawatts of electricity

[42]Western Interstate Energy Board, "Environmental Assessment for a Monitored Retrievable Storage Facility," *Nuclear Waste Policy Act: Monitored Retrievable Storage Submission to Congress, vol.* 2, DOE/RW-003, unpublished review manuscript, December 1985, p. 54.1.

might be caused by nonradiological risk, such as the magnitude of the accident, fire, and damage associated with an accident severe enough to damage a spent fuel cask. The nonradiological risk of death associated with moving the spent fuel is estimated to be 1 million times greater than the radiological risks.[43]

Sabotage has also been used as a condition for assessing the possible consequences of a spent fuel accident. Data show that historically, sabotage and vandalism have not been problems associated with the transportation of hazardous materials (see chapter 2, part II for detailed information). However, the increase in international terrorist activities indicates that the possibility of a successful sabotage effort is not to be discounted. Early analyses for NRC indicated an estimated five to nine early fatalities and up to 1,800 latent cancer fatalities associated with radioactive material releases following a successful act of sabotage on a spent fuel cask in an urban area.[44] Based on a conservative assumption that about 0.7 percent of the contents of a spent fuel cask could be released in respirable form following a successful sabotage attack, NRC developed transportation safeguard rules requiring an armed guard to accompany each spent fuel shipment. In 1981 and 1982 simulation tests were conducted to evaluate the release consequences of an explosive attack on spent fuel casks.[45] The simulations showed a release of 0.0006 percent of the cask contents,[46] reducing estimates to no early fatalities and, at most, 14 latent cancer fatalities in an urban population that would normally experience 250,000 cancers over the same period.[47] On the basis of these revised estimates, NRC proposed relaxing the safeguard rules. Their proposal met with objections from a number of States, and a final decision on safeguard requirements is still pending.[48]

Future Spent Fuel Shipments Under the Nuclear Waste Policy Act

The passage of the NWPA of 1982 established that DOE will take title to spent fuel from utilities in 1998 and assume responsibility for its transportation and ultimate disposal. As there will be some 90,000 spent fuel assemblies in U.S. spent fuel pools by that time,[49] DOE may be responsible immediately for a number of shipments to a repository or monitored retrievable storage facility. Depending on the type and carrying capacity of the casks ultimately constructed and certified for these shipments, DOE estimates that approximately 250 rail and 725 truck shipments will be required annually to move spent fuel from eastern reactors to a monitored retrievable storage facility or repository .50 For NWPA shipments, DOE has agreed to meet DOT and NRC safety and security requirements in effect at the time and will use only transportation casks that have received an NRC certificate of compliance.[51]

A new generation of casks is being designed and tested and will be employed to move spent fuel to a national repository under NWPA. Sometime in 1986 the Office of Civilian Radioactive Waste Management at DOE will issue a "Request for Proposal" for the design and construction of these casks. The new casks are likely to have somewhat different characteristics from those of the current casks, which carry between 1 and 24 assemblies (see table 3-5), because they will be designed to hold older, less

[43]R. R. Fullwood, "Risks Associated With Nuclear Material Recovery and Waste Preparation," *Nuclear Safety,* vol. *25, No. 5,* September-October 1984, pp. 654-667.
[44]U.S. Nuclear Regulatory Commission, *Transportation of Radionuclides in Urban Environs,* op. cit.
[45]R.P. Sandoval, et al., *An Assessment of the Safety of spent Fuel Transportation in Urban Environs,* SAND82-2365•TTC-0398 (Albuquerque, NM: Sandia National Laboratories, June 1983).
[46]Robert M. Jefferson, *Shipping Cask Sabotage Source Term Investigation,* NUREG/CR-2472 (Washington, DC: U.S. Nuclear Regulatory Commission, 1982).
[47]Sandoval, et al., op. cit.

[48]Terry Lash, Director, Illinois Department of Nuclear Safety, at U.S. Nuclear Regulatory Commission/U.S. Department of Transportation, Spent Nuclear Fuel Transportation Seminar, Chicago, IL, Aug. 1, 1985.
[49]George Russ, Atomic Industrial Forum, Bethesda, MD, personal communication, 1985. See also U.S. Congress, Office of 'technology Assessment, *Managing the Nation's Commercial High-Level Radioactive Waste,* OTA-O-171 (Washington, DC: U.S. Government Printing Office, March 1985), p. 28.
[50]U.S. Department of Energy, "Environmental Assessment for a Monitored Retrievable Storage Facility," op. cit., p. 2.23.
[51]U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Office of Storage and Transportation Systems, "Transportation Institutional Plan," unpublished internal review draft manuscript, Mar. 3, 1986, pp. 3 and D-57.

radioactive spent fuel. Since the oldest fuel will be shipped first, most of the initial shipments will be of fuel at least 20 years old,[52] and it is likely that the next generation of casks will carry significantly greater numbers of assemblies. The designs will be based on carrying the maximum possible number of spent fuel elements within weight and safety limits, to reduce the number of shipments necessary. Recent improvements in materials, such as ductile, nodular cast iron, and design, such as monolithic steel, have yielded casks that may meet many concerns voiced about today's casks.

DOE is also examining the possibility of employing very large capacity dual-use casks for transportation. These dry casks, currently under review by NRC for utility-site storage purposes only, offer an opportunity to minimize the number of shipments and the handling of the spent fuel. Once the fuel has been removed from the reactor and placed in dry, onsite storage in these dual-use casks, the handling and worker-exposure risk would be reduced if the same casks could be used to transport the spent fuel to a repository. However, the conditions for casks used for transportation are more stringent, and although NRC has pending applications for certification of two such casks, none has yet been certified for both purposes.[53]

Moreover, questions will need to be answered about the effects of the large, heavy casks on the stability of the carrying vehicles, whether truck or railcar. The weight would not be a concern if barge transportation were used, and water transportation has the best modal safety record. However, the increased handling necessary to transfer the cask from truck or rail to barge and the increased turnaround time required for reusable casks by the slower barge travel are trade-offs that must be considered. Finally, the integrity of the casks for transport after possible weakening from corrosion and thermal effects, subsequent to extended onsite storage of a decade or more, must be studied.

[52] Lake Barrett, Director, Transportation and Waste Systems Division, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, personal communication, Dec. 5, 1985.

[53] U.S. Department of Energy, Office of Civilian Radioactive Waste Management, *Annual Report to* Congress, DOE/RW-0004/2 (Washington, DC: March 1986), p. 23.

Spent Fuel Transportation Risks and Public Perceptions

About 6,500 spent fuel assemblies have been shipped to date in the United States. while several accidents have occurred involving spent fuel casks in the United States (in one case the cask was empty), there has never been a shipping accident involving a Type B package carrying spent fuel that caused a significant release of radioactive material. (See box 3F for a brief description of four typical incidents involving Type B casks.)

DOT maintains a Hazardous Material Information System (HMIS) which, with additional data

Box 3F.-Spent Fuel Casks involved in Transportation Accidents*

December 8, 1971.–A tractor-trailer rig carrying a spent fuel cask with one fuel element left the highway to avoid a head-on collision. The truck rolled over and threw off the cask. The driver died of injuries. The cask sustained minor damage and did not release any contents.

February 9, 1978.–Shortly after leaving its point of origin, a trailer, carrying a cask containing six fuel elements, buckled from the weight. The cask stayed on the trailer and was not damaged. There was no leakage.

August 3, **1978.–An empty cask being loaded on a trailer broke through the trailer bed causing minor damage to the impact limiter and the cask base plate. No radioactive material was released.**

December 9, 1983.–The trailer carrying a spent fuel cask, containing seven spent fuel assemblies, uncoupled from the tractor, leaving the cask sitting on the trailer supported by its rear wheels and a "jo-dog'* in front. When the air and electrical lines parted, the brakes on the trailer and "jo-dog" locked, bringing the unit to a rapid stop on the highway. The uncoupling occurred as the tractor began moving after a momentary stop in a construction zone. There was no damage to the cask and no release of radiation.

[1] R. Jefferson, former Manager, Transportation Technology Center, Sandia National Laboratories, Albuquerque, NM, personal communication, 1985,

*A "jo-dog" is an apparatus that connects the front end of a trailer to a tractor. It has its own set of wheels. [t was used in this case to dia. tribute the weight more evenly over the axles.

from NRC files and other sources, supports the Radioactive Materials Transportation Accident/Incident Data Base developed by the Transportation Technology Center at Sandia National Laboratories under DOE contract. HMIS records since 1971 indicate that about 0.6 percent of all entries involved radioactive materials; of these, about 20 percent were transportation accidents.[54] Table 3-6 lists the numbers and categories of all radioactive materials involved in reported transportation accidents occurring between January 1971 and March 1985.

This safety record not withstanding, public attention focuses sharply on any accident involving nuclear materials, and Federal officials must respond frequently[55] to questions about the adequacy of Federal safety requirements.[56] The effect of this debate has been a heightened public awareness of the risks associated with transporting radioactive materials, especially spent reactor fuel. One result of this awareness has been the enactment of numerous State and local laws restricting operations and routing of radioactive materials, especially spent fuel and high-level waste shipments. Such restrictions have frequently led to local and national legal disputes. For further discussion of these disputes, see chapter 4.

At the root of much of the discussion, debate, and concern over spent fuel shipments are three factors:

1. The extent to which risk and benefit issues are difficult to explain. In the case of spent fuel shipments, there is no actuarial record of public fatalities, so risk estimates must be based on calculations.
2. The extent to which the public is apprehensive about nuclear energy and radiation in general or distrusts the nuclear industry because of previous accidents and transfers this to the movement of spent fuel on routes in their State or city.
3. The extent to which the public is aware of the demonstrations and technical information now available and the extent to which it is possible to explain the relevant technical information in a popular forum.

These factors all involve problems that are common to technology and risks, and nuclear energy in general, and are not specific to the transportation of spent reactor fuel. Nonetheless, a brief examination of some of the disparities between perceived and statistically determined risks may be useful.

A large and growing body of literature is devoted to the issues of risk, public perception, risk management, and education. Nuclear energy is often used as a specific case.[57] The fact that public and expert opinion diverge dramatically, for example, on the issue of nuclear safety is a case in point—in one poll, out of 30 activities involving risk, experts ranked nuclear power number 20 while the public ranked it number l—the most hazardous.[58] The explanations for this phenomenon are not simple and are themselves a subject of debate.

The difference between the statistical risks and perceptions of risk are substantial. For example, the actuarial record for the shipment of other energy commodities provides evidence for much greater risk and a consistent record of public fatalities. There are estimated to be some 29 annual public fatalities associated with highway shipments of gasoline, 14 associated with highway shipments of propane, and 9 associated with rail shipments of chlorine.[59] The record for public fatalities from spent fuel shipments to date is zero, and is estimated to be 0.0001 fatalities due to radiological factors per year with 2,000 shipments per year;[60] 15 to 100 fatalities are esti-

[54] OTA calculations based on Sandia National Laboratories, *A Review of Accident/Incident Experience Involving the Transportation of Radioactive Material*, SAND81-1330C-Summary (Albuquerque, NM: March 1982). Reported categories include handling accidents and "actual or suspected release of radiation or materials" and "surface contamination" in excess of regulatory requirements.

[55] R. Jefferson, *Transporting Spent Reactor Fuel: Allegations and Responses, SAND82-2778* (Albuquerque, NM: Sandia National Laboratories, March 1983); R. Jefferson, et al., *Analysis of Recent Council on Economic Priorities Newsletter*, SAND82-1250 (Albuquerque, NM: Sandia National Laboratories, March 1983); Dircks, *Fission Product Release From Highly Irradiated Fuel*, op. cit.

[56] Sierra Club, "Shipping Casks: Are They Safe?" *Sierra Club Radioactive Waste Campaign Fact Sheet* (Washington, DC: no date); and Resnikoff, op. cit.

[57] See for example, Alvin Weinberg, "Science at Its Limits," *Issues in Science and Technology, vol.* II, No. 1, fall 1985, pp. *59-72;* Peter Huber, "The Bhopalization of U.S. Tort Law," *Issues in Science and Technology*, vol. 11, No. 1, fall 1985, pp. 73-82; and Baruch Fischoff, "Managing Risk Perception," *Issues in Science and Technology, vol.* II, No. 1, fall 1985, p, 83.

[58] William F, Allman, "Staying Alive in the 20th Century," *Science* 85, vol. *6, 1985, pp. 31-41.*

[59] Andrew P. Hull and Edward T. Lessard, *Risk Comparisons for the Nuclear Transportation of Spent Fuel From Nuclear Reactors,* BNL #36390 (Long Island, NY: Brookhaven National Laboratory, no date). These estimates exclude fatalities due to collision forces.

[60] Ibid.

mated for spent fuel shipments over the lifetime of a repository. Some of the radiological fatalities associated with a spent fuel accident are latent cancers calculated to occur over the life of the exposed individuals, as opposed to the prompt deaths associated with the other accidents.[61]

Yet such disparities are common in the area of public perceptions of risks, and the pitfalls associated with the conventional means for addressing these perceptions have been widely discussed.[62] Although OTA suggests many of these same methods in the conclusions for this chapter, their effectiveness has limitations. To paraphrase one expert's observations:

- *Those presenting factual information* must recognize the role that personal values play in assessing information.
- *Those giving statements of regulatory philosophy* must remember that people can understand risk-benefit trade-offs.
- *Experts explaining* technical material must communicate in an appropriate manner.
- *Communities considering problems* need to keep in mind that their-decisions will affect many other jurisdictions.

Conclusions

OTA finds that technical evidence and cask performance in service indicate that NRC performance standards yield spent fuel shipping cask design specifications that provide an extremely high level of public protection, much greater than that afforded in any other current hazardous materials shipping activity. However, meticulous adherence to the designs during cask manufacture and to required safety procedures during loading and transport are critical factors in ensuring public and environmental safety. Transportation accidents involving shipments of spent fuel will inevitably occur. However, OTA concludes that the probability of an accident severe enough to cause extensive damage to public health and the environment caused by a radiological release from a properly constructed cask is extremely remote. Moreover, the health and environmental consequences in the event of a severe accident are likely to be lower than those resulting from many hazardous materials transportation accidents considered more routine.

The most difficult issue pertaining to the transportation of spent fuel is how best to reduce the risks. Areas for technical improvement to the casks often involve trade-offs that adversely affect overall transportation safety. For example, increasing the thickness of the cask walls to increase accident resistance slightly would necessitate reducing the carrying capacity of the cask to remain within weight limits. More shipments would be necessary to carry the same amount of spent fuel, increasing the probability of accidents. Moreover, an increased number of shipments would require more handling by workers, raising their total radiation exposure.[63]

OTA further finds that continued research is needed in certain technical areas to determine where safety improvements could be effective. Such research needs include: the interface between the carrying vehicle and the casks, such as tiedowns and fasteners; the evaluation of real accident stresses as compared to those specified by the current regulations; and methods of extending accident modeling capabilities to encompass accidents more severe than those currently incorporated in the models. In addition, continued study of safe routes and different transportation modes and configurations and sharing the results of these studies with affected jurisdictions would have useful results. To enhance the risk assessment capability of jurisdictions, DOE could revise for microcomputers its existing mainframe computer program for analyzing the risks to population of differing transportation routes. This is discussed more fully in chapter 2.

The level of public apprehension about shipments of spent fuel requires well planned and coordinated programs to address the concerns. Sensitivity to public concerns and programmatic coordination have heretofore not been outstanding at DOE, which will be responsible for NWPA shipments. The technical specifications for the shipping casks are difficult to explain and comprehend, creating widespread misunderstanding of the stringency of the standards

[61]See for example Hull and Lessard, op. cit.; Sheperd, op. cit.; and Jefferson, op. cit.

[62]Fischhoff, op. cit.

[63]Robert Jefferson, former Manager, Transportation Technology Center, Sandia National Laboratories, Albuquerque, NM, personal communication, 1985.

for ensuring spent fuel cask integrity. Industry and government will do well to address these apprehensions in a forthright manner.

OTA further finds that fruitful areas for improvements in the overall safety of spent fuel transportation are to be found in the institutional, procedural, and operational controls and arrangements, such as quality assurance and quality control measures in cask manufacture; maintenance activities; operator, handler, and driver training; and inspection.[64] NRC inspection and quality assurance requirements are intended to ensure that each user establishes and implements a comprehensive cask inspection and operational testing program. The duration of the inspection depends on the inspectors' confidence in the quality assurance programs, training procedures, and the shippers' ability to demonstrate that procedures are being followed.[65] It is appropriate to consider actions that will ensure that the quality control standards are followed. Furthermore, tight management supervision during all transportation operations and strict accountability for adhering to procedures are crucial to ensuring safety. DOE could minimize one area of current public concern by agreeing immediately to use NRC-approved casks for all its shipments.

The nontechnical aspects of spent fuel transportation safety need continued and forceful emphasis. Special attention to shipping operations, including quality control and inspection can have a positive impact on overall safety. Especially important are those related to the carrying vehicle, and training and information programs for drivers, engineers, and other transportation personnel.

OTA finds that sustained and comprehensive public information efforts are necessary to address concerns about the level of safety provided by Federal regulations and cask specifications. Citizens and public officials repeatedly say, "show me"[66] that the casks are safe, and experts often respond with technical evidence that, due to its extreme complexity, may not be comprehensible. Education programs for nonexpert audiences must be developed, and continued examination of the issues by nonpartisan, nonexpert individuals is important. For example, in its publication, "A Nuclear Waste Primer," the League of Women Voters, although expressing some concerns, concluded that "compared to the transport of other hazardous materials, radioactive shipments have an excellent record. "[67]

The broadest possible public participation and information sharing will be important for successful undertaking of NWPA shipments. The enactment of State and local regulations pertaining to this transportation reflects the desire of jurisdictions to determine for themselves the conditions under which they will accept the risks associated with spent fuel transport. Figures 3-1, 3-2, and 3-3 indicate the routes used and the most frequent origin and destination States for highly radioactive shipments. These and other States, as well as Indian tribes and local governments affected by shipments have an interest in an acceptable level of safety. States and tribal and local governing bodies have indicated that they will require negotiations with DOE to permit successful completion of NWPA shipments. The activities undertaken by utilities to accomplish spent fuel shipments are documented in box 3G. Because DOE will fill the role of the utilities for shipments made under NWPA, Congress may want to consider requiring DOE to undertake the same activities under NRC regulations.

Furthermore, OTA concludes that State, local, and Indian tribal officials must be included in the transportation planning and decisionmaking process for transportation under NWPA. A Federal approach that incorporates public perceptions, opinions, and responsibilities starting immediately could be helpful. In November 1985, DOE sponsored a workshop for State, tribal, and local officials to determine the extent and specific nature of their concerns about DOE's plans for shipments of spent nuclear fuel under NWPA. Such activities provide a

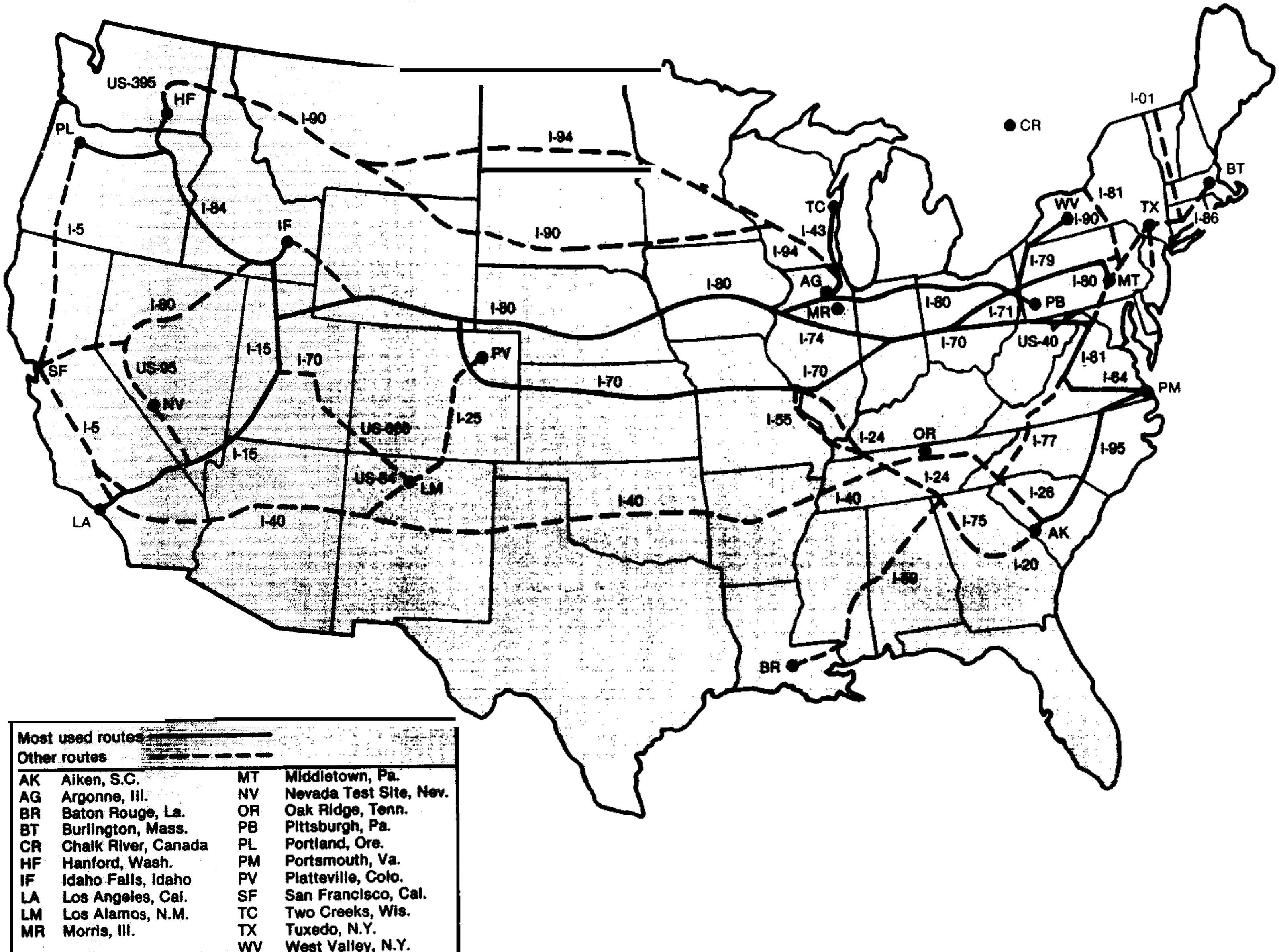
[64] This aspect was a persistent theme in both the Office of Technology Assessment workshop and Advisory Panel meetings; see for example Richard Cunningham, Nuclear Regulatory Commission in U.S. Congress, Office of Technology Assessment, "Transcript of Proceedings—Transportation of Hazardous Materials Advisory Panel Meeting, " op. cit., p. 230.

[65] Charles E. MacDonald in U.S. Congress, Office of Technology Assessment, "Proceedings of OTA Workshop on Nuclear Materials Packaging Technology," op. cit., p. 142.

[66] U. S. Congress, Office of Technology Assessment, "Proceedings of OTA Workshop on Nuclear Materials Packaging Technology," op. cit.

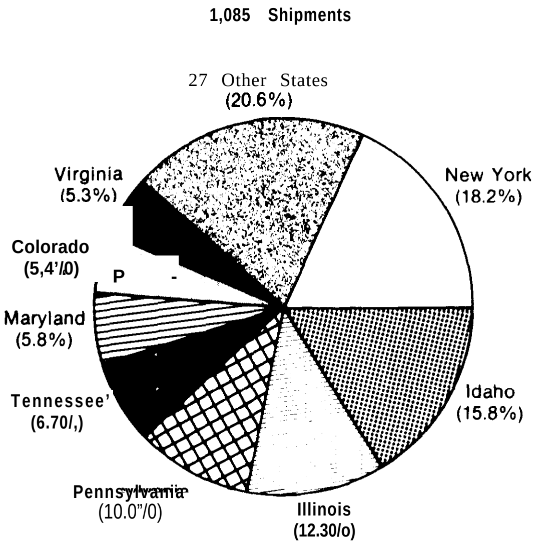
[67] League of Women Voters Education Fund, *The Nuclear Waste Primer (New* York: 1985), p. 42.

Figure 3-1.—Highways Commonly Used for Radioactive Materials Shipments



SOURCE: Sandia National Laboratories, *An Assessment of the U.S. Department of Transportation's Radioactive Materials Routing Report*, January 198_.

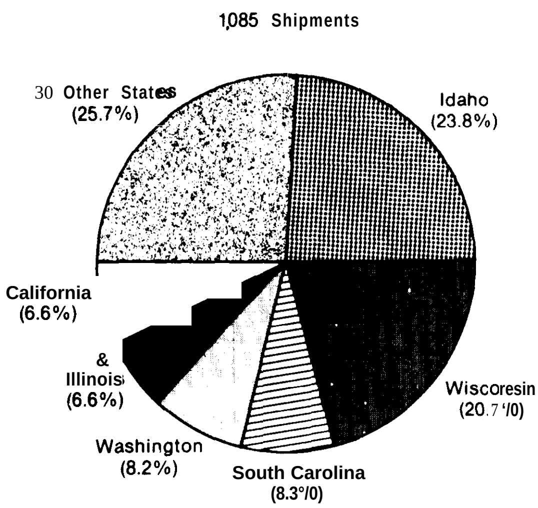
Figure 3-2.–Point of Origin, 1982-84



Most frequent points of origin for spent fuel, large quantity, and highway route controlled quantity shipments.

SOURCE: Sandia National Laboratories, An Assessment of *the* U.S. Department of *Transportation's Radioactive Materials Routing Report,* January 19S6.

Figure 3-3.—Destination, 1982-84



Most frequent destinations for shipments of radioactive materials.

SOURCE: Sandia National Laboratories, *Arr Assessment of the U.S Department of Transportation's Radioactive Materials Routing Report,* January 1986.

forum for airing differences and moving toward resolution of conflicts. OTA concludes that additional meetings, sponsored jointly by DOT, NRC, and DOE, in cooperation with public interest groups such as the National Governor's Conference, the **National Conference of State Legislatures, and the International Conference of Mayors are essential to informing the public and improving intergovernmental coordination.**

States and localities are greatly concerned with routing for spent fuel shipments, since they have the authority under DOT routing regulations to designate alternative shipping routes. State authorities can work with Indian tribes, local jurisdictions, and neighboring States to develop an alternative route meeting DOT guidelines. DOE and DOT may find it necessary to work together and with the States to provide guidance and support in achieving consensus on routes. (Chapter 4 gives further information on routing.)

Finally, full-scale tests of cask durability, like those conducted by Sandia National Laboratories in 1976 to 1977 (see box 3D) and Britain's Central Electricity Generating Board test in 1984 can demonstrate that accident damage and the behavior of the casks have been adequately predicted and validate the engineering models and analytical methods.[68]

OTA concludes that once a new generation of casks has been developed and fulfilled the analytical test requirements for NRC certification, full-scale demonstration tests could play an important role in gaining public confidence. The following considerations are important:

- Will a demonstration be for the purpose of increasing public confidence or does the technical evidence show the need for benchmark full-scale tests to prove the validity of current engineering analyses and regulations?
- If technical or material changes in the cask designs require a full-scale technical validation experiment, how can questions about any subsequent changes to cask designs be addressed?
- If a "show me" test were conducted, assurances that it would address public concerns would be essential. Organizations and individuals critical of current transportation procedures and cask standards could be included in advance planning for a test, so that their views are incorporated from an early point.

[68] Huerta and Yoshimura, Op. cit.; see also International Atomic Energy Agency Safety Series 6, 1985; and David Fishlock, "Nuclear Fuel Shipping Cask Comes Through Great Train Wreck With Its Virtue Intact," *Energy Daily, vol.* 12, No. 142, July 24, 1984, p. 3.

Box 3G.—Anatomy of a Spent Fuel Shipment

Utilities have found that transporting spent nuclear reactor fuel from one storage site to another is a lengthy process, requiring careful planning and preparation. The transporter must deal with numerous complicated and seemingly conflicting Federal and State regulations as well as pressure not to expose the public to the perceived danger of such shipments. OTA asked several companies that have shipped fuel successfully to document their shipping procedures as well as the attendant legal difficulties and public discussions.

After reactor fuel has been irradiated so that it is no longer a useful part of the power-producing process, it is removed from the fuel core and termed spent fuel. Initially, spent fuel is highly radioactive, exceeding lethal radiation levels, and is consequently carefully contained. Upon removal from the reactor, the spent fuel rods are placed in water-filled containment pools. The water shields the rods while their radiation content decays to safer levels. After 6 to 12 months in the containment pool, the spent fuel is ready for either onsite storage or shipment to other storage facilities.

Spent nuclear fuel is shipped for two main reasons: 1) space in a reactor storage facility is near full capacity, or 2) lawsuit settlements between a State and a utility necessitate the removal of spent fuel to an alternate storage site. It is generally cheaper to ship spent fuel to remote storage sites than to enlarge existing onsite facilities or build new ones. Of the various transport modes, truck and rail are the most common. The truck mode is used most often because—legal and public relations difficulties notwithstanding—it provides quick, flexible, and relatively inexpensive transport.

OTA asked three companies that have undertaken three different types of shipments—transshipments; multi-State, utility-operated shipments; and second party shipments—to provide information on their spent fuel transportation experiences. Transshipments, such as those carried out by Duke Power, occur between various sites operated by the same utility. Consequently, utilities carrying out these shipments deal primarily with people in their own service areas. Shipments to a remote storage site, in contrast, usually span several States and are carried out by the utility responsible for the spent fuel. An example of this type of shipment was Wisconsin Electric's transfer of spent fuel from West Valley, New York, and Morris, Illinois, to its Point Beach Nuclear Plant in 1983 and 1984. Finally, second-party shipments are those shipments conducted by a-company, such as General Electric, that is paid by a utility to transport the spent fuel. The following discussion draws in part on reports from these three companies.

As soon as it is determined that spent fuel shipments are to take place, the transporter must begin processes both to comply with regulations and to alleviate public safety concerns of communities affected by the shipments, particularly in the case of second-party shipments. The first step is usually route selection, and regulations require that the shipper submit a proposed shipping route for Nuclear Regulatory Commission approval. After final route determination, the utility often assembles mailing lists of public officials and media contacts in areas through which the shipment is to pass. Informational material is prepared that typically touches on the following topics: the nature of spent fuel, why it must be shipped, measures being taken to prevent radioactive release during transport, and the excellent safety record of spent fuel shipments to date. In addition, the company usually prepares a news release, plans informational briefings for the press and public officials, and arranges to monitor public reaction. Informational briefings may include films to dramatize the integrity of spent fuel casks. All of these activities are completed prior to public announcement of the shipments.

Once these preparations are made, the company makes a public announcement that spent fuel shipments are to take place. Utility representatives brief local media, mail information to public officials and other media, send out briefing invitations to public officials, and—as required by Federal regulations—notify the Governor or his designee in each State through which the shipment is to pass. The transporter seeks to learn as much as possible about road conditions, media, public attitudes, and State and local authorities in all areas along the route. When appropriate, company representatives meet with local officials, participate in public meetings, and give demonstrations of the safety techniques used to safeguard spent fuel. These measures may help prevent the passage of local ordinances prohibiting or severely restricting the transport of radioactive materials. Compounding the shipper's difficulties is the legal obligation not to release shipping schedules until 10 days after the shipments have occurred; such secrecy lends itself to public perception that the shipments are not as risk-free as the power company maintains. The more effective the effort to alleviate public concern, the less complicated the local constraints on transport are and the more straightforward the shipment procedures.

The shipper must also accommodate the various State regulations covering nuclear spent fuel transportation. Each State has its own authorities responsible for formulating and enforcing rules. Upon notification of upcoming shipments, the responsible agencies from each State make preparations and notify the transporter of any regulations it will have to observe. Typically, the relevant agencies are the State departments—or their equivalents—of transportation, nuclear safety, health, and the highway patrol as well as the State Police.

State regulations can require any of the followi[illegible]: thorough truck and cargo inspections at State borders, armed escorts (expenses to be paid by the utility), avoiding large urban areas during daylight and evening hours, compensation for emergency personnel training, and continual in-transit progress reports to be relayed to local officials along the route. Meeting these requirements on a State-by-State basis places a substantial responsibility on the shipper. Nuclear power utilities contacted by OTA noted that there seems to be little or no coordination between States regarding rules and enforcement procedures or between States and the U.S. Department of Energy. To avoid conflict and [illegible] utilities sign separate agreements to abide by individual State and local regulations. In the case of particularly onerous requirements, utilitie[illegible] to reques[illegible] Federal preemption of the regulation. Federal preempti[illegible]on is not used often, however, as it is time-consuming and damaging to public relations.

Onc[illegible] is reached between the utility and the States, the shi[illegible] spent in planning, preparation, and negotiation prior to transport can amount to 2 years or more. The issues outlined above are typical of the potential legal and local conflicts that nuclear utilities must deal with when transporting spent nuclear fuel. The accompanying table summar[illegible] tactics used for each type of shipment.

Summary of Spent Fuel Shipping Experiences

Company	Problems encountered	[illegible]sed
Duke Power Co.	Public opposition Routing decision difficulties	Public i[illegible] Negotiation with NRC
Wisconsin Electric	State requirements regarding inspections, routing, and shipping escorts Complications arising from inconsistent Federal and State regulations	Negotiations, compliance with State requirements Same, and subsequent legal action
General Electric	Opposition from citizens groups along the shipping route State legislation	Intense public information activities Legal ac[illegible]tion

- An extensive public information program would be essential prior to the test to help the public officials, affected emergency personnel, and the general public understand the technical background for the tests to the extent feasible.

If full-scale validation testing proves unnecessary from an engineering standpoint, conducting a full-scale demonstration test could enhance public understanding and confidence. DOE, as the responsible agency under NWPA, has both a source of funds and a program in which test series could be housed, and is giving consideration to such tests.

However, given the technical complexities involved, it is wise to be realistic about the extent to which a full-scale cask accident demonstration will allay all public concerns. Although a well--planned and constructed full-scale demonstration could prove persuasive to many, it would need to accommodate a wide range of interests. OTA finds that the appropriate test goals could best be determined by a panel of advisors—experts and concerned citizens to provide guidance to the technical organization conducting the demonstration.

PART II: BULK CONTAINERS AND SMALL PACKAGING FOR HAZARDOUS MATERIALS TRANSPORTATION

Most of the estimated 180 million annual shipments of hazardous materials reach their destinations safely, both because hazardous materials transportation is heavily regulated and because industry is concerned that its products reach customers intact. The strength and integrity of packaging used to ship hazardous materials, including tank trucks, railroad tank cars, and barges, as well as bottles, boxes, and drums, are an important factor in transportation safety. The Research and Special Programs Administration (RSPA) of the Department of Transportation is responsible for issuing packaging and hazard communication regulations for all hazardous materials containers except bulk marine containers, which are regulated by the U.S. Coast Guard, and containers for highly radioactive materials (see part I of this chapter).

This part of chapter 3 discusses DOT's requirements for all packaging, then looks at the specific issues relating to bulk containers and small packagings. It focuses on issues regarding the packaging regulations codified in Parts 173, 178, and 179 of Title 49 and portions of Title 46 of the Code of Federal Regulations. Part 173 contains general requirements for shipments and packaging and lists the authorized packages that can be used for each commodity. Parts 178 and 179 contain the specific, highly detailed requirements for the authorized packages referred to in Part 173. Title 46 contains the Coast Guard regulations for the water mode. (Chapter 4 presents an overview of the entire regulatory system, including a discussion of the historical development of packaging regulations.) Sources of information included technical literature, an OTA workshop on packaging, and extensive interviews with container experts.

General Packaging Criteria

DOT requires packaging for shipping hazardous materials to be so designed and constructed, and its contents so limited, that under conditions norreally incident to transportation:

- there will be no significant release of the hazardous materials to the environment;
- the effectiveness of the packaging will not be substantially reduced; and
- there will be no mixture of gases or vapors in the package which could, through any credible spontaneous increase of heat or pressure, or through an explosion, significantly reduce the effectiveness of the packaging.[69]

In addition, packaging materials and contents must ensure there will be no significant chemical reaction among any of the materials in the package. Closures must prevent leakage, and gaskets must be used that will not be significantly deteriorated by the contents. Polyethylene packaging must be minimally permeable to and compatible with the cargo.

DOT regulations apply to hazardous materials containers of all sizes. Some regulations apply equally to all packaging, but most of the requirements depend on whether the material is shipped in bulk or in small packages. As a general matter, the dividing line between nonbulk (small) and bulk (large) containers is 110 gallons or 1,000 pounds. Small packages of hazardous materials are carried by all modes: water, rail, highway, and air. Approved packaging include drums, cylinders, boxes, cans, and bags. Bulk packages—ships and barges, railroad tank cars, tank trucks (called cargo tanks in the regulations) and intermodal portable tanks—generally do not travel by air. Analysis of incident and accident data (see chapter 2) reveals that hazardous materials packaging generally has been adequately designed, although there are some problem areas.

The premise underlying packaging design for hazardous materials other than highly radioactive materials is that the packages must maintain their integrity in the normal transportation environment, including minor accidents.

The classification of a hazardous material has a critical influence on the selection of packaging. Many commonly transported materials are listed *in* the regulations, and shippers need only locate the

[69] 49 CFR 173.24.

listing to be guided to the required packaging. If the material is not listed, however, the shipper must determine if it is hazardous and classify it according to definitions in the regulations. There are no specific regulations in 49 CFR that tell a shipper how to classify a material, a difficult process, the results of which affect packaging, marking, labeling, and placarding.[70]

The sorting of hazardous materials into hazard classes by either DOT or the shipper does not necessarily mean that all the potential dangers posed by these substances have been taken into account. For example, methyl isocyanate, which caused the death of thousands in Bhopal, India, had until recently been classified by DOT as a flammable substance and could legally be transported in the least stout highway cargo tanks or rail tank cars. DOT is now in the process of adopting an international classification scheme (described in more detail in a later section of this chapter) that should better correlate the strength of regulated packaging to the hazards posed by the materials. In the meantime, large manufacturing and shipping companies have incorporated additional strength and protective features into the design of containers they use for materials with a very high hazard potential. Some of these designs have become part of the Federal specifications for packages. More often, however, these additional safety features represent industry efforts to take into account special transportation circumstances.

Containers for bulk transport, discussed next, represent the inherent possibility of larger consequences in the case of an accident than do small packages and provide opportunities for commensurately larger impacts on safety.

Bulk Packaging

More than 60 percent of accidents and spills in any mode of transport are a result of human error.[71] thus modal safety is closely tied to the opportunities for error. The highway mode experiences more accidents, spills, injuries, deaths, and property damage than does the rail or water mode, in both absolute numbers and accidents per ton-mile traveled,* while the rail mode experiences more than the water mode.

Several other factors also affect safety: the extent of coverage and enforcement of Federal regulations; the amount and quality of training the vessel or vehicle operators and loaders receive; the frequency of maintenance and inspection of the vessel or vehicle; and finally, the coordination between the agencies responsible for regulation, inspection, and enforcement activities. Table 3-8 presents a comparison of modal characteristics for bulk shipping of hazardous materials. Descriptions of the containers and specific safety factors will be treated separately for each mode.

Bulk Highway Transport

Of the three modes of bulk transport of hazardous materials, the highway mode is the most versatile and widely used. (See chapter 2.) While portable tanks and tank trucks are the smallest bulk containers and thus the consequences of a release on the highway will be lower than for the other modes, the probability of an accident is greatest for the highway mode because it has:

- more miles of network,
- the largest number of individual shipments,
- the largest number of operators,
- the greatest traffic density in an unrestricted right-of-way, and
- the highest average traffic speed.

Cargo tanks are the main carriers of bulk hazardous materials over the roads, although intermodal portable tanks, discussed later in this chapter, are also used. Cargo tanks are usually made of steel or aluminum alloy but can be constructed of other materials such as titanium, nickel, or stainless steel. They range in capacity from about 2,000 to 9,000 gallons depending on road weight laws and the properties (including density, vapor pressure, and corrosiveness) of the commodity or commodities to be

[70] U.S. Department of Transportation, Materials Transportation Bureau, Research and Special Programs Administration, *A Guide ro the Federal Hazardous Materials Transportation Regulatory Program* (Washington, DC: January 1983).

[71] Mark Abkowitz and George List, "Hazardous Materials Transportation: Commodity Flow and Information Systems," OTA contractor report, January 1986.

*A ton-mile is the product of the tons of material carried and the distance carried in miles. For example, a truck with a load of 20 tons that traveled 100 miles would have logged 2,000 ton-miles. Ten trucks each carrying 2 tons and each traveling 100 miles would also have logged 2,000 ton-miles in the aggregate (each truck logging 200 ton-miles).

Table 3-8.—Modal Characteristics of Bulk Shipping of Hazardous Materials

	Highway	Rail	Water
Containers regulated by DOT[a]	Most	All	All
Inspection or testing frequency	Upon manufacture	Upon manufacture plus every 5-10 years[c]	Yearly[d]
Commodity flow data[e]	Very little	Nearly complete	Complete
Regulators and inspectors	RSPA, BMCS, NHTSA[f]	FRA, RSPA, AAR[g]	USCG, RSPA[h]
Fleet size	130,000 cargo tanks[i]	115,600 tank cars[j]	4,909 tank barges[k]
Fleet database[l]	Partial (BMCS)	Yes, complete (AAR)	Yes, complete (ACofE)
Number of operators	*260,000*	*26,000*	45,000
Size of load (gals)	4,000-12,000	10,000-30,000	300,000-600,000

[a]Federal regulations cover the transportation of hazardous materials by railcar, aircraft, vessel, and interstate transportation by motor vehicle. Intrastate highway transport of hazardous wastes, hazardous substances, and flammable cryogenics in portable tanks or cargo tanks is also covered (49 CFR 171.1). Unless a State has specifically brought intrastate commerce under regulation, containers in such service need not meet any standards. The Department of Transportation does not know the precise extent to which the States have extended the Federal regulations to intrastate commerce. Most gasoline transport by truck is intrastate and these shipments are a large percentage of the total hazardous materials shipments.

[b]Cargo tanks must undergo an external visual examination every 2 years but generally do not have to be leak tested or pressure tested. However, cargo tanks carrying chlorine must be pressure tested every 2 years and tanks carrying compressed gas (e.g., liquefied petroleum gas) must be pressure tested every 5 years; cargo tanks for flammable cryogenics are inspected prior to each loading. Most tanks, however, are not leak or pressure tested after they are built unless they have been out of service for a year or more, had repairs or modifications performed on them, are operating under an exemption to the regulations, or are used in an area of nonattainment of Clean Air Act standards for ozone. (49 CFR 177.824.)

[c]Tank cars carrying some cargoes are tested more frequently, For example, tank cars carrying chlorine must be tested every 2 years, Also, the frequency of inspection of some tank cars increases to once per year after they are 22 years old. General American Transportation Corp., *GATX Tank Car Manual, 4th Edition* (Chicago, IL: 1979).

[d]46 CFR 31.10-15, and 31.10-17.

[e]Data on the identity and amount of hazardous materials shipped over the highways is collected by the Bureau Of the Census every 5 to 6 years, however the quality and comprehensiveness of the data is poor (see ch. 2). Records of 60 percent of all rail traffic are kept by the Association of American Railroads (AAR). A record of 1 to 6 percent of all rail traffic is kept by the Interstate Commerce Commission. Records of all origins and destinations of hazardous material cargo that travel on U.S. waterways are kept by the U.S. Army Corp of Engineers (ACofE).

[f]The Research and Special Programs Administration (RSPA) develops and publishes regulations *on* the cargo tanks. The Bureau of Motor Carrier Safety (BMCS) regulates in-use motor vehicles and drivers, and enforces regulations pertaining to the manufacture, marking, repair, etc. of cargo tanks. The National Highway Traffic Safety Administration (NHTSA) has responsibility for the original manufacture of the vehicle.

[g]AAR and the Federal Railroad Administration (FRA) established the basic technical specifications for tank cars. After public rulemaking and comment, RSPA adopts the final specifications in the regulations. Both AAR and FRA inspect tank cars in rain service, Both AAR and FRA inspect tank manufacturers.

[h]For bulk vessels (tank ships and tank barges), the United States Coast Guard (USCG) establishes the regulations, performs the inspections, administers licenses, and specifies the design of vessels. RSPA sets the standards for intermodal portable tanks that can be carried on container ships and barges.

[i]Estimates from the 1977 Truck Inventory and Use Survey. Of these, 36,000 carry hazardous materials 25 to 49 Percent of the time, 14,000 carry them 50 to 74 percent of the time, and 67,000 carry them 75 to 100 percent of the time.

[j]Written communication with AAR. This is about 60 percent of the total number of tank cars.

[k]American Waterways Operators, This is the number of inland tank barges, most of which carry hazardous materials. There are also a small number *of* ocean going barges and tankers that carry hazardous materials, but tank barges are responsible for most inland traffic.

[l]While the Army Corp of Engineers (ACofE) keeps track of the number of active and inactive vessels that may carry hazardous materials in U.S. commerce, and the AAR's UMLER file lists all tank cars by DOT specification that are in service, there is no comparable database for the highway mode. Although individual companies know how many and what types of cargo tanks or intermodal portable tanks they have, no single agency has an accounting of all bulk highway vehicles nationwide.

[m]"Operator" refers to the vehicle or vessel "driver." The number of people driving cargo tanks (carrying hazardous materials) is estimated by assuming there are two drivers per cargo tank. Large interstate private carriers often have three or more drivers per vehicle, while other carriers typically have fewer. Information on the rail mode was obtained from AAR and on the water mode from USCG. The number presented in the water mode represents all those licensed by USCG to operate commercial vessels; most of these would not routinely be involved with hazardous materials.

SOURCES: Unless otherwise indicated in footnotes, Office of Technology Assessment, based on information from participants of workshops and panel meetings or comments to draft reports by the affected parties.

carried. Federal road weight laws usually limit motor vehicle weights to 80,000 pounds gross. Some States, however, allow higher gross weights, and in these States cargo tanks can have larger capacities. Table 3-9 lists the primary contemporary specification for cargo tanks and examples of commodities each type of cargo tank might carry.

All newly constructed cargo tanks must meet current specifications, which prescribe the requirements for the thicknesses of the bodies of the tanks, pressure relief devices, manhole covers, gauging devices, overturn protection, pressure test methods, and other features affecting safety. However, older specification tanks–for example, an MC-304 or an MC-31 l—may still be used to carry hazardous materials, even though it does not meet current requirements.

The nature of the bulk trucking business differs from that of rail or water bulk transport in that there are many more carriers of a wider variety and businesses are generally much smaller. The carriers include private interstate carriers; large interstate common and contract carriers; and small common, contract, and private intrastate carriers.* The quality of the equipment varies within each of these groups, but generally the large private interstate transporters have the newest equipment and the small intrastate private carriers have the oldest, with the common carriers somewhere in between.

Turnover of equipment is slow, and cargo tanks generally go through several tiers of owners. Large private interstate carriers, primarily large petrochemical companies, have the resources to purchase new equipment and maintain it well. They use their trucks around the clock 6 to 7 days a week. After 8 to 10 years, when maintenance becomes uneconomical because of downtime for repairs, they sell the cargo tank to another firm, usually a smaller one with fewer resources. The second-tier owner uses it until it becomes uneconomical and sells it to yet another owner. The useful life of a cargo tanker used to transport fuels can easily exceed 20 years.

Cargo tanks carrying some corrosive commodities have much shorter lifespans. According to one tank truck company safety director his “acid tanks are junk” after 4 years. [72] In the past, a carrier frequently dedicated some of his fleet to carrying particular commodities. While this practice minimized corrosion and incompatibility problems, it often meant that the cargo tanks returned empty after delivering the product. In recent years, economic pressures have forced carriers to reduce the number of

*Private carriers transport commodities that they own and the transport is integral to their business. Common carriers are transporters of freight for compensation; common carriers must accept all traffic tendered to them that is within their operating authority (to the extent that they have equipment and drivers to do so). Contract carriers are transporters of freight by motor vehicle for compensation in the exclusive service to one or more specific shipper(s) as authorized by duly constituted Federal or State authority. This classification includes owner-operators under long-term lease to certificated carriers.

[72] National Tank Truck Carriers, Inc., National Tank Truck Safety Seminar, St. Louis, MO, Apr. 14-15, 1986.

Table 3-9.—Cargo Tank Table

Cargo tank specification number[a]	Types of commodities carried	Examples
MC-306 (MC-300, 301, 302, 303, 305)	Combustible and flammable liquids of low vapor pressure	Fuel oil; gasoline
MC-307 (MC-304)	Flammable liquids, Poison B materials with moderate vapor pressures	Toluene diisocyanate
MC-312 (MC-31O, 311)	Corrosives	Hydrochloric acid; caustic soda solution
MC-331 (MC-330)	Liquefied compressed gases	Chlorine, anhydrous ammonia, LPG
MC-338	Refrigerated liquefied gases	Oxygen, refrigerated liquid; methane, refrigerated liquid

[a]The number in parenthesis designates older versions of the specification; the older versions may still be operated but all newly constructed cargo tanks must meet current specifications.

SOURCE: 49 CFR 172.101 and 178.315 to 178.343.

Photo credit: Waste Age Magazine

An MC-312 cargo tank delivers hazardous waste to a treatment plant. MC-312s typically carry corrosive commodities.

dedicated trucks and to seek return-trip loads (backhauls) whenever possible. Backhauls often necessitate cleaning the tank between loads to accommodate different products, thus subjecting the tank to additional wear, increasing pitting and corrosion, and shortening its lifespan.

Regulations and Intrastate Trucking.-The extent of Federal regulatory coverage for the highway mode is fundamentally different from that for rail and water modes, where all commerce is subject to Federal hazardous materials regulations. Under the predecessor statute to the Hazardous Materials Transportation Act, only interstate commerce was regulated, and this restriction was maintained when DOD issued revised hazardous materials regulations in 1976.[73] However, because a large percentage of hazardous materials truck transport is in intrastate commerce, with gasoline, fuel oil, and propane deliveries comprising the bulk of it, the question of applicability of Federal regulation is important.[74]

Except for those transporting certain materials,[75] carriers operating solely intrastate need not meet Federal standards, unless the State in which they do business has similar regulations. In some States, intrastate carriers have become the market for used equipment that no longer meets Federal standards. Moreover, new tanks built solely for intrastate trade need not meet DOT specifications, because those specifications are not applied. Such tanks also do not need to meet the periodic retest and maintenance requirements prescribed in the Federal rules. The noncompliance of these tanks with Federal standards has caused administrative problems for some States implementing the Federal rules.[76] In addition, intrastate carriers have no obligation to report releases of hazardous materials to RSPA, even if they are under State regulation in other respects. This alone makes the Federal spill and accident reporting system incomplete, a problem further documented in chapter 2.

The extent to which individual States have applied 49 CFR to intrastate commerce is an open question. In conversations with Federal and State regulators, shippers, and representatives of major bulk carriers, OTA found widespread disagreement over the degree to which Federal hazardous materials regulation has been extended to intrastate traffic. RSPA officials state that 49 CFR does not apply to all intrastate highway traffic and that some cargo tanks were never built to Federal specifications because they were for use only in intrastate commerce.[77] Carrier representatives and BMCS staff

[73] U.S. Department of Transportation, Docket No. HM-134, 41 *Federal Register 38175,* Sept. 9, 1976.

[74] About 55 percent of the hazardous materials transported over the highways is intrastate in South Dakota, for example. See U.S. Congress, Office of Technology Assessment, *Transportation of Hazardous Materials: State and Local Activities,* OTA-SET-301 (Washington, DC: U.S. Government Printing Office, March 1986). Gasoline comprises a large percentage of hazardous materials shipments over the highway and most gasoline deliveries are intrastate. About half of all gasoline is delivered by large interstate oil companies that are subject to Federal regulations. Much of the rest of the gasoline is delivered by intrastate operators.

[75] 49 CFR 171.1. Hazardous wastes, hazardous substances, and flammable cryogenics comprise the only groups of hazardous materials whose transport is regulated by the Federal Government regardless of whether the commerce is intrastate or interstate.

[76] In the State of Washington, of all heavy truck accidents involving hazardous materials from 1979 to 1983, 64 percent involved private intrastate carriers of hazardous materials, unregulated by both the State and the U.S. Department of Transportation. The Utilities and Transportation Commission notes that the private carriers' terminals are not subject to survey, his driver records are not subject to review, and his safety record is known only to himself. The continually violating private carrier cannot be removed from the highway, nor does he face any deterrent to violation in the form of administrative penalty. Washington Utilities and Transportation Commission, *Summary and Analysis, Heavy Truck-Hazardous Materials Accidents 1982-1983* (Olympia, WA: 1983), p. viii.

[77] James O'Steen in U.S. Congress, Office of Technology Assessment "Transcript of Proceedings-OTA Workshop on State and Local Activities in the Transportation of Hazardous Materials," unpublished typescript, May 30, 1985; and Alan Roberts, in U.S. Congress, Office of Technology Assessment, "Transcript of Proceedings–Transportation of Hazardous Materials Advisory Panel Meeting, " unpublished typescript, Washington, DC, Jan. 24, 1985.

counter that States participating in the Motor Carrier Safety Assistance Program must apply 49 CFR in motor vehicle inspections for all hazardous materials traffic, both intrastate and interstate.[78]

BMCS has records of the States that have adopted 49 CFR, but not of the numerous variations to it enacted by many States. Moreover, adoption of 49 CFR by a State does not mean that intrastate highway commerce will be regulated. For example, the State of Washington adopted 49 CFR in 1978, and based on BMCS records, Washington regulates intrastate transport of hazardous materials. However, according to the Public Utilities Commission of the State of Washington, the State legislature did not decide to regulate private intrastate transport of hazardous materials until 1985.[79] Since the new State regulations will not be promulgated until summer 1986, this transport is still unregulated.

MC-306 Tank Trucks.–The large volume of gasoline carried by MC-306 tank trucks, making over 40,000 daily deliveries to retail service stations in every locality in the country, is a primary reason that truck transportation of gasoline is responsible for more deaths, injuries, and property damage than all other hazardous materials in transportation. Most of the hazardous material highway deaths in recent years (five out of eight in 1983) have been the result of gasoline truck accidents, and many of the worst incidents are the result of tank truck rollovers

[78] Clifford Harvison and Al Rosenbaum, National Tank Truck Carriers, Inc., and Merritt Sargent, Bureau of Motor Carrier Safety, personal communications, March 1986.

[79] Don Lewis, Rail and Motor Carrier Training Officer, Washington Utilities and Transportation Commission, personal communication, Mar. 21, 1986.

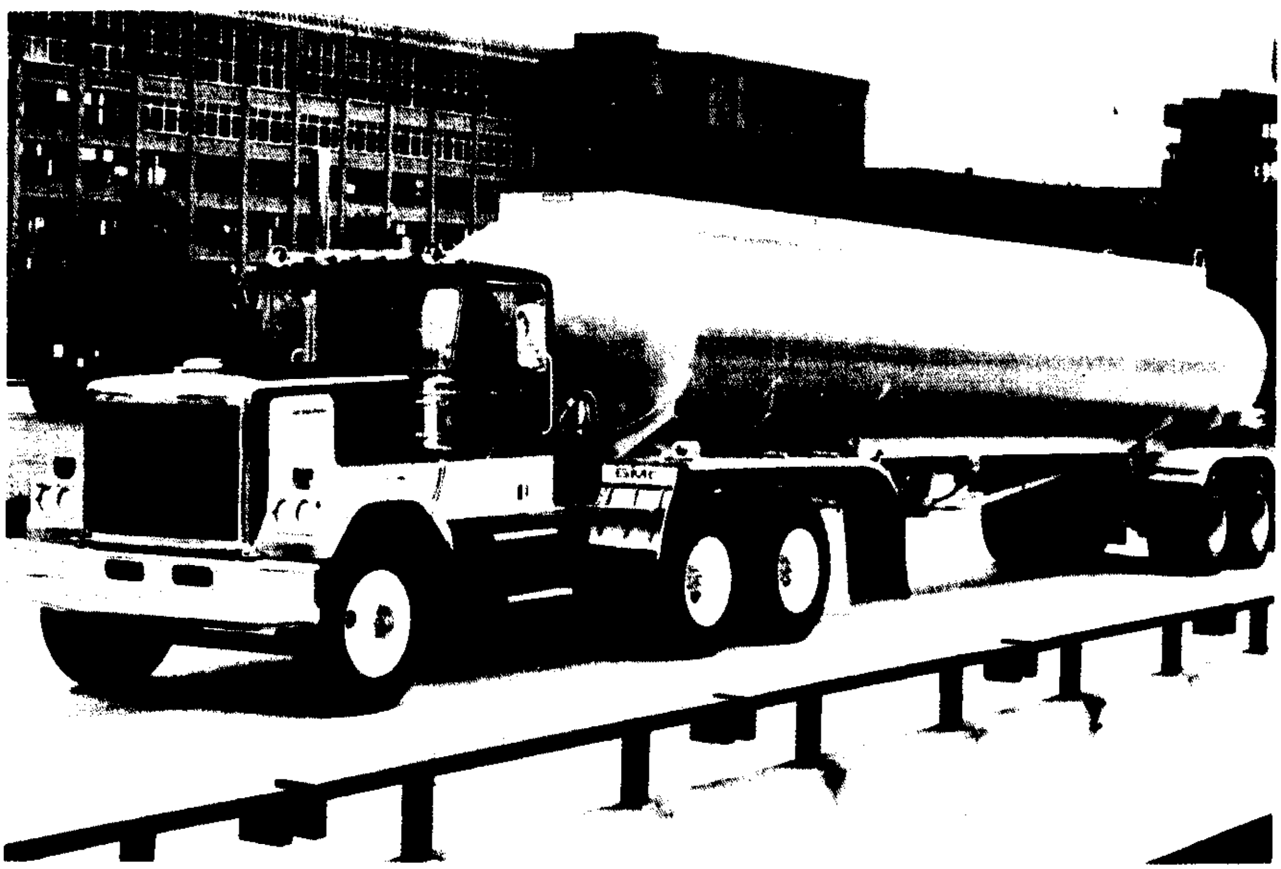


Photo credit: Modern Bulk Transporter

MC-306 tank trucks transport the most prevalent hazardous material, gasoline.

and leakage of hundreds to thousands of gallons of gasoline.

The design of the MC-306, the most common cargo tank, may be an important factor in the truck's frequent involvement in accidents. The MC-306 has a high center of gravity and consequently high rollover susceptibility. Industry and academic research efforts have produced several new designs to improve the safety performance of the MC-306.

For example, the University of Michigan's Highway Safety Research Institute (HSRI) proposed a new design of large cargo tank semi-trailers for use in Michigan.[80] The basic change from the standard MC-306 is an increase in the maximum width of the tank and chassis from 96 to 102 inches to allow a wider track and permit a lower center of gravity. The increased size allows the tanker combination to carry more gasoline, but also increases the gross weight. Designs with three, four, or five semi-trailer axles are needed to keep the load per axle within Michigan's legal limits. HSRI estimates that the improved stability and fewer trips of the larger vehicle would result in a 40-percent reduction in the single-vehicle-accident rollover frequency.

The Fruehauf Corp. has applied similar principles to a tri-axle trailer design that is much closer to existing tanker design, although the tank center of gravity is about 11 inches lower than that of existing units. This change makes the vehicle one-half as likely to be involved in a rollover. A prototype vehicle has been constructed and has been tested in service for at least 30,000 miles by different oil companies, and several major oil companies are purchasing some of these new trailers for use in Louisiana, where weight laws allow them to operate. The Fruehauf design has a capacity about 550 gallons greater than the standard MC-306, and this difference was very important in the decision to purchase them. A new design that did not have at least the capacity of current models would not be attractive to carriers, as many carriers use their cargo tanks so extensively that a difference in capacity of several hundred gallons is significant.

These truck designs require consideration of a number of trade-offs. Both involve gross truck and trailer weights above the 80,000 pounds currently allowed on most of the Nation's highways. The Michigan tankers range up to 125,000 pounds, and the Fruehauf truck weighs about 86,000 pounds. Accordingly, widespread use of these or similarly designed tankers depends on whether other States are willing to approve heavier truck weights on their roads. An increase in truck weights accelerates the damage rate to road surfaces. Moreover, the new designs employ a 102-inch-wide wheel base. While this width is allowed on all Interstate and primary roads, many urban areas do not permit trucks of that width to operate in their jurisdictions. Access restrictions facing the wider cargo tankers are important factors in decisions about purchasing such vehicles. Finally, accidents involving trucks with increased load capacities have potentially more serious consequences than those involving current trucks.

The safety benefits derived from a design change would be proportional to the percentage of the fleet having the new design, and any major design change will likely be implemented gradually, as older cargo tanks are taken out of service. RSPA has estimated, in a cost-benefit analysis, that if $1 million were expended for each annual gasoline tanker death (where the death was due to the gasoline), the amount available to make safety modifications in all existing gasoline trucks would be about $200 per truck per year. If the average lifespan of a cargo tank is 20 years, then about $4,000 would be available per truck, a figure that is close to the price difference between the old design and some new ones. Decreases in injuries, property damage, and deaths that are attributable to the vehicle accident rather than to the hazardous nature of the cargo (the latter are the only deaths that RSPA notes in its incident reports) would be additional benefits. OTA'S independent calculations suggest the benefits may be substantially larger and the trade-off time may be much less (box 3H), although admittedly much uncertainty exists for several of the estimates used in calculating the costs and benefits of a design change.

Three cargo tanks built to a new design, employing fiberglass reinforced plastic (FRP), are being used for gasoline transport on a trial basis.[81] The FRP tanks, built in the United Kingdom, have better im-

[80] R.D. Ervin, et al., *Future Configuration of Tank Vehicles Hauling Flammable Liquids in Michigan* (Ann Arbor, MI: University of Michigan Highway Safety Research Institute, December 1980). This research organization is now called the University of Michigan Transportation Research Institute.

[81] George Jennings, Mobil Oil Corp., Fairfax, VA, personal communication, March 1986.

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Approximately one-half of all rollovers would be avoided using the new design, Injuries are ignored; they are about four to seven times as common as deaths. Avoided injuries would add to the benefit.

Based on these figures, it would take 4.4 years for the investment in safer equipment to pay for itself via reduced accident expenses ($220 million/$50 million/yr = 4.4 yr). The average useful lifespan of an MC-306 cargo tanker is at least 20 years.

Results of our analysis show that the costs and benefits are of comparable magnitudes and that the breakeven point lies well within the expected life-span of the cargo tanker. A more rigorous analysis of the safety and economic impacts associated with a major redesign of the MC-306 cargo tanker would be useful. The estimates of costs of rollover accidents and the reduction in the number of deaths after adoption of the new design need refinement.

pact resistance, fire resistance, and lower rollover susceptibility than the standard aluminum MC-306. The three models on the road currently, however, have a higher tare (container) weight than most MC-306s and thus cannot carry as much gasoline. Unless the weight of the FRP tank can be reduced, it will not be widely used because of road weight law restrictions.

OTA analysis shows that highway common carriers experience the highest frequency of releases with corrosives (see chapter 2). Because they are relatively unreactive chemically, plastics and composite materials also have potential for use in cargo tanks carrying acids and corrosives, which quickly degrade metal cargo tanks. A U.S. manufacturer received DOT approval to build a composite tanker and has constructed a prototype. However, more research is needed on the durability and road-worthiness of the tankers before carriers will invest in them. Current research, sponsored jointly by RSPA and BMCS, into tank truck corrosion problems should address significant industry and safety concerns, Results are expected in late 1986.

Changes to Cargo Tank Regulations.-The number of cargo tanker releases reported to RSPA averaged over 1,500 per year from 1976 through 1984, although as indicated in chapter 2, OTA finds this figure to be an underestimate. Both human and mechanical factors affect the highway spill rate. In its studies of cargo tank safety, DOT has identified widespread deficiencies in the design and maintenance of cargo tanker manhole covers, pressure relief valves, and vents.[82] One study found leaks in every compartment of the 20 cargo tanks tested, primarily in the areas cited above, and many of the manhole covers used on cargo tanks constructed in the 1960s and 1970s are unable to withstand the forces of a rollover and leak their contents whenever a rollover occurs.

No single governmental agency or industry group knows with any precision how many of the different types of tank trucks are in use, * kinds of commodities carried in them, and the classifications of the carriers using the trucks. Requiring registration of each tank truck on manufacture and submission of sale records for the tanker could give DOT much of this information. If tied to an inspection program and better reporting of accidents and releases, such information could help identify inadequacies in tank designs and would be useful in evaluating changes to regulations.

Problems with the maintenance of cargo tankers are well documented, and many of the problems and appropriate corrective measures could be identified through regular tests or inspections. Although pressure testing and inspection of containers are important safety tools, DOT requires periodic pressure testing of only some cargo tanks after construction.**

[82]Dynamic Science, Inc., *Cost-Effective Methods of Reducing Leakage Occurring in Overturns of Liquid-Carrying Cargo Tanks* (Washington, DC: U.S. Department of Transportation, Federal Highway Administration, September 1980); and U.S. Department of Transportation, Federal Highway Administration, *Integrity of MC 307/312 Cargo Tanks* (Washington, DC: October 1984).

*The U.S. Department of Transportation (DOT) does know how many MC-338 cargo tanks there are. The trucks carry flammable cryogenic cargo (e.g., liquefied carbon monoxide) and comprise a very small portion of the cargo tank fleet. The highly hazardous nature of the cargo carried in them has led DOT to extend regulation to intrastate carriage and to create a special registry for these trucks.

**MC-331 and 338 cargo tankers that typically carry anhydrous ammonia, liquefied petroleum gas, and cryogenic liquids are required to be pressure tested. These tanks, if covered by Federal or State regulations must be tested every 5 years (every 2 years if used for chlorine transport). All other cargo tanks must undergo an external visual examination every 2 years and the inspection can be made by the operator. Gasoline cargo tanks in regions of air quality nonattainment are required by the Environmental Protection Agency (EPA) to have annual leak tests. Most States have some areas of nonattainment, commonly metropolitan areas. EPA does not keep track of the tanks required to be leak tested, leaving the implementation of the regulation to the States.

After 10 years of study, DOT has issued a Notice of Proposed Rulemaking (NPRM) for cargo tankers[83] calling for, among other things, annual pressure tests of all cargo tanks under Federal regulation. The rulemaking would greatly increase the number of cargo tanks that must be pressure-tested and would also increase the frequency of such tests. More effective pressure relief valves would be required, and many gasoline cargo tanks would have to be retrofitted with stronger manhole covers.

At a public hearing on NPRM, several industry groups expressed concern that the rulemaking would have unintended deleterious results, particularly in the areas of MC-306 body construction, tank truck inspection costs and pressure relief valve design. Rigorous estimates of increased costs under the proposed regulations were developed by industry for submission to DOT in May 1986.

Roadside inspections of vehicles carrying hazardous materials have shown that problems with the vehicles themselves—faulty brakes, tires, or lights—are more frequently the cause of accidents than are problems with the hazardous materials container itself. Increased attention to maintenance practices would help reduce accidents caused by faulty equipment.

Improving Driver Performance. -Many of the most serious hazardous materials releases during bulk transport over the highway are caused by vehicle accidents, most of them the result of driver error.[84] Improving driver performance could thus increase safety. Methods of accomplishing this include both improving equipment and improving driver training. The Shell Oil Co., employing both techniques, has experienced a 58-percent reduction in its preventable vehicular accident rate over the course of its driver safety training program instituted in 1979.[85] (See table 3-10.)

The program entails several days of instruction in relevant hazardous materials regulations and vehicle operating procedures, followed by 1 or 2 weeks of field training, during which each driver is accompanied on the job by an instructor. Each of the trucks owned by Shell has a tachograph that automatically records when the motor starts, when motion starts, travel speeds, when the truck stops, distance between stops, total distance traveled, and the duration of all trips. The tachograph records make each driver aware that he is accountable for his performance, that his driving behavior can be readily evaluated. He also knows that the records can work to his benefit in the case of an unavoidable accident.

The Insurance Institute for Highway Safety (IIHS) has recommended that tachographs be required on all large trucks. Furthermore, the IIHS holds that speed limiters should be placed on trucks, better braking systems should be employed, and that recapped tires should not be allowed on front wheels. Tire failures follow brakes as the leading equipment-

[83] U.S. Department of Transportation, Research and Special programs Administration, Materials Transportation Bureau, *Federal Register,* Notice of Proposed Rulemaking, Requirements for Cargo Tanks, vol. 50, No. 180, Sept. 17, 1985.

[84] Abkowitz and List, op. cit.

[85] Shell Oil Co., personal communication, January 1986.

Table 3=10.-Major Oil Company, Total Vehicle Accidents (safety programs begun in 1979)

	Number		Rate[a]		Number of serious incidents involving					
					Fire		Rollover		Spill[b]	
Year	TOT VEH ACC[c]	Total PVA[d]	TOT VEH ACC	Total PVA	NPVA[e]	PVA	NPVA	PVA	NPVA	PVA
1979	**236**	**82**	**7.14**	**2.48**	**2**	0	0	1	0	0
1980	*222*	*74*	*7.19*	*2.40*	0	0	3	1	0	0
1981	185	**71**	7.18	2.73	**1**	**1**	1	1	0	0
1982	144	**39**	5.96	1.62	**0**	0	2	0	0	0
1983	120	46	5.08	1.95	0	0	0	0	1	0
1984	115	21	5.68	1.04	1	0	0	0	0	0
1985	–	–	—	—	o	0	0	0	1	0

[a] Rate is the number of accidents par 1 million vehicle miles.
[b] These are spills other than those associated with fires or rollovers.
[c] TOT VEH ACC—total vehicle accidents.
[d] PVA—preventable vehicular accidents, an accident where the driver failed to do everything possible to avoid the accident.
[e] NPVA—nonpreventable vehicular accidents.

SOURCE: Private written communication to Office of Technology Assessment staff.

related causes of truck crashes.[86] A pilot project could be developed to equip a number of trucks with such safety equipment and carefully monitor the safety performance of the fleet. Any change in accident rates and severity would permit evaluation of equipment's contributions to safety.

Coordination Among Federal **Agencies.**—Improving coordination among agencies currently regulating motor carriers is also essential. Responsibilities are currently spread over three agencies:

- RSPA—container specifications, marking and labeling, and placarding;
- BMCS—inspecting cargo tank manufacturers and motor carrier operating procedures; and
- National Highway Traffic Safety Administration—manufacture of vehicles.

Difficulties in coordinating activities and sharing accident data have resulted in disjointed and often ineffective regulation. For example, both RSPA and BMCS support accident databases, but there are few cross-checks made between them. Perhaps more importantly, specifications for cargo tanks have been developed separately from specifications for the motor vehicles on which the tanks are mounted. Thus, all components of the transportation system (including container, load, vehicle, and highway) have not been considered in developing design standards. For example, studies of a tank truck's interaction with the road system have shown that the truck's stability and resistance to rollover is dependent on such factors as the center of gravity, height, track width, suspension, fifth-wheel characteristics, and the tires of the vehicle; yet these factors are not a part of RSPA's cargo tank specifications.*

Compounding the difficulties in implementing design or technological innovations is the fact that no single trucking industry group exists to consider such issues for the cargo tanks used in truck shipments of hazardous or other materials. The Truck Trailer Manufacturers Association has a committee dealing with tank trucks and the National Tank Truck Carriers, Inc., serves some of the for-hire tank truck industry. The American Trucking Associations, the American Petroleum Institute, and other groups also have an interest in such issues. Achieving consensus on decisions affecting tank truck designs is thus a difficult and lengthy process.

Rail Tank Cars

Rail shipments account for about 5 percent of the tonnage of hazardous materials transported annually with about 3,000 carloads shipped each day. (See chapter 2.) The numbers of daily shipments are far fewer than those made by highway, and the shipments are transported by a much smaller number of carriers. Most of the ton-miles are logged by just 9 of the 25 Class 1 railroads doing business in 1985; Class 2 and Class 3 railroads carry few hazardous materials.[87]

OTA analysis of RSPA and Federal Railroad Administration (FRA) data indicates that, on a ton-mile basis, the rail mode has a lower release rate than the highway mode and a somewhat higher rate than the water mode. (See chapter 2.) However, modal differences such as the number of miles of network, traffic density, and average speed affect the release rates in each mode, making direct modal comparisons difficult. Moreover, the rates themselves are questionable, as documented in chapter 2.

As all hazardous materials rail traffic falls under Federal regulations, all rail containers are required to be of the proper specification regardless of the origin, destination, or duration of the trip or characteristics of the shipper or carrier. About 80 percent of annual rail shipments of hazardous materials involve tank cars, which have useful lives of 30 to 40 years. Since 1970, the capacity of tank cars for carrying hazardous materials has been limited to 34,500 gallons or 263,000 pounds gross weight (weight of tank car and commodity).

The two main categories of tank cars are pressure and nonpressure, and different tank car designs accommodate both gases and liquids. Each category has several classes that differ from each other in such

[86] Anne Fleming (cd.), *Big Trucks and Highway Safety* (Washington, DC: Insurance Institute for Highway Safety, 1985), p. 14.

*A stability requirement for cargo tankers need not specify any particular arrangement of tires or suspension, but might require tilt-table tests to evaluate the rollover stability of different designs. Tilt-tables are platforms on which a truck or cargo tank can be placed and tilted sideways until the wheels on one side lift off the platform. The angle to which the tilt-table must be raised before the truck wheels lift off is a measure of the static stability of the configuration being tested.

[87] Jim Reiter, American Association of Railroads, personal communication, March 1986. A Class 1 railroad has gross revenues greater than $87,935 million; a Class 2 between $17.587 and $87.935 million; and Class 3 less that $17.587 million.

Photo credit: Association of American Railroads

A pressure tank car, DOT 112J, transports liquefied petroleum products.

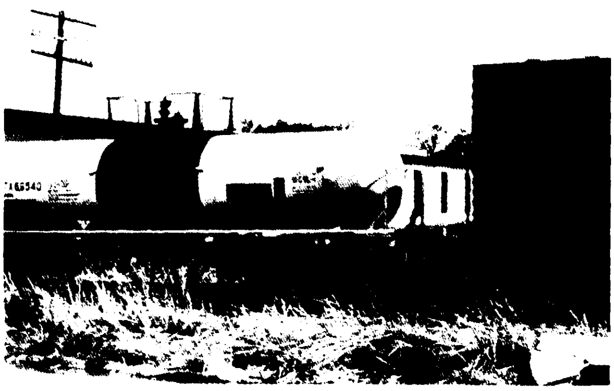

Photo credit: Association of American Railroads

An example of a non pressure tank car, a DOT 111, used in this case to transport aqueous hydrofluoric acid.

things as test pressure, presence or absence of bottom discharge valves, type of pressure relief system, and type of thermal shielding. Ninety percent of tank cars are made of steel; aluminum is the second most common construction material. The thickness of the tank car shell is specified by regulation (see table 3-11).

Tables 3-12 and 3-13 list the common classes of tank cars of both categories and provide examples of typical cargo that each may carry. Approximately 66 percent of the rail tonnage consists of chemicals, and approximately 23 percent consists of petroleum products. Based on DOT's hazard classification scheme, the most common commodities are flammable liquids and corrosive materials, each accounting for about 25 percent of the tonnage.[88]

DOT prescribes tank car design specifications in 49 CFR Part 179. The specifications have generally been developed from industry standards adopted by the Tank Car Committee of the Association of American Railroads (AAR). AAR, an industry organization, is involved in all aspects of railroad operations, including evaluation of new tank car designs, inspection of manufacturers, and collection and analysis of accident data. In addition, the Mechanical Division of AAR participates in the approval of tank car designs, materials, and construction, as well as the conversion or alteration of tank cars.[89] Although AAR approves all new tank car designs prior to acceptance by FRA and RSPA, RSPA is not involved in the design approval activities of AAR and is not permitted to attend sessions where the designs are analyzed and evaluated. RSPA'S exclusion from these sessions makes it difficult for the agency to evaluate requests for special waivers or exemptions to design requirements. After tank cars are constructed, qualification, maintenance, and use is governed by Section 173.31, as well as by individual commodity sections of the regulations. FRA is responsible for inspecting railroad operations and tank car manufacturers.

In the mid- 1970s, a series of derailments occurred, one involving the puncture of flammable gas tank cars by the couplers of adjoining cars. The ignited material venting from the punctured car impinged on other derailed flammable gas cars, simultaneously heating and expanding their contents beyond the capacity of safety relief devices and weakening the tank shells. The resulting explosions and fires caused enormous damage.

Recommendations made prior to 1978 by the National Transportation Safety Board (NTSB) and investigations by the Federal Railroad Administration led DOT to mandate installation of top and bottom shelf couplers that would be less likely to disengage and puncture adjacent cars.[90] For flamma-

[88]Abkowitz and List, op. cit.

[89]See 49 CFR 179.3.

[90]National Transportation Safety Board recommendations R-74-033 (October 1974) and R-75-19 (April 1975).

Table 3-il.—Minimum Tank and Jacket Plate Thickness

Minimum plate thickness after forming	Common use of plate thickness
Steel:	
11 gauge (approximately 1/8 inch) also aluminum '	Jacket of insulated tank cars; or jacket for thermally protected cars.
7/16 inch	Tank for nonpressure tank cars; jacket for nonpressure tank within a tank; or shell portion of jacket for cryogenic liquid tank cars.
1/2 inch	Head puncture resistance (head shield); or head portion of jacket for cryogenic liquid tank cars.
9/16 inch	Tank for steel pressure tank cars with tank test pressures of 200 psi and below.
11/16 inch	Tank for steel pressure tank cars with tank test pressures of 300 psi and greater.
3/4 inch	Tank for steel pressure tank cars in chlorine service.
Aluminum:	
1/2 inch	Tank for nonpressure aluminum tank cars.
5/8 inch	Tank for aluminum pressure tank cars.

SOURCE: Charles J. Wright and Patrick J. Student, Union Pacific Railroad, "Tank Cars," unpublished typescript, no date

Table 3.12.—Common Pressure Tank Cars

Class	Material	Insulation	Test[a] pressure	Valve[b] setting	Notes
DOT 105	Steel/ aluminum	Required	100	75	No bottom outlet or washout; only one opening in tank; e.g., DOT 105 A 500W = chlorine[c]
			200	150	
			300	225	
			400	300	
			500	375	
			600	450	
DOT 112	Steel	None	200	150	No bottom outlet or washout; e.g., DOT 112J 400W = anhydrous ammonia[d]
			340	225	
				280.5	
			400	300	
				330	
			500	375	
DOT 114	Steel	None	340	255	Similar to DOT 105; optional bottom outlet; e.g., DOT 114 T 400W = LPG
			400	300	

[a]Pressure in psi to which the tank car is tested upon manufacture and Periodically thereafter.
[b]Setting at which pressure relief value will start to discharge, Tank cars may also be equipped with vents; the vents would operate when the pressure inside the tank reached the test pressure.
[c]"DOT 105" specifies the general class; "500" specifies the tank car test pressure; the "W" indicates the method of welding of the tank; and, a number, if present after the "W", indicates specific fittings, materials, or linings.
[d]The "J" indicates that the tank car has jacketed thermal protection, A "T" would indicate the presence of spray-on thermal protection. Both "J" and "T" indicate that the tank car is equipped with head shields.

SOURCE: Charles J. Wright and Patrick J. Student, Union Pacific Railroad, "Tank Cars)" unpublished typescript, no date

ble gas, anhydrous ammonia, and ethylene oxide tank cars, the agency also required installation of head shields as further protection against coupler damage, and the addition of thermal protection to prevent rapid overheating if a neighboring tank car were on fire. AAR, its Tank Car Committee, FRA, and RSPA with participation by the Railway Progress Institute (RPI), the rail manufacturers, jointly established these tank car modifications, which have greatly improved the safety of bulk movement of hazardous materials by rail.

After the retrofits of the DOT 112/114 tank cars* were completed during 1981, the number of railroad accidents involving disastrous releases of flammable gases decreased dramatically. A 1981 study by AAR and RPI showed that the frequency of head punctures for retrofitted tank cars decreased by 95 percent from the preretrofit rate, and the frequency

*These tank cars are pressure cars that carry flammable gases—for example liquefied petroleum gas—and nonflammable gases, such as anhydrous ammonia.

Table 3=13.—Common Nonpressure Tank Cars

Class	Material	Insulation	Test[a] pressure	Valve[b] setting	Notes
DOT 103	Steel/aluminum Stainless steel/ nickel	Optional	60	35	Optional bottom outlet DOT 103 DW = whiskey
DOT 104	Steel	Required	60	35	Similar to DOT 103; optional bottom outlet
DOT 111	Steel/aluminum	Optional	60	35	Optional bottom outlet and bottom washout
			100	75	DOT 111A 60W5[c] = corrosive hydrochloric acid
					DOT 111A 60W1 = gasoline

aPressure in psi to which the tank car is tested upon manufacture and periodically thereafter.
bSetting at which pressure relief valve will start to discharge. Tank cars may also be equipped with vents; the vents would operate when the pressure inside the tank reached the test pressure.
cThe "DOT 111" is th, class; th, "60" is the pressure; the "W" indicates the type of welding construction; and the "5" indicates that the tank is rubber lined.

SOURCE: Charles J. Wright and Patrick J. Student, Union Pacific Railroad, "Tank Cars," unpublished typescript, no date.

of thermal ruptures dropped by 93 percent.[91] Experience since that study shows that while the shelf couplers tend to keep the cars more securely attached to one another, which results in more car derailments per accident, they have continued to prevent punctures and ruptures.[92] All DOT 111A tank cars carrying flammable gases and ethylene oxide and DOT 105 tank cars will be retrofitted with head shields and thermal protection by December 31, 1986. Because of the efficacy of the shelf couplers, all hazardous materials tank cars are now being fitted with them.

Table 3-14 lists the periodic inspection and test requirements for several common tank cars. Typically, the tank must be pressure tested every 5 to 10 years, although for some commodities—chlorine, for example–the tests are much more frequent. For some tank cars, the frequency of inspection increases as the car ages. In addition, some shippers inspect their cars more frequently than regulations demand, often prior to each loading.[93]

[91]American Association of Railroads, *Effectiveness of Shelf Couplers, Head Shields and Thermal Shields on DOT 112 (114) and 105 Tank Cars*, Railway Progress Institute–American Association of Railroads Tank Car Safety Project Report RA-Oi-5-51 (Washington, DC: June 13, 1985).

[92]Charles Batten, National Transportation Safety Board staff, personal communication, 1984.

[93]Robert Christman, Mobay Chemical Corp. and Hugo Andricain, Dow Chemical U. S. A., personal communication and demonstration, October 1985.

Table 3-14.—Retest Requirements for Selected Tank Cars

	Retest interval years				Retest pressure—psi		
	Tank and interior heater systems					Safety relief valve	
Specification	Up to 10 years	Over 10 to 22 years	Over 22 years	Safety relief valve	Tank	Start-to-discharge	Vapor tight
103DW ... , . .	5[a]	3	1	(b)	60	35	28
105A5OOW . . .	10[c d]	I@[d]	I o[c d]	5[c e]	500	375[f]	300
111 A60W1 . . .	—	20[g]	10	10	60	35	28
111 A60W5 . . .	5[d]	3	1	None	60	—	—
112A400Wh . . .	10	10	10	5	400	300	240
114A400W . . .	10	10	10	5	400	300	240

aA commodity for which a tank is approved may be used when retesting tanks in service not over 10 Years.
bSafety relief valve retest period is same ss tank retest period.
cTanks and safety relief valves i, chlorine service must be retested every 2 years at any time during the calendar month the retest falls due.
dNickel clad tanks i, bromine service and any glass, rubber, or lead lined tank need not be periodically retested, but the interior heater Systems and Safety relief valves must be retested at the prescribed interval.
eSafety relief valves in bromine service must be retested every 2 years.
fIf safety relief valves are used in combination with breaking pins designed to break at 375 psi, the safety relief valves must be retested and must start to discharge at 360 psi plus or minus 3 percent.
gRetest period for interior heater systems on cars so equipped is 10 years.
hNote: Tank cars stenciled 112S, 112T, 112J, 114S, 114T, or 114J will have the same retest requirements as 112A or 114A respectively.

"S" indicates car equipped with tank shield and top and bottom shelf couplers.
"J" indicates car equipped with jacketed thermal protection, tank head shield, and top and bottom shelf couplers.
"T" Indicates car equipped with spray-on thermal protection, tank head shield, and top end bottom shelf couplers.

SOURCE: General American Transportation Corp., *GATX Tank Car Manual, 4th Edition* (Chicago, IL: 1979), p. 14.

Coincident with the retrofit of certain tank cars and the reduction in serious accidents, FRA also increased the number of over-the-rail inspections of railcars, which may have contributed to reducing the number of rail accidents. There are about 183,000 tank cars, approximately 63 percent of which are used for hazardous materials. FRA performed 39,000 tank car inspections in 1982 and 31,000 in 1983, twice the number of annual inspections (16,000) performed in 1978 and 1979.

The coordination of Federal agencies involved in regulating the rail mode needs improvement. FRA has primary responsibility for regulation, inspection, and enforcement of safety regulations in the rail mode. RSPA has the final say in hazardous materials tank car specifications, although FRA and AAR perform the safety evaluations. RSPA sets regulations for intermodal portable tanks, and keeps track of incidents or spills in the rail mode, while FRA must approve securement for the tanks when they are carried over the rails on flatcars.

A comparison of RSPA's database on hazardous materials incidents with the records of NTSB demonstrated that the inaccurate and incomplete accident records are serious problems for the rail mode.[94] Between 1976 and 1983, 165 accidents involving hazardous materials appeared in the NTSB database that did not appear in the RSPA database. These accidents resulted in 37 deaths, 92 injuries, and $89 million in damages. The value of damages reported to NTSB but not to RSPA exceeded the damages of all rail incidents reported to RSPA over the same time period. Better coordination of Federal activities in data collection could provide a more complete base on which to make regulatory decisions about whether changes in tank car specifications are called for.

The railroads keep detailed records of commodity flows. If this capability were combined with better reporting of releases to RSPA, problems with particular types of tank cars or with particular commodities could be rapidly identified and alleviated. For example, more than 60 percent of all spills are due to loose or defective fittings (chapter 2). This finding indicates a need to reevaluate the specifications for the fittings or the procedures to operate them, or both. Also, OTA contractor data analysis shows that corrosives had the highest release rate in rail transport. Some tank cars that carry corrosive acids (hydrochloric acid, for example) are rubber-lined and are pressure tested only before lining. Additional study is needed to determine whether there is a relationship between test data and release occurrence or whether tank cars carrying corrosives need to be redesigned.

[94] Abkowitz and List, op. cit.

Bulk Water Transport

The largest bulk containers are self-propelled tank ships and tank barges, which together account for about 91 percent of all marine shipping of hazardous materials. Tank barges range in size from 300,000 to 600,000 gallons, and self-propelled tankers can be 10 times larger. About 8 percent of marine shipping of hazardous materials occurs in dry cargo barges, which can carry both bulk (portable tanks) and nonbulk (drums) containers.[95]

[95] Abkowitz and List, op. cit.

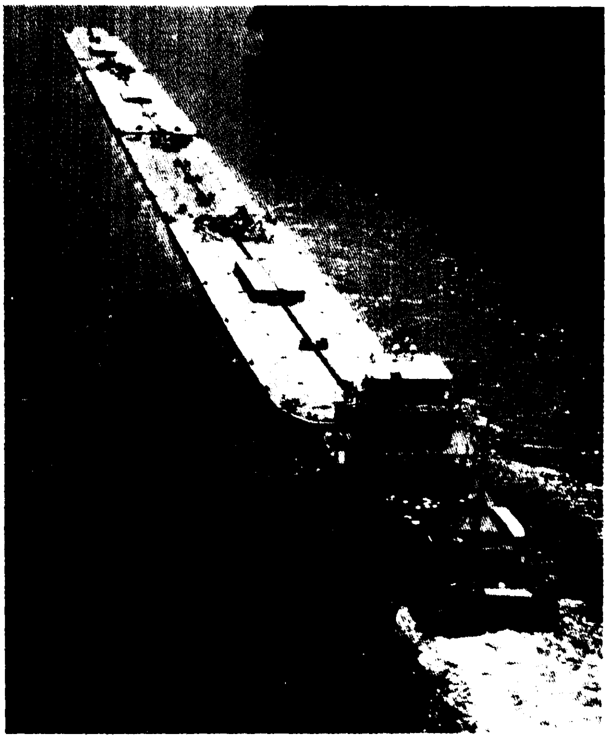

Photo credit: American Waterways Operators

Approximately 35 percent of the hazardous materials tonnage transported in 1982, was by waterborne commerce.

More than 90 percent of the tonnage in bulk marine transport consists of petroleum products and crude oil. Chemicals constitute about 7 percent, primarily basic chemicals, such as sulfuric acid, fertilizers, sodium hydroxide, alcohols, benzene, and toluene.

Because marine shipments typically involve very large quantities, fewer trips are required to move a given amount of product by water compared to the other modes. Bulk marine shippers and recipients are generally large companies, well aware of the potential liability they assume with each shipment. Because of the substantial economic investment these shipments represent, the companies expend the necessary resources to ensure safe transport as a matter of course. In addition, the vessels travel slowly. For all these reasons, the water mode has the lowest probability of an accident, and is statistically the safest, both in absolute numbers of accidents and spills per ton-mile, although when a spill does occur, the damage can be enormous.

However, other factors also explain why the water mode has the the fewest releases. In the first place, all vessels carrying bulk hazardous materials are subject to Federal hazardous materials regulations. Records kept by the government list every vessel in commerce in U.S. waters and note every shipment of commodities to or from every port in the United States. This recordkeeping emphasizes the accountability of those involved in bulk marine transport.

Photo credit: U.S. Coast Guard

Coast Guard personnel examine **a vessel carrying hazardous materials.**

Moreover, the captains and operators of bulk marine vessels are tested and certified by the U.S. Coast Guard. Regulations require that the self-propelled tank ships and tank barges that carry most of the hazardous materials on water be loaded and unloaded by tankermen who have been tested and endorsed by the Coast Guard. A tankerman must demonstrate familiarity with the general arrangement of cargo tanks, suction, and discharge pipelines and valves, and be able to operate pumps and other equipment connected with the loading and discharging of cargo, as well as fire extinguishing equipment, In addition, the tankerman must demonstrate knowledge of pollution laws and regulations, procedures for discharge containment and cleanup, and methods for disposal of sludge and waste materials from cargo and fueling operations.[96] Because many spills occur during loading and unloading (see chapter 2), shippers generally provide special training to those who load and unload barges and self-propelled tankers.

The Coast Guard also regulates tank barges and self-propelled tank ships. All new vessels to be used for hazardous cargoes in bulk must meet the design requirements of 46 CFR. New vessels must be inspected and certificated by the Coast Guard or by the American Bureau of Shipping. All existing self-propelled tank ships carrying hazardous cargoes must be inspected by the Coast Guard every year. Tank barges are inspected every 2 years, although an additional midterm inspection makes the effective time between inspections just 1 year. Moreover, some major shippers inspect bulk vessels prior to each loading. This frequency-of-inspection requirement may partly explain why the bulk water mode has the best safety record for hazardous materials.

Nonetheless, despite this safety record, bulk water shipments of hazardous materials have been declining; the number of active tank barges in U.S. domestic commerce decreased from 4,900 in 1982 to 4,100 in 1983.[97] One reason is that chemical companies have recently been reducing inventories, partly in response to safety recommendations made

[96] 46 CFR 12.20.5.
[97] The analysis of the changing business practices is based on interviews with representatives of several major chemical and petrochemical companies and on Monsanto Co., *One Year Later: Report of the Monsanto Product and Plant Safety Task Force* (St. Louis, MO: December 1985). The data on numbers of tank barges are from the Waterborne Commerce Statistics Center of the U.S. Army Corp of Engineers.

after the Bhopal disaster, that smaller volumes of extremely hazardous substances be stored or used in batch processes. In addition, inventory reduction is also one way of making operations more efficient. Storage costs dictate that chemical companies store less and buy only what they will use immediately and that goods be delivered quickly, so production is not interrupted.

Intermodal Tank Containers

Intermodal tanks carry 4,000 to 6,000 gallons of liquid in a metal container surrounded by a rigid metal protective frame that facilitates the handling and securing of the tank container in the marine, rail, and highway modes of transport. They are versatile and efficient containers for substances that must travel long distances by several different modes. Used extensively in international trade, they are often carried by rail, water, and truck on a single journey. The capacity of a typical intermodal tank is equivalent to about 100 55-gallon drums, and intermodal tanks are displacing the 55-gallon drum in international commerce when such quantities are transported. In domestic commerce, the tanks are being used for special commodities or on long trips that involve a rail leg, and their use is rapidly increasing in this country as the volume of international trade increases.

For the most part, DOT regulations follow the International Maritime Organization guidelines for tank containers. These tanks are built either to the American Society of Mechanical Engineers Boiler and Pressure Vessel Code or to an equivalent code and must be certified by a DOT approval agency as being designed, manufactured, and tested in compliance with DOT regulations. The three largest approval agencies are the American Bureau of Shipping, Lloyds Register, and Bureau Veritas.

DOT requires a prototype of each tank design series to be performance tested in accordance with the tests required by the International Convention for Safe Containers. The tests simulate the in-service conditions of a tank container in marine, rail, and highway transport. To ensure that tank containers are maintained in good operating condition, DOT requires each tank to be visually inspected at 2½-year intervals and to undergo a hydrostatic pressure test at 1½ times the maximum allowable working pressure every 5 years. The visual test may be conducted by an owner, although when it coincides with a hydrostatic test bath it must be certified by inspectors of the designated approval agencies.[98]

For use in the United States, the tanks must be registered by serial number with DOT, and regulatory responsibility for them and their carrying vehicles is shared by RSPA and the modal administrations. The poor interagency coordination at DOT is a particularly acute problem affecting adequate regulation of the transport of these vessels.

Few appropriate truck chassis for intermodal tank containers are available in the United States. Most of the available chassis are deficient either in length, securement devices, or overall design, which typically incorporates a high center of gravity. Loaded portable tanks must generally be carried on 40-foot chassis in order to comply with bridge laws that limit the vehicle weight per axle and per wheelbase. However, only about 400 40-foot chassis in this country have twist locks that positively secure the portable tank in the center of the chassis, preventing lateral or vertical motion, although there are several thousand portable tanks available for commercial use.[99] Thus, most intermodal tank containers now travel by highway on 40-foot flatbed trucks secured by hooks and chains, legal securement under current regulations, or on 20-foot chassis, which may have proper securement devices, but which violate road weight laws. Industry leaders adamantly maintain that J hooks and chain binders provide grossly inadequate securement for the tanks on flatbed chassis, and accident records are beginning to corroborate this.[100] As recently as November 1985,

[98]Much of this information is derived from written communication from Donald L. Monroe, American Bureau of Shipping (ABS), Paramus, NJ, April 1986. The ABS is a private not-for-profit, international classification society comprised of shipowners, shipbuilders, naval architects, and others associated with the marine industry, concerned with assuring mechanical and structural fitness of vessels. They establish standards, adopted internationally, by which ships and other marine structures are built and maintained.

[99]George Graham, President, Chemical Leaman Container Corp., agents for Sea Containers Inc., a major owner, leaser, and transporter of intermodal containers, personal communication, October 1985.

[100]George Graham, President, Chemical Leaman Container Corp., agents for Sea Containers, Inc., has strongly advocated that intermodal tanks not be allowed to travel on flatbed trailers secured only by chains. Chain or chain binders allow for tank movement and make the vehicle dangerously unstable. His comments were made at the first semi-annual meeting of the Hazardous Materials Advisory Council, held at Hilton Head Island, SC, Nov. 14, 1985, and reported by Laurie Bradford, in "Inexperience Poses Major Threat to Safety in Transport of 'HM,' " *Traffic World, Nov. 25, 1985.*

Photo credit: American Bureau of Shipping

American Bureau of Shipping inspector examining the **securement** device, a “twist lock, ” on a trailer.

however, DOT officials were claiming that no new regulations were needed for the type of trailer used to transport portable tanks as long as existing securement regulations were followed. *O'

In addition, few chassis are specifically designed for intermodals. A “low boy” chassis with a flatbed several feet lower than normal is ideal for intermodal tank transport. The chassis design keeps the center of gravity low and the vehicle more stable. These chassis are used throughout Europe, but there are fewer than 100 appropriately configured chassis in the United States. Any requirement for increased use of low boy chassis would need to allow time for manufacture of a fleet sufficient for domestic commerce. Moreover, the concentration of the weight of a 20-foot portable tank in the middle of a 40-foot chassis is a new design problem for some manufacturers. Flaws in the design or manufacture of some low boy chassis have caused fractures and failures at the goose neck portion where the support beams descend from the fifth wheel area to the bed of the chassis,[102] and one new chassis failed within 3,000 miles of use.[103]

The behavior of intermodal tanks on trailers is very different from that of regular intermodal containers or even cargo tankers. Intermodal tanks are rarely compartmentalized, so the effects of sloshing liquid cargo can be pronounced when the tank is not full or nearly full. Current regulations require that intermodal tanks be filled to at least 80 percent of their capacity (by volume),[104] close to the level that produces the most unstable conditions in the tank.[105] Not only is the configuration inherently unstable, but the driver often cannot feel the instability until it is too late.[106] For certain commodities, road weight laws may limit the filling of an intermodal tank to 80 percent by volume; thus obeying all the relevant regulations could result in the least stable set of circumstances possible.

Furthermore the use of intermodal tanks in rail traffic is likely to increase, and the safety characteristics of intermodal tanks on trailers on railroad flatcars are not well known. Currently, FRA, which approves securement devices for tanks during travel by rail, is studying the safety characteristics of containers and trailers on rail flatcars. However, appropriate coordination between FRA and the Federal Highway Administration has not been established. FRA is now testing a configuration involving an intermodal tank on a 20-foot truck chassis[107] that is illegal for highway travel in most States, because the weight is not distributed over a long-enough wheelbase to satisfy highway bridge laws. Although the tank and chassis may be within the 80,000 pound gross weight limit, the configuration is either carrying too much weight per axle or for the length of wheelbase. Although FRA is aware that carrying portable tanks on the 20-foot chassis is illegal on most highways, it nonetheless is using the chassis in safety studies.

The Coast Guard monitors the acceptance of portable tanks entering the United States. It also

[101]Ken Pierson and Alan Roberts, in response to questions at the Hazardous Materials Advisory Council meeting, Hilton Head, SC, November 1985, as reported in *Modern Bulk Transporter,* January 1986.

“"*Donald L. Monroe, Principal Engineer, American Bureau of Shipping, personal communication, April 1986.

[103]George Graham, President, Chemical Leaman Container Corp., personal communication, April 1986.

[104]49 CFR 173.32c(j).

[105]The most unstable load for steady-state cornering is when the tank is loaded to 75 percent of capacity. R. D. Ervin, et al., University of Michigan Transportation Research Institute, *Liquid Cargo Shifting and the Stability of Cargo Tank Trucks, Final Technical Report,* vol. 11 (Washington, DC: Federal Highway Administration, Bureau of Motor Carrier Safety, U.S. Department of Transportation, September 1985).

[106]*Hazardous Cargo Bulletin,* “Ullage and Roll Stability,” June 1985.

[107]Clair Orth, Federal Railroad Administration (FRA), personal communication, January 1986. FRA is testing an intermodal tank on a 20-foot chassis. Such an arrangement is likely to violate highway bridge laws which specify the gross weight allowed for a given distance between axles.

determines whether a tank carrying hazardous materials may be shipped out by vessel and where and how it will be stowed aboard the vessel. Much of the use of intermodal tanks in the marine mode is international.

Ton Tanks.–Certain multiunit **cylindrical pres**sure vessels, commonly called ton tanks because of their characteristic size,[108] are meant to be lifted on and off vehicles for filling and emptying. Specifications for these are published as part of the tank car rules in 49 CFR Part 179. Used chiefly for chlorine transport, these are some of the heaviest and most effective containers in commerce.

Nonbulk Containers

Nonbulk containers are used to transport hazardous materials in all modes but constitute different proportions of traffic in each mode. By tonnage, small packages make up a small proportion of rail and water traffic, about half the highway traffic, and virtually all air traffic. Correspondingly, nonbulk packages constitute a small percentage of the incidents reported in the Hazardous Materials Information System in the rail and water modes, but comprise about 80 percent of the containers cited in highway releases and all the containers cited in air releases.

Materials used in nonbulk packaging include fiberboard, plastic, wood, glass, fiberglass, metal, and combinations of these. Combination packaging or packages within packages are often used in hazardous materials transport and include, for example, glass bottles in fiberboard boxes. Composite packaging are made of two or more materials such as a plastic-lined steel drum. Most containers can be used for a multitude of products, although certain types of packaging are designed for a particular commodity. Free-standing single units such as steel drums and cylinders for compressed gases are also widely used.

Factors related to the realities of the transportation system also influence container design. For example, products that are used only in small unit quantities often are transported packaged in those quantities, and many packaging that will be transported on trucks and railcars are designed to facilitate loading, unloading, and using vehicle space efficiently. The type of handling equipment available is also a consideration. The 55-gallon steel drum, for example, has been called "man-sized" packaging, because it is about the largest unit that can fit through a normal doorway and can be handled by a single person.

Releases from nonbulk packages of hazardous materials, while numerous, generally do not have serious consequences because of the small amounts of materials in the packages. Human error, such as improper packing or handling, rather than poor container design, causes the majority of releases. Moreover, errors such as the use of improper packaging, frequently stem from ignorance, since shippers, especially small companies, find the hazardous materials regulations confusing.

Current packaging regulations are complicated and cumbersome and do not encourage development of packaging innovations. DOT has proposed a rulemaking (Docket No. HM-181) to change the current regulations from design standards specifying how a package must be constructed to performance standards that say what a package must do. * This section of chapter 3 focuses on operational changes affecting safety and on regulatory changes that would simplify and clarify packaging requirements and enable U.S. industry to be more competitive internationally.

Current Design Specifications for Packaging

Although some materials of low hazard do not require "specification packaging" (packages of such materials need only satisfy the general requirements),** DOT specifies detailed packaging requirements for most hazardous materials.

[108] Specifications 106 and 110.

*performance standards are described in detail later in this chapter. Rather than stating exactly how and of what materials a package must be constructed, performance standards lay out tests that packages must pass before they can be used. If a package passes the appropriate tests (for example, a 6-foot-drop test or a 4.8 psi pressure test) then it can be used without consideration of the details of its construction. For performance standards to work well, the tests must correlate to the stresses that packages experience in transport.

**For example, dichloromethane, classified as an ORM A material, does not require specification packaging.

As described in a recent DOT advance notice of public rulemaking, a specification typically:

> . . . includes requirements for material, thickness, fastenings, capacity, coatings, openings, joining, carrying devices and miscellaneous other construction requirements. Much of the information is given in great detail and is repetitious. For example, there are fourteen specifications for wooden boxes, Most specifications list the acceptable types of wood from which lumber must be used to construct the box, and this list may be repeated in the next specification for a similar, but slightly different box. In addition to the types of acceptable wood being specified, the thickness and width of the boards, the kind and dimension of nails, and the spacing of the nails in joining the box may also be specified.[109]

While specifications developed over the years have brought a measure of uniformity and familiarity to hazardous materials packaging, they often act as an impediment to new packaging designs. Nevertheless, over the years, new packaging ideas have been developed by container makers and shippers and then discussed with the regulatory agencies.[110] In the era prior to the Hazardous Materials Transportation Act (HMTA), if new packaging appeared to be well designed and to have been successfully tested, regulatory agencies would issue a special permit approving its use by the developers, but would seldom authorize more general use. After the passage of the HMTA in 1975, such authorizations were formalized as exemptions and were controlled and limited. If a shipper wishes to make shipments in a container different from that specified in-the regulations, a petition for an exemption must be submitted to DOT. Each exemption is issued for up to 2 years and can be renewed. The exemption holder must report any adverse experiences in addition to any other incident reporting requirements. An ongoing rulemaking (Docket No. HM-139) exists to incorporate successful exemptions into the rules for general applicability. * However, rulemaking is sometimes too slow to keep up with the demand. For example, exemptions covering plastic drums and cryogenic cargo tank specifications were eventually incorporated into the regulations, but only many years after they were first authorized (17 years in the case of the cargo tanks).

Exemptions have become time-consuming administrative problems for both industry and government. RSPA has spent a large portion of staff time processing exemption applications over the years.[111] Staff typically handles about 100 exemptions per month, about half of these dealing with small packages. Exemptions are issued to an original applicant, but other persons can become "parties to" that exemption. Exemptions that have been in effect for several renewal periods and have multiple parties to them are indicators of a deficiency in the rulemaking process. In fact, about 90 percent of all exemptions applications are for renewals or to become parties to existing exemptions.

Performance Standards

In 1969, a conference of transportation experts from government and industry[112] recommended performance standards for packaging. Those experts believed performance standards could eliminate much of the Federal process for granting exemptions, approvals, or specific rulemaking petitions on packaging; eliminate many of the existing voluminous and complex regulations; and open the door to new technologies and innovations in the development of packaging designs. However, not until 1982, did DOT issue an advance notice of proposed rulemaking, Docket No. HM-181, proposing a framework of performance standards governing the design of containers with a capacity of 450 liters (119 gallons) or 400 kilograms (880 pounds) or less.

Effective performance standards require a thorough understanding of the transportation environment to determine precisely how the packaging must perform. Package designers need to know temperature variations, physical stresses during turns and

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[109] *Federal Register*, "Performance-Oriented Packaging Standards, HM-181," vol. 47, No. 73, Apr. 15, 1982.

[110] See ch. 4 for a description of the evolution of hazardous materials regulations and the special relationship that industry has had with the regulatory bodies over the years.

*Rulemaking dockets are the procedural means by which new regulations are promulgated. The HM in HM-139 stands for hazardous materials.

[111] U.S. Congress, Congressional Research Service, *Hazardous Materials Transportation: A Review and Analysis of the* Department *of Transportation Regulatory Program* (Washington, DC: CRS, April 1979), p. 125.

[112] National Research Council, Highway Research Board and the Committee on Hazardous Materials, *A Study of Transportation of Hazardous Materials: A Report to the Office of Hazardous Materials of the U.S. Department of Transportation* (Washington, DC: National Academy Press, 1969).

stops, and the nature of shocks and vibrations that their packages are likely to encounter during transport. Once transportation conditions are sufficiently documented, tests can be developed to ensure that the packaging will contain its cargo during transport. Several years ago DOT issued contracts for a study of the transportation environment,[113] which, while not comprehensive, provided useful information on the stresses to which packages are subjected during transportation.

The performance standards proposed by DOT are based on the United Nations Recommendations for the Safe Transport of Dangerous Goods,[114] which divide hazardous materials into three "Packing Groups" depending on their relative hazards. Packing Group I consists of very dangerous materials, such as fuming sulfuric acid, a Group I corrosive. Packing Group II involves materials presenting a moderate degree of danger, such as hydrochloric acid, also a corrosive. Packing Group III addresses materials presenting only minor danger.

The U.N. Dangerous Goods standards also have general requirements for materials, construction, and maximum size, and specify tests that must be met by packages for each packing class. For example, if it is to carry liquids, the U.N.1A1 steel drum, one of two types of steel drums in the recommendations, must have welded seams and welded or mechanically seamed chimes (the edges of the drum where the side-wall meets the top and bottom); its opening may not exceed 7 cm in diameter, and the drum may not exceed 450 liters capacity.

Even these requirements may be waived as advances in science and technology occur, as long as the packages are able to withstand performance tests. The strength and integrity of the drums are established by a series of performance tests the drum must pass before it is authorized to carry hazardous materials in each packing group. The principal tests are a drop test, a stacking test, a leak test for containers for liquids, and a hydraulic pressure test. The drop test consists of filling the drum as if for shipment and allowing it to fall to a level, unyielding surface without spilling its contents. The height specified for the drop test is determined by the packing group of the hazardous materials to be transported. The steel drum would have to survive a drop from a height of 1.8 meters (6 feet) if it were to carry a material in Packing Group I, 1.2 meters for Group 11, and 0.8 meters for Group 111.[115] Thus the most dangerous materials, Packing Group I, must be packaged in the most robust containers.

Adoption of the U.N. recommendations would include not only the U.N. system of packaging, but also the U.N. materials classification, labeling, and shipping descriptions. Unlike the DOT classification system, the U.N. classification system classifies commodities within a given hazard class by degree of hazard, and the placards displaying the hazard class show degree of hazard as well. This aspect is important to emergency response personnel, as these distinctions give an immediate indication of the level of danger during response to an incident.

Some U.S. industry representatives hold that the U.N. standards by themselves will not result in packaging adequate to withstand the rigors of international commerce. They feel that the correlation between the performance tests and the stresses of the transportation environment is not well established and that some minimum design specifications should be retained. For example, a drum manufacturer contends that steel drums intended to contain liquids belonging to Packing Groups I or II should be of 1 mm minimum thickness, equivalent to a thickness of 19 to 20 gauge, to ensure against external puncture.[116]

Moreover, some of the U.N. tests are not as stringent as current DOT specifications. For example, leak test pressures that are part of DOT's current specifications for steel drums are in every case greater than those that would be required under the U.N. system; DOT's requirements range from 7 to 15 pounds per square inch (psi) while the U.N. 'S range from 2.8 to 4.3 psi. Some U.S. additions to the tests to address inadequacies in the international standard may be proposed. For example, DOT is expected to require a vibration test as part of the perform-

[113] Fred E. Ostrem and Basil Libovicz, General American Transportation Corp., General American Research Division, *A Survey of Environmental Conditions Incident to the Transportation of Materials Phase II* (Washington, DC: U.S. Department of Transportation, April 1978).

[114] See ch. 4 for a discussion of the U.S. involvement in the development of these recommendations.

[115] Much of this discussion is taken from the Supplementary Information section of HM-181, *Federal Register*, "Performance-Oriented Packaging Standards," op. cit.

[116] William H. Gushard, Grief Brothers Corp., Springfield, NJ, written communication, February 1986.

ance standards test program in an effort to model more closely the transportation environment. However, additional testing requirements for packaging used in the United States could become barriers to international trade, a result that the U.N. standards are designed to avoid.

Because of the uncertainty about the appropriateness of the performance tests in mimicking the transportation environment, it is important to collect data on releases from small packages to permit evaluation of the adequacy of the tests.[117]

Adoption of performance standards would constitute a major change in the way regulations address design of small packaging for hazardous materials transportation. However, DOT and some package manufacturers already have experience with performance standards. For example, the approval process for pressurized cylinders, many steel drums, and many combination packaging of glass bottles inside fiberboard boxes includes performance tests. Comments received by DOT on the proposed performance-oriented packaging standards have generally been favorable, citing the removal of unnecessary impediments to the flow of international commerce, and making the DOT exemption process either unnecessary or at least less cumbersome.

The fate of current U.S. container specifications, once U.N. performance standards are accepted here, is still a subject of debate. Smaller container manufacturers and shippers will probably limit themselves to proven packaging described in the current 49 CFR. DOT has stated that many, if not most, existing DOT packages would successfully pass the performance tests and could continue to be used with U.N. markings.

[117]U.S. Department of Transportation (DOT) has published an "Advanced Notice of Proposed Rulemaking" ("Detailed Hazardous Materials Incident Reports," Docket No. HM-36B, *Federal Register, 10042,* Mar. 16, 1984), which would reduce the reporting requirements for incidents involving small packages. If a small package releases hazardous materials, the incident would not need to be reported unless: the material was a hazardous waste, someone was injured or killed, people were evacuated, the package involved was shipped under the Research and Special Programs Administration's exemption program, or property damage including cleanup and decontamination costs exceeded $1,000. While such a rulemaking would relieve carriers of reporting releases with small consequences, it would also deprive DOT of information regarding the safety of particular container types. The cost of a particular release is related more to the contents of the container than its safety. Upon adoption of performance-based standards, it may be prudent to retain the current comprehensive reporting requirements so that the performance tests can be evaluated.

Moreover, there is little indication that removal of regulatory constraints would bring about significant changes in packaging because the factors leading to a design—such as new products or materials—were never regulatory. Developing a system of performance standards does open the way for greater design flexibility and should smooth the authorization process. Performance standards themselves are unlikely to stimulate greater innovation, although they have the potential for allowing innovations to be implemented more quickly than they are today. Finally, DOT will still be required to consider major innovations and new technologies not addressed in performance standards.

Assessing Small Package Performance

Currently, neither industry (with a few exceptions) nor government appears to monitor systematically the success rate of small packages. An OTA sampling of manufacturers and shippers indicated that customer complaints and package failure reports are the primary means of assessing package performance in the field.

A packaging problem area that may require attention is the compatibility of wastes and their containers. Carriers have unwittingly accepted loads of wastes from shippers unaware of the wastes' composition or properties, and have had corrosion problems in their containers as a result.[118] With many small-quantity generators of hazardous wastes soon becoming subject to Federal regulation under the Resource Conservation and Recovery Act, the potential for mispackaging becomes enormous. These generators will need both information and assistance from EPA and DOT in complying with the new law. (See appendix A.)

Metal drums and glass bottles are the containers that appear most frequently in the incident reports (they were involved in about 2,000 incidents per year from 1976 to 1984 according to RSPA records), but this figure is only a small percentage of the drums and bottles carrying hazardous materials in commerce. However, release rates on either a per-ton-mile or a per-package-shipped basis are nearly im-

[118]Robert S. Shertz, Chemical Leaman Tank Lines, personal communication, October 1985; and Richard O'Boyle, Quality Carriers Inc., in U.S. Congress, Office of Technology Assessment, "Transcript of Proceedings–OTA Workshop Proceedings on State and Local Activities," op. cit.

possible to calculate because the commodity flow and release data are poor, especially for the air mode. Without this type of data, RSPA cannot adequately evaluate container design from its release reports. Release rates would yield information on the adequacy of packaging and indicate needs for revised packaging requirements.

Third-Party Testing and Certification for All Packaging

Under U.N. performance standards, the design of a container must be tested and officially certified. Under the U.S. packaging rules in 49 CFR, the marking of the specification number on a container constitutes a certification of compliance with that specification, including any prescribed tests. Testing, marking, and certification are usually done by the maker of the packaging in this country—essentially, self-certification. In Europe, government-owned or specially designated testing laboratories do most of this testing and certification. European road and rail regulatory conventions require U.N. standards in Europe, and U.S. packaging shipped to Europe must comply with those standards, including U.N. marking and certification. Under DOT's proposed performance standard system, container manufacturers would still be able to self-certify their packages. Whether European countries will accept this certification is uncertain, but third-party testing facilities are now available in the United States to certify packages for international trade, should that prove necessary.

In DOT Docket No. HM-194, effective July 1, 1985, DOT established a method for granting government approval to third-party testing facilities. HM-194 spells out various approval requirements for a laboratory, but allows the test facility to determine the precise equipment it needs. As of February 1986, eight such laboratories had been approved by DOT.

Third-party inspection and testing is already required by U.S. regulations for some containers, notably high-pressure compressed gas cylinders and most intermodal portable tanks. For pressure vessels in all modes except rail, construction usually must be completed in accordance with design codes of the American Society of Mechanical Engineers and must be inspected by an authorized third-party inspector. In practice this means that only MC-331 and MC-338 cargo tanks undergo third-party inspection, and there is no third-party role in the construction of most nonpressure tank trucks, the vast majority of cargo tankers. AAR's Mechanical Division is involved in approving tank car construction. Although self-certification is broadly advocated for smaller packaging, third-party testing and certification for larger units is still an open question.

Training in Operations and Procedures

OTA analysis shows that more than 60 percent of hazardous materials releases involving small packages can be attributed to human errors such as improper packing, bracing, loading, or unloading. Vehicle accidents cause another 5 percent of all hazardous materials releases, and human error causes 60 to 70 percent of these accidents.[119] These failings have compromised even well-designed packages, and the greatest opportunity to reduce the frequency of spills may come from programs to address factors other than the containers themselves.

DOT's release reporting system, the Hazardous Materials Information System, cites "struck by other freight, " "cargo shifted," "improper loading, " and "external puncture" as the reasons for more than 50 percent of small packaging spills. These causes usually occur because shipper or carrier personnel did not properly load, block, and brace packages inside of the vans, railroad cars, and airplane holds in which the small packages travel.

For most transport, the regulations state simply that packages must be secured against movement during normal transportation, although somewhat more specific requirements apply to individual modes or for particular hazard classes. Packages containing explosives have special loading provisions in all the modes, for example. Corrosives must not be loaded above other materials, and compressed gases must be secured in an upright position, or packaged to prevent movement, or placed horizontally on the floor of the vehicle. Other provisions prohibit certain hazard classes from being carried together in the same vehicle or vessel stowage compartment, but generally the regulations do not spe-

[119] Washington Utilities and Transportation Commission, op. cit., p. 8.

cify what constitutes appropriate blocking and bracing techniques. Methods of blocking and bracing for the rail mode, recommended by AAR, are referenced in 49 CFR.[120] The high rate of releases associated with loading and unloading activities implies that more explicit procedures might improve safety.

Analysis of hazardous materials violations also supports a need for shippers to improve operations and procedures. A 1983 informal survey of States participating in a DOT enforcement training program identified the following as the most common hazardous materials violations found during roadside inspections of motor carriers:

- failure to display the correct placard,*
- failure to block or brace hazardous materials containers,
- leaking discharge valves on cargo tanks,
- improperly described hazardous wastes,
- inaccurate or missing shipping papers, and
- excessive radiation levels in the cab of the truck.[121]

In addition, a 1979 report issued by the National Transportation Safety Board cited a number of reasons for noncompliance with the hazardous materials regulations, including:

- the regulations are complex and difficult to understand,
- economic pressures,
- industry personnel often are unaware of the regulations, and
- lack of available training for inexperienced personnel.[122]

Data on both accidental releases and violations of regulations raise questions about the adequacy of private sector training. RSPA's hazardous materials regulations contain only a general statement about training:

> It is the duty of each person who offers hazardous materials for transportation to instruct each of his officers, agents, and employees having any responsibility for preparing hazardous materials for shipment as to the applicable regulations in this subchapter.[123]

However, the complex regulations cover driver qualifications, hazardous materials classification, shipping papers, marking, labeling, and placarding, as well as general operational procedures for loading and unloading, and blocking and bracing of hazardous materials packages.

Good driver performance is especially important for bulk highway transport, where 20 percent of releases are caused by vehicle accidents, most due to driver error. However, RSPA has not specified how drivers are to be instructed in the regulations and has expanded on the general training requirement for the highway transport of only two commodity types: flammable cryogenics and highly radioactive materials. RSPA based the driver training requirement for carriage of flammable cryogenics on the need to increase the driver's knowledge of the hazards of cryogenic liquids, the applicable regulations, and the handling and operating characteristics of the particular vehicle used to transport the material. A certificate indicating completion of training must be on file with the driver's employer.[124]

In addition, drivers hauling highly radioactive materials must receive written training on:

- regulations pertaining to the radioactive materials being transported;
- the properties and hazards of the radioactive materials transported; and
- procedures to be followed in case of an accident or other emergency.[125]

The driver must have in his possession a certificate of training stating that he has received training, the dates of training, and the name and address of the person providing the training.[126] In the final rule-

[120] The general requirements for loading and unloading, and blocking and bracing are presented in: 49 CFR 174.55 for the rail mode; 49 CFR 175.81 for the air mode; 49 CFR 176.57 and 49 CFR 176.69 for the marine mode; and 49 CFR 177.834 and 49 CFR 177.848 for the highway mode.

*Accurate placards and shipping papers are particularly important for the safety of first responders to hazardous materials emergencies, as they provide essential, basic information on the nature of the materials the responders face.

[121] US Department of Transportation, Research and Special Programs Administration, "Quarterly State Hazardous Materials Enforcement Development (SHMED) Program Progress Reports: 1984 -1985," unpublished reports.

[122] National Transportation Safety Board, *Noncompliance With Hazardous Materials Regulations,* NTIS # PB-299 432 (Washington, DC: Aug. 3, 1979), p. 17.

[123] 49 CFR 173.1(b).

[124] *Federal Register,* vol. 48, No. 117, June 16, 1983, p. 27684.

[125] *Federal Register,* vol. 46, No. 12, Jan. 19, 1981, p. 5317.

[126] Ibid., pp. *5298-5318.*

making notification, RSPA noted the possibility of extending driver training requirements to cover other commodities and of specifying a more structured training program in the future if a need exists.

Recently BMCS proposed new requirements, similar to those for drivers of flammable cryogenics and large quantity radioactive materials, for drivers of trucks carrying other hazardous materials.[127] However, little guidance is given on how to conduct the training or how long each element of the training might take. Furthermore, no provisions are included for nondrivers who may handle hazardous materials during loading and unloading operations.

Of the DOT modal administrations, only the Federal Aviation Administration has established an explicit training requirement for employees of commercial air carriers. All crewmembers and ground personnel with responsibilities in the acceptance, handling, and carriage of hazardous materials must complete training in an appropriate program established by the carrier.[128] Some air carriers, such as Federal Express and Flying Tigers, also provide training for shippers of hazardous materials. *

The water mode also has training requirements, although they are not specific. Carriers in the water mode must be licensed by the Coast Guard, which tests ship and barge operators to ensure that they are properly trained. In addition, the loading and unloading of tank ships and barges must be done by licensed tankermen who have passed an examination sponsored by the Coast Guard.

Recognizing the factors leading to noncompliance and unsafe procedures, several States have instituted additional training requirements. For example, effective in 1984, Michigan began requiring that intrastate drivers of bulk hazardous materials have 80 hours of training, of which 60 had to be in operation of the vehicle they were to handle. However, in 1985, 21 of 22 Michigan firms failed management audits, because they lacked any record of training, pointing to the necessity for enforcement if training requirements are to be effective.[129] Michigan did not extend training requirements to interstate transporters of bulk hazardous materials because of concerns over preemption of their law by Federal regulations. Several other States have also instituted training requirements.*

Many European countries have also recently implemented definitive training requirements for drivers of transport units carrying tanks or tank containers of hazardous materials. In many cases training courses must be approved by the government or an agency designated by the government. The training must cover:

- general requirements governing the transport of dangerous goods;
- the main types of hazards;
- appropriate prevention and safety measures for the various types of hazards;
- what to do after an accident (first aid, road safety, basic knowledge about the use of protective equipment, etc.);
- labeling and marking to indicate danger;
- what a vehicle driver should and should not do during the carriage of dangerous goods; and
- the purpose and methods of operation of technical equipment on vehicles and the behavior of vehicles carrying tanks or tank containers on the road including the movements (sloshing) of the load.[130]

It is too early to quantify the effect of the training on road safety, but both drivers and safety officials feel it is positive.[131]

[127] *Federal Register*, "Qualification of Drivers, Notice of Proposed Rulemaking," vol. 51, No. 92, May 13, 1986, pp. 1752-17581.

[128] 14 CFR 135.333. The Federal Aviation Administration (FAA) regulations require training on: proper shipper certification, packaging, marking, labeling, and documentation for hazardous materials; and the compatibility, loading, storage, and handling characteristics of hazardous materials. Commercial air carriers must also maintain records on initial and recurrent training given to crewmembers and ground personnel. FAA has issued an Advisory Circular that provides general guidance to air carriers for training manuals and programs. See U.S. Department of Transportation, Federal Aviation Administration, AC 121-21B, Jan. 3, 1984.

*For example, U.S. Environmental Protection Agency employees from Region IV have attended Federal Express courses to learn how to send environmental samples to laboratories by air.

[129] Sergeant Gary Koss, Michigan Motor Carrier Enforcement Division, Michigan State Police, personal communication, May 1986,

*Massachusetts, Maryland, New Hampshire, Rhode Island, Pennsylvania, California, Georgia, and New Jersey, for example, have training requirements for drivers of vehicles hauling either hazardous materials or, more commonly, hazardous wastes.

[130] United Nations, Economic Commission for Europe, Inland Transport Committee, *European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR) and Protocol of Signature, Volume III (Annex B)* (New York: 1985), p. 15.

[131] United Nations, Economic Commission for Europe, Inland Transport Committee, *Driver Training Requirements*, GE. 85-21354 (New York: United Nations, Apr. 4, 1985), pp. 2-4.

In the United States, shippers and carriers of hazardous materials and some private firms have developed training programs or courses designed to instruct industry personnel on Federal and State regulations. The recent collective bargaining agreement of the Teamsters Union calls for at least 3 hours of mandatory training of certain workers, including drivers, dock workers, clerical workers, and shop employees, on specified sections of hazardous materials regulations.[132] However, the duration and intensity of the training is left to the discretion of the shipper or carrier.

The American Trucking Association (ATA) provides compliance training through its State organizations and through sale of items such as the publication, *Handling Hazardous Materials,* which describes the hazardous materials regulations in layman's terms, and a five-part slide program that consists of 20-minute modules on specific hazardous materials requirements, such as shipping papers or marking and labeling. The National Tank Truck Carriers, Inc. (NTTC), has produced and sells a slide program and accompanying manual for tank truck drivers on flammable liquids, the most commonly transported hazard class carried by its members. NTTC has nearly completed development of a similar training program on corrosives. Both of these programs were put together by the safety officers of major carriers affiliated with NTTC. Some trucking companies also provide hazardous materials training for their personnel, although small transport companies are generally not able to provide the same level of training as larger firms.[133]

AAR offers training courses for railroad employees, and large railroads instruct transport and yard personnel in hazardous materials regulations and emergency response procedures. * Shippers of tank car quantities of hazardous materials are often large companies that own or lease their tank cars. Such companies frequently have training programs for employees involved with loading and unloading hazardous materials. Recently an interactive videodisk training program covering all aspects of railroad operation, including hazardous materials regulations and handling procedures, was developed by the Port Terminal Rail Authority in Houston, Texas, as a demonstration supported by FRA.[134] Arranged in modules so the trainee can learn at his or her own pace, the training program can be customized for different railroads, and one of the demonstration conditions was that the program be made available to other railroads. Marine shippers generally provide special training to those who load and unload barges and self-propelled tankers.

In addition to the modal trade and professional associations, other private organizations and individual companies offer hazardous materials compliance training. The Chemical Manufacturers Association sponsors training seminars nationwide and on request to industry employees. The Chlorine Institute provides training publications and films on chemical and physical properties of chlorine, appropriate regulations, and handling procedures for normal and emergency operations. Training courses are also available through private consulting firms. However, the courses vary in content and emphasis.

Conclusions and Policy Options

Federal regulations specify the design, physical characteristics, and method of construction for all packages subject to the hazardous materials regulations, and generally, with a few exceptions, the packages perform adequately. However, the correct use of the packaging and the quality of procedures and operations affecting them are equally important to safe transportation. Conclusions and policy options for this section of chapter 3 address regulatory, technical, and procedural issues.

Federal hazardous materials regulations apply to all commerce in all modes with the exception of intrastate commerce by motor carrier.* Release of hazardous materials from trucks owned by a company that operates solely intrastate need not be reported to DOT, and equipment not meeting Federal re-

[132] National Master Freight Safety& Health Committees, 1985-1988 National Master Freight Agreement, *Hazardous Materials Employee Protection/Training Program* (Washington, DC: International Brotherhood of Teamsters, Dec. 19, 1985), pamphlet.

[133] U.S. Congress, Office of Technology Assessment, "Proceedings of Hazardous Materials Packaging Technology Workshop," unpublished typescript, Jan. 24, 1985.

*For example, Union Pacific Systems, Conrail, and Boston & Maine Co. provide hazardous materials compliance training.

[134] Larry Helms, Port Terminal Rail Authority, Houston, TX, personal communication, 1986.

*49 CFR 171.1. Certain materials are covered by Federal regulations even during intrastate commerce. These are hazardous wastes, hazardous substances, and flammable cryogenics, quirements maybe used in some States. Although States are now required to extend enforcement of hazardous materials regulations to intrastate commerce to qualify for Motor Carrier Safety Assistance Program funds, it is not clear how the reporting requirement and container regulations will be handled. OTA concludes that explicitly extending the reporting requirement and container regulations in 49 CFR to cover intrastate highway commerce would provide important information about container performance, improve safety, and make enforcement and enforcement training more consistent and efficient. This policy option is also discussed in chapters 2 and 4.

The highway mode has more shipments and more releases of hazardous materials than the other modes, and more than 20 percent of bulk highway releases are caused by vehicle accidents, most of these due to driver error. The qualifications required for a truck driver's license vary from State to State, although the concept of a national truck driver's license has been endorsed by ATA, insurance industry representatives, and State motor vehicle administrators and enforcement personnel. OTA concludes that establishing national requirements for a truck driver's license, with a special certification class for hazardous materials that requires over-the-road training in the type of vehicle specified on the license and a good driving record, could greatly improve the safety of the highway mode. National license requirements and driver training standards could be developed by DOT in cooperation with the States, labor, and industry. However, responsibility for issuing licenses and certifying that the training requirements are met might remain with the States, which could set appropriate fees to cover program costs. The licenses should differentiate between types of vehicles, as varying configurations have different handling characteristics. Special training is important for drivers of tractor-trailers carrying intermodal tanks. If a national drivers license is instituted, special training could be required of carriers of intermodal tanks. Their high center of gravity, concentration of weight in the middle of the chassis, and slosh effects give them unique handling characteristics that demand special training. Ensuring that experienced, safe drivers operate vehicles carrying hazardous materials could reduce the risk to the public significantly.

Analysis of the data on accidental releases of hazardous materials and violations of hazardous materials regulations indicates a need for increased industry training on operating procedures, such as loading, unloading, blocking and bracing, and applicable regulations, particularly for the highway mode. OTA finds that expanded and more specific guidance for shippers and carriers on the content and extent of training courses for carrier personnel is an important priority. Congress might wish to require DOT to establish guidelines for training course content and duration through a consensus process including Federal, shipper, carrier, and freight forwarder expertise to utilize existing resources. Federal encouragement for expanded motor carrier industry compliance education could be accomplished through the Motor Carrier Safety Assistance Program.

Problems with all varieties of cargo tanks have been studied by DOT over the past 10 years. DOT found that many of the releases from cargo tanks come from discharge valves, pressure relief valves, and manhole covers, and that poor maintenance and inspection of the tanks contributed to the spill problem. Many parts of a rulemaking proposed by DOT in September 1985 address these shortcomings. OTA finds that adoption of the proposed changes calling for higher and more specific manufacturing standards, annual leak testing of all cargo tanks, and stronger manhole covers on gasoline tankers, would improve the safety performance of cargo tanks. These requirements, would directly address many of the inadequacies uncovered in the DOT studies.

Furthermore, because gasoline cargo tankers are involved in a high percentage of highway deaths and damages due to hazardous materials, Congress may wish to have DOT carefully evaluate more stable designs for this vehicle, the MC-306. The evaluation should take into account both safety and economic considerations. RSPA and the Federal Highway Administration would need to work together effectively to bring about improvements in cargo tank design.

Intermodal portable tank containers are being used in steadily increasing numbers in domestic and international commerce. They present special problems during truck transport, chief among them, the method of securement onto their chassis. Currently, the regulations permit intermodal tanks to travel on flatbed trucks secured by chains, an inexact and frequently unsafe method. OTA finds that immediate and intensive study of the motor vehicle chassis and securement methods for intermodal portable tanks is urgently needed. Some chassis built specially for intermodal tanks have twist locks that positively secure the tank against vertical or lateral motion (such chassis are required in Europe). In addition, although currently there are few of them in the United States, the "low boy" chassis with a flatbed several feet lower than normal is ideal, for carrying the tanks, as it keeps the center of gravity low and the vehicle more stable.

Data shows that many releases of hazardous materials arise from failures in the fittings used in sealing the package. In the rail mode, defective or loose fittings were cited as the package failure in more than 60 percent of all spills. Congress could require DOT to continue research into the design of effective closures and fittings on packages.

Because many packages containing hazardous materials are mailed by people with no understanding of the hazardous nature of the materials they are shipping, public education has an important impact on safety. The problem is especially severe in the air transport of small packages, where both mailers and passengers unknowingly violate regulations. An ongoing and widespread public information program on safety and packaging requirements for hazardous materials, directed at both the handlers of small packages and the general public, could reduce the misuse of packaging and improve safety, especially in the air mode. In addition, generators of small amounts of hazardous wastes, who will soon be brought under Federal regulation, will need assistance from DOT and EPA in complying with packaging requirements.

Performance standards for small packages are likely to be adopted within the next few years, and the prospective changeover has been widely supported by most of the affected parties. OTA finds that the new system will simplify the regulations making compliance with them easier; bring U.S. regulations into greater conformity with those of our international trading partners, and make packaging innovations easier and faster to evaluate and implement. Adoption of performance standards should reduce the time required of the relatively small RSPA staff to handle exemption applications and free them for other functions such as data and trend analysis, and planning. If the revised regulations allow packages that meet current specifications to be manufactured after performance testing is adopted, small manufacturers and shippers that do not have full design and testing divisions will not be unduly harmed by the new requirements. To ensure that performance tests adequately represent the stresses of the transportation environment, collection of release data for small packages needs to be continued to identify and remedy packaging deficiencies.