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HISTORICAL OVERVIEW OF DOMESTIC SPENT FUEL SHIPMENTS--UPDATE

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DISCLAIMER

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PREFACE

The information in this report summarizes historic data on spent fuel shipments in the United States. The report is updated periodically to keep abreast of changes. Information is provided for planning purposes, to support program decisions of the Office of Civilian Radioactive Waste Management (OCRWM), and to inform the interested public and representatives from Federal, State, and local governments, Indian Tribes, and the transportation community. For those unfamiliar with the generation of spent nuclear fuel and its management, a section within the Introduction provides a brief overview. Terminology specific to the transportation community is also introduced. Individuals already familiar with the subject and terms may wish to begin their reading with the section titled "Spent Fuel Shipments."

ACRONYMS AND ABBREVIATIONS

BWR	boiling-water reactor
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
Dresden 2	Dresden Nuclear Power Station, Unit 2, Dresden, IL
EBR	Experimental Breeder Reactor
EMAD	Engine Maintenance, Assembly, and Disassembly Facility, Nevada Test Site, Nevada
GE-Morris	General Electric Reprocessing facility, Morris, IL
GPU Nuclear	General Public Utilities Nuclear Company, Middletown, PA
HFIR	High Flux Isotope Reactor, Oak Ridge, TN
HRCQ	highway route-controlled quantities
HTGR	high-temperature gas-cooled reactor
ICPP	Idaho Chemical Processing Plant, Idaho Falls,ID
INEL	Idaho National Engineering Laboratory, Idaho Falls, ID
LWR	light-water reactor
MRS	monitored retrievable storage
MTU	metric ton of uranium
NAC	Nuclear Assurance Corporation, Norcross, GA
NFS-West Valley	Nuclear Fuel Services, West Valley facility, West Valley, NY
NRC	U. S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
OCRWM	Office of Civilian Radioactive Waste Management
ORNL	Oak Ridge National Laboratory, Oak Ridge, TN
Oyster Creek	GPU Nuclear Oyster Creek Power Plant, Toms River, NJ
Point Beach 1	Point Beach Nuclear Reactor,Wisconsin Electric Power, Two Rivers,WI
PWR	pressurized-water reactor
RAMRT	radioactive material routing report
R.E. Ginna	Rochester Gas & Electric Ginna Power Plant, Ontario, NY
SMAC	Shipment Mobility/Accountability Collection
TMI	Three Mile Island Nuclear Power Plant, Middletown, PA

EXECUTIVE SUMMARY

This report presents available historic data on most commercial and research reactor spent fuel shipments in the United States from 1964 through 1989. Data include sources of the spent fuel shipped, types of shipping casks used, number of fuel assemblies shipped, and number of shipments made.

Shipment data for spent nuclear fuel were compiled from information provided by the U.S. Department of Energy (DOE), the U.S. Department of Transportation (DOT), and from other sources. These data were assembled into a single, comprehensive source of information on spent fuel shipments. Two databases were used in preparing this data: the DOE's Shipment Mobility/Accountability Collection (SMAC) and the DOT's Radioactive Material Routing Report (RAMRT). In some cases, collating from these sources was difficult because of inconsistencies in shipping records and subtle differences between the codes for spent fuel shipments and codes for the shipment of other hazardous materials. Analysis of this data results in the following observations:

- During the period reported, commercial carriers transported the majority of spent fuel; approximately 2,600 commercial shipments were made, for a total of about 1,900 metric tons of spent fuel shipped. Ninety-one percent of the shipments were made by truck; but only 52 percent of the spent fuel, by weight, was carried by truck. On the other hand, rail shipments, while accounting for only nine percent of the number of shipments, transported nearly half of the spent fuel.

- Although the greatest number of fuel assemblies was moved in 1986, the greatest number of shipments was made in 1974. Due to the greater capacity of the rail casks used in later campaigns as compared with truck casks which were used mostly in the earlier campaigns, the number of cask shipments decreased from 224 in 1974 to 144 in 1986, while the total number of assemblies shipped increased from 346 in 1974 to 1,027 in 1986. The majority of assemblies shipped in 1986 was from boiling-water reactors.

- The amount of spent fuel shipped shows four periods of major activity: (1) the mid-1960s, (2) the early 1970s, (3) the mid-1970s, and (4) from 1984 to 1989. These periods correspond with the startup of the Nuclear Fuel Services West Valley plant (NFS-West Valley) in New York (1964-1966), additional shipments for commercial reprocessing at NFS-West Valley (1971-1974), storage at GE-Morris in Illinois (mid-1970s), and the decommissioning of NFS-West Valley (1984-1986) and GE-Morris contract shipments (1984-1989).

- NFS-West Valley received shipments of spent fuel for reprocessing until 1976, when reprocessing was discontinued. Decommissioning of the plant meant that all of the commercially-owned, spent fuel onsite had to be shipped back to the utilities' own storage pools – the purpose for many of the shipments made in 1984 and 1985. A small amount of spent fuel remains in storage at the West Valley facility. Shipment of this spent fuel to a DOE facility is pending.

- Although it was designed for reprocessing and did accept spent fuel from 1972-1989, GE-Morris never operated as a reprocessing plant. Spent fuel assemblies were shipped from the facility back to reactors in 1981 and 1987.

- Core debris shipments from Three Mile Island (TMI) to Idaho National Engineering Laboratory (INEL) began in July 1986. Rail, rather than truck transport, was chosen as the mode of transportation because of the reduced number of shipments that would be needed. Through September 1989, 43 TMI cask-loads were shipped in 20 shipments. All core debris has been shipped to INEL.

- Three commercial motor carriers participated in the majority of shipping campaigns involving truck shipments: Tri-State Motor Transport, Home Transport, and McGil Specialized Carriers. Spent fuel shipments have been historically dominated by a few carriers. These carriers have chosen to provide the driver training, specialized equipment, and communications operation needed to support shipments of spent fuel.

This report also addresses the shipment of spent research reactor fuel. These shipments have not been documented as well as commercial power reactor spent fuel shipment activity. Available data indicate that the greatest number of research reactor fuel shipments occurred in 1986. The largest campaigns in 1986 were from the Brookhaven National Laboratory, Brooklyn, New York, to the Idaho Chemical Processing Plant (ICPP) and from the Oak Ridge National Laboratory's High Flux Isotope Reactor (HFIR) in Tennessee and the Rockwell International Reactor in California to the Savannah River Plant near Aiken, South Carolina. For all years addressed in this report, DOE facilities in Idaho Falls and Savannah River were the major recipients of research reactor spent fuel. In 1989, 10 shipments were received at the Idaho facilities. These originated from universities in California, Michigan, and Missouri.

INTRODUCTION

Purpose

The purpose of this report is to provide available historic data on most commercial and research reactor spent fuel shipments that have been completed in the United States between 1964 and 1989. This information includes data on the sources of spent fuel that has been shipped, the types of shipping casks used, the number of fuel assemblies that have been shipped, and the number of shipments that have been made. In addition, three case studies highlight selected shipment experiences involving three primary sites — the West Valley facility, in West Valley, New York, the General Electric facility, in Morris, Illinois, and Three Mile Island in Middletown, Pennsylvania. These case studies are presented in the Appendix of this report.

Most of the shipments addressed in this report were transported by commercial carriers to and from privately owned facilities. Data for these shipments were contained in many separate sources and were, in some cases, incomplete. This document compiles the available data to provide a comprehensive compilation and analysis on the shipment of spent fuel.

Historic information on the shipment of spent nuclear fuel can be useful in planning future shipments. Such information can provide an account of experience which is useful for (1) anticipating transportation needs, (2) interacting with the public and public officials, and (3) conducting shipments. The experience gained from over 25 years of shipments can provide a framework for understanding transportation challenges and the resolutions developed to meet those challenges. The historic record can also provide a basis, or point of reference, for lessons learned.

Data Sources

The data contained in the report rely primarily on two existing databases; The U.S. Department of Energy's (DOE's) Shipment Mobility/Accountability Collection (SMAC) and the U.S. Department of Transportation's (DOT's) Radioactive Material Routing Report (RAMRT). The SMAC database contains information on unclassified shipments that have been made to and from DOE facilities. It does not include routing data. The RAMRT database contains historic data (beginning in 1982) on all shipments of highway route-controlled quantities (HRCQ) of radioactive materials by truck; it does not include data on shipments by rail. RAMRT was developed to monitor the use of highway routes by HRCQ shipments; it contains a record of the actual highway segments used for the shipments. Data from RAMRT requires interpretation to determine which shipments involved spent fuel payloads. Delays by carriers of up to 6 months in reporting shipments limit its usefulness in addressing current shipments, though it presents an important historic record. The data presented in this report have also been supplemented by summary reports prepared by the Nuclear Assurance Corporation ("Spent Fuel," March 1986 and "Transportation of U.S. LWR Spent Fuel," June 1989), the Office of Technology Assessment (Transport. Haz. Mat., July 1986), U.S. Nuclear Regulatory Commission's Public Information Circular for Shipments of Irradiated Reactor Fuel (NUREG-0725) and personal interviews conducted with DOE traffic managers and commercial cask suppliers. The DOE traffic managers and the cask suppliers provided much of the information on rail shipments of commercial spent fuel.

The data in this report are compiled according to the type of spent fuel that was shipped, i.e., commercial reactor or research reactor. In addition, the data reported are for all domestic shipments of commercial fuel including shipments made by DOE, e.g., Three Mile Island core debris shipments. Shipments from points of foreign origin are not included.

Background

History

Today, in the United States alone, more than 100 nuclear power plants operate using nuclear fission. These plants generate about 20% of the domestic electricity used.

The generation of electricity at nuclear power plants has also resulted in the generation of spent nuclear fuel. A brief background of nuclear fuel and the practices used in its transport within the United States follows.

The majority of domestic nuclear reactors in commercial use are fueled by enriched uranium dioxide pellets encased in 12- to 14-ft. long metal tubes, which are bundled to form fuel assemblies. After about three years, the fuel can no longer sustain an efficient fission reaction and is removed from the nuclear reactor, then replaced with fresh fuel. However, the removed fuel remains thermally hot and radioactive as the fission products in the assemblies decay.

The used (spent) fuel is cooled (a term used to refer to the continuous decline in radioactivity as time progresses) by temporarily storing it near the reactor in a concrete-walled storage pool filled with water. After three months of storage, spent fuel loses about 99.0 percent of its radioactivity; after one year of storage, it has lost about 99.5 percent of its radioactivity. After five years, the fuel has cooled to the point that it can be stored in dry storage containers out of the pool. Strict regulations and equally strict application and enforcement have guided the safe management of this stored spent fuel to ensure its isolation from the environment at the storage sites.

In 1982, Congress passed the Nuclear Waste Policy Act (NWPA), establishing a national policy for deep, geologic disposal of spent fuel and high-level radioactive waste. The legislation established the Office of Civilian Radioactive Waste Management (OCRWM) within the Department of Energy. This office was charged with developing an integrated system for transportation, safe storage, and permanent disposal of the waste. Under this integrated system, called the Federal Waste Management System, spent fuel will be transported from nuclear power plants to either a (1) monitored retrievable storage (MRS) facility for temporary storage, and, possibly, packaging of spent fuel for repository emplacement, or (2) directly to a geologic repository for permanent disposal.

In 1987, Congress amended the NWPA, directing that Yucca Mountain, Nevada, be studied as a potential candidate site for a permanent repository. A comprehensive program of detailed investigation called "site characterization" is being planned and will be conducted to determine the suitability of the site as a permanent, nuclear waste repository. The site must meet all applicable regulations to ensure technical feasibility, protect human health and safety, and minimize effects on the environment. In addition, in the NWPA, as amended, Congress established an independent MRS Review Commission to evaluate the need for an MRS. In November 1989, the Commission issued a report and recommended that Congress provide for interim storage before permanent geologic disposal.

Transportation of spent fuel to either a repository or MRS facility will only begin when the facilities are licensed and operating. Disposal of spent fuel in the permanent repository was projected, in the Secretary of Energy's "Report to Congress on Reassessment of the Civilian Radioactive Waste Management Program" (November 30, 1989), to begin in the year 2010. However, based on contractual obligations of DOE to accept spent fuel from utilities, spent fuel shipments are scheduled to begin in 1998. An MRS facility is planned to manage the waste until permanent disposal.

In preparing for transportation of spent fuel to either an MRS facility or a repository, and in accordance with the provisions of the NWPA, as amended, OCRWM will continue to interact with Federal offices, including the Department of Transportation and the U.S. Nuclear Regulatory Commission (NRC), and with State and Indian Tribal authorities to insure compliance with all applicable regulations.

While NWPA spent fuel shipments will take place in the future, it is important to note that spent fuel has been shipped safely in the United States for years. In recent years, commercial spent fuel has been shipped primarily because storage space at many utility reactor sites is limited. Transportation has been required, in some cases, by decisions between a State and a utility to move the spent fuel to an alternate storage site (Transport. Haz. Mat., July 1986). Also, various research reactors across the United States have shipped spent fuel for reprocessing at government-owned plants. And, when fuel is removed from research reactors at a university, DOE has been responsible for the disposal or reprocessing of the fuel under its university assistance program (Characteristics, June 1988).

Approximately 2,600 commercial spent fuel shipments have taken place domestically during the past 25 years. Few incidents have been involved with these shipments. There have not been any fatalities due to the radioactive cargo. Nor has there been radiation injury or damage to the environment. These shipments have been made both by rail and by truck. When an MRS facility and/or a permanent high-level waste disposal facility is available, domestic annual shipments of spent fuel by rail, truck, and barge, or a combination of these (i.e., intermodal), are expected to increase significantly above the levels reported here.

Transportation of Spent Fuel

Spent fuel is, and has been, shipped in casks specially designed and manufactured to contain and shield the spent fuel during normal shipment. Also, they must withstand tests that are designed to verify that a cask could contain and continue to shield its spent fuel payload even during and following severe accidents. The requirements for design and operation of spent fuel casks are found in the regulations of the NRC and the DOT. These casks are shipped primarily by truck and train. Truck shipments are further divided into legal-weight shipments and so-called "overweight" truck shipments. The "overweight" shipments are specially approved and permitted by each State traversed because they exceed a gross vehicle weight of 80,000 pounds or do not meet weight distribution (bridge formula) requirements. During train shipments, spent fuel casks are transported on heavy-duty flat cars. Trains dedicated to fuel shipments and general freight trains have both been used. Casks designed for carriage by train are capable of carrying more spent fuel than those designed for carriage by truck.

An estimated 90,000 commercial spent fuel assemblies (with spent fuel weighing approximately 40,000 metric tons) will be in reactor-site storage at utilities by the turn of the century. Depending on cask capacity and type, DOE has estimated that up to 250 rail and 725 truck shipments may be required annually to move this spent fuel from the reactors (Transport. Haz. Mat., July 1986). The duration of shipments and their precise number will depend, in part, upon the mix of rail and truck shipments, the type of casks designed, future spent fuel generation, and facility development.

Federal Agencies Involved in the Regulation of Spent Fuel Shipments

The primary regulatory responsibility for shipments of all radioactive materials, including spent fuel, lies with the U.S. Department of Transportation. However, NRC and DOE also have specific responsibilities.

DOT regulates all aspects of transporting radioactive materials, including container design (called packaging in the regulations), mechanical condition of transportation vehicles, and training of transportation personnel. DOT is also responsible for establishing highway routing requirements and specifying requirements and standards for package labels, vehicle placards, and shipping papers.

The NRC is responsible for regulating, reviewing, and certifying the packaging (cask) designs and certain transportation operations for spent fuel shipments when the shipments involve NRC licensees or shipments to an MRS facility or repository. Commercial nuclear facilities and universities are among these licensees. NRC approval of transport routes is required prior to all shipments of spent fuel where a licensee is the shipper. Shippers licensed by the NRC are required to notify the Governor's designee in each State through which spent fuel is to be shipped. The NRC regulations also require provisions for the physical security of spent fuel in transit; these provisions include the use of armed guards in highly populated areas.

The NWPA requires all shipments under the Federal Waste Management System to be made in NRC-certified casks. To receive NRC certification, a cask must be designed to withstand tests that measure its performance in hypothetical, severe accident conditions. To be certified, a cask must demonstrate it is capable of withstanding a sequence of tests. These tests include a free drop from 30 ft. onto an unyielding surface and a drop from 40 in. onto a steel bar 8 in. long and 6 in. in diameter with the package oriented to sustain maximum damage, and total engulfment in a thermal environment of at least 1,475°F for 30 minutes. In a fourth test, a separate cask is submerged below 50 ft. of water for 8 hours and then below 3 ft. of water to further demonstrate criticality safety.

DOE has authority (recognized by DOT in 49 Code of Federal Regulations [CFR] 173.7) to approve spent fuel packaging and certain aspects of transportation for research, defense, and contractor-related shipments of spent fuel. DOE is required to use standards and procedures that are approved by DOT to be equivalent to those of the NRC. In August 1987, DOE adopted procedures similar to those of the NRC for notifying States on all unclassified spent nuclear fuel shipments. Previously, notification was oral. The new policy requires written notification that specifies the time of shipment and shipment related information. In March 1989, DOE modified its physical protection requirements to include the use of carrier escorts for shipments by highway (second driver) and rail (special agent or train crew). In addition, DOE may, at its option, assign a health physicist or other professional to support the escorts. These modified requirements are based on an NRC Notice of Proposed Rulemaking and on 10 CFR 1047.7.

SPENT FUEL SHIPMENTS

Overview

Historic information for two categories of spent nuclear fuel shipped in the contiguous United States—commercial reactor fuel and research reactor fuel—is addressed in this report.

Most commercial fuel is discharged from light-water reactors (LWRs), either boiling-water reactors (BWRs) or pressurized-water reactors (PWRs). In both types of LWRs, light water (as opposed to heavy water, a deuterium-enriched form of water used in nuclear research) is used to transfer heat from the fuel. BWRs are light-water reactors in which the water that passes through the reactor is maintained at such a pressure as to allow it to boil directly in the reactor pressure vessel and form high-pressure steam that flows through a turbine, which in turn powers a generator that produces electric power. PWRs are light-water reactors in which water is circulated under enough pressure to prevent it from boiling, while serving as a heat transfer medium for the uranium fuel. The heated water is then used to produce steam in a secondary loop steam generator that drives the turbines.

Light-water reactor fuel is made of uranium dioxide pellets typically contained within 14-ft. tubes, or rods, of stainless steel or zirconium alloy. A fuel assembly contains from 39 (for BWRs) to 289 (for PWRs) rods. Each rod (BWR or PWR) contains approximately 2 to 3 kg. of uranium (U-235 enriched between 1 and 4%). Present-day BWR fuel assemblies typically contain 180 kg. of uranium and PWR assemblies can contain up to 500 kg. In general, the core of a BWR contains more assemblies than the core of a PWR. Spent nuclear fuel consists of these full assemblies after the fuel has been used ("burned") in a nuclear reactor to produce heat for power. Following use, the spent fuel is very radioactive and continues to produce small amounts of heat.

Spent nuclear fuel must be shipped in heavily shielded containers designed to survive severe accident conditions without releasing the radioactive contents. Present truck casks can carry between 1 (PWR) and 7 (BWR) assemblies and weigh 24 to 40 tons. Rail casks currently in service can carry between 7 (PWR) and 18 (BWR) assemblies and weigh approximately 70 tons. Future casks proposed for shipping fuel to a permanent disposal site or an MRS facility are expected to have greater capacity. Truck casks may contain 4 (PWR) to 9 (BWR) assemblies per cask, Figure 1, and rail casks may accommodate 21 (PWR) to 52 (BWR) assemblies per cask, Figure 2.

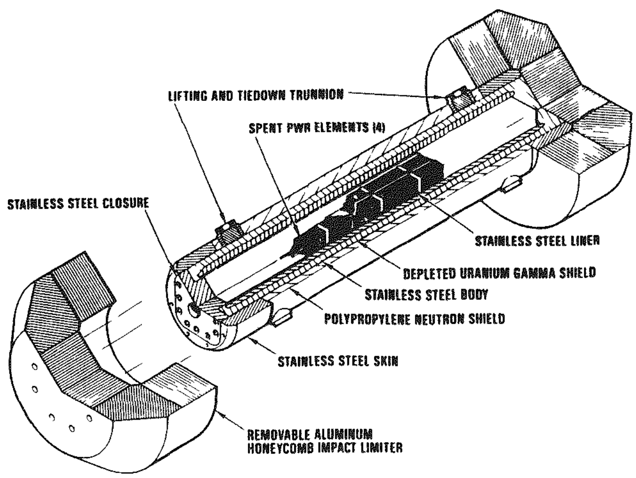

Figure 1. GA-4/GA-9 Legal-Weight Truck Shipping Cask

Research reactor fuel, which differs substantially from power reactor fuel, varies widely in form, U-235 concentration, and total uranium weight. The weight of this type of fuel varies from a few grams to a few hundred grams of uranium per element (assembly), or about 1/1,000 the net weight of a commercial spent fuel element. Thus, in general, research reactor fuel is much smaller and weighs only a fraction of commercial fuel. The casks designed to move this fuel are commensurately smaller and require less complex design. Because the quantity of fuel material is low, research reactor fuel may be shipped before it is allowed to cool significantly; commercial fuel must be cooled for a year or more to qualify for shipment.

Since spent commercial and research reactor fuels vary substantially in terms of form, weight, and activity, information for each type is presented separately. The primary focus of this report is on commercial spent fuel shipments since this comprises over 99% of the tonnage to be transported. In the future, the vast majority of spent fuel shipped will be that generated by utilities and shipped under NWPA provisions.

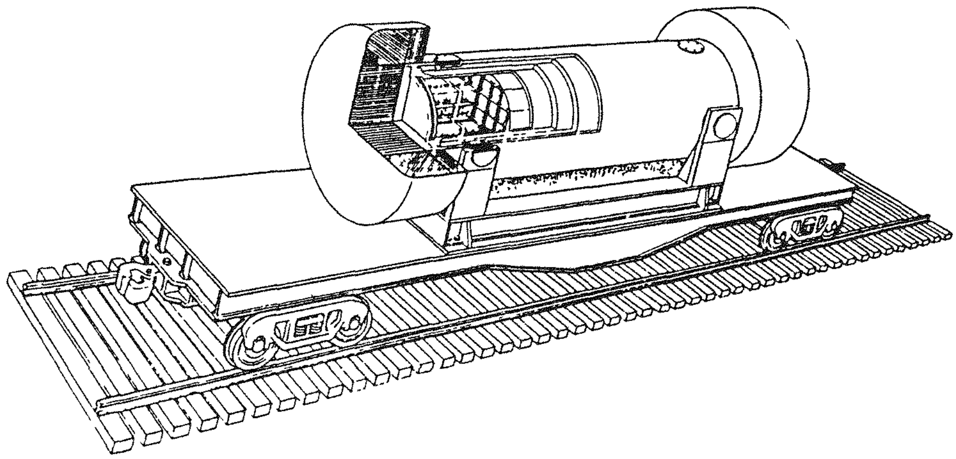

Figure 2. BR-100 Rail/Barge Shipping Cask

History of Shipments of Commercial Spent Fuel

This section provides an overview of domestic, commercial spent nuclear fuel shipments that have occurred during the past 25 years. These are shipments that traversed U.S. highways (as represented in Figure 3) or railways; not included are transfers that have taken place between reactors on the same site.

For the purposes of this report, commercial shipments are defined as shipments containing fuel assemblies discharged from a commercial, NRC-licensed power reactor. Shipping of spent fuel by an NRC licensee is accomplished according to regulations published in Title 10, Code of Federal Regulations (10 CFR). In accordance with the provisions of the NWPA, as amended, commercial spent fuel shipped by DOE will also be regulated by the NRC.

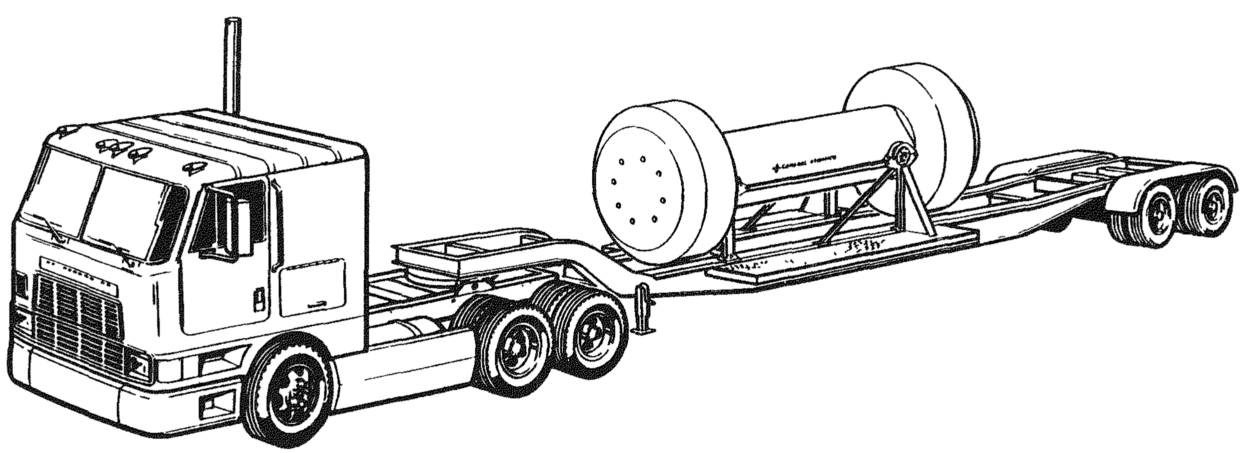

Figure 3. Motor Transport of Spent Fuel

Classes of Commercial Spent Fuel Shipments

In the United States, commercial power reactor spent nuclear fuel has resulted from the operation of light-water reactors and gas-cooled reactors. The light-water reactor is the principal reactor type in commercial use in the United States. Until September 1989 only one gas-cooled commercial power reactor was in operation–this was the Ft. St. Vrain reactor owned by Colorado Public Service. The reactor is now permanently shut down. One other small commercial gas-cooled reactor, Peach Bottom 1, owned by Philadelphia Electric Co., discontinued operations in the early 1970s.

Spent Fuel from Light-Water Reactors

The majority of the spent fuel originates from the light-water reactors. LWR fuel makes up 94% of the commercial spent fuel shipments and 99% of the MTU shipped. As discussed previously, LWRs include pressurized-water reactors and boiling-water reactors. PWRs discharge approximately 60 fuel assemblies, whereas BWRs discharge about 175 assemblies once each year to year-and-a-half.

The first reactors built and put in service were designed with the goal of recycling the spent fuel in a commercial, closed fuel cycle. (In a closed fuel cycle, the portion of the uranium not used and all the plutonium produced would be returned for use again.) As envisioned, once the fuel cycle had been closed, the fuel was to be shipped to a facility for reprocessing (or recycling) 90 to 120 days after removal from the reactor. As a consequence, the fuel storage capacity at each reactor was not designed to accommodate long-term storage needs. However, in the United States reprocessing is no longer considered a nuclear fuel cycle alternative. Thus, many reactor operators have had to modify their storage methods to ones that can better accommodate long-term storage needs. More recently, reactors have been built to accommodate the discharged fuel storage requirements for many years into the future. These reactors can typically store 20 or more years of spent fuel discharges onsite.

Three commercial spent fuel reprocessing plants were constructed in the United States: (1) Nuclear Fuel Services, West Valley, New York; (2) General Electric Nuclear Energy, Morris, Illinois; and (3) Allied General Nuclear Services, Barnwell, South Carolina. Only one, NFS-West Valley, was opened for fuel reprocessing. In 1972, NFS was shut down for modification and was never restarted. GE-Morris never reprocessed spent nuclear fuel, but presently has in storage close to 3,200 fuel assemblies. Allied General Nuclear Services never reprocessed spent fuel, never accepted spent fuel for storage, and now is closed.

Most spent fuel casks that were in service in 1989 were originally designed to transport fuel to reprocessing plants for recycling. Thus, these casks were designed to ship spent fuel that had been cooled for only 90 to 120 days. However, the typical, commercial spent fuel shipment today involves fuel that has cooled at least several years (Transport. Haz. Mat., July 1986), and is less radioactive.

Most of the recent commercial spent nuclear fuel shipments have been performed either to return fuel to the generating reactors from NFS-West Valley, to GE-Morris under contracts between General Electric Company and utilities, or to provide spent fuel to facilities where research is performed.

General Electric owned and operated the IF-100, IF-200, and IF-300 casks and used these primarily to service the Morris facility. The IF-100 and IF-200 casks were removed from service by 1974. The IF-300 casks were sold: two are now owned by Pacific Nuclear and the remaining two by Carolina Power and Light Co. The NFS-100 and NFS-4 casks were owned by Nuclear Fuel Services and were used primarily to service the West Valley facility. In addition to these casks, casks manufactured by Nuclear Assurance Corporation and Trans Nuclear were used to ship spent nuclear fuel to these facilities.

Occasionally, a shipment of spent fuel rods (a portion of a fuel assembly) is made to a commercial testing facility by fuel manufacturers for research and development work. In the past, many of these LWR fuel rod shipments went to Battelle Columbus Laboratories in Ohio or Babcock & Wilcox in Virginia. These shipments usually involve only a part of an assembly (several fuel rods) and occur only a few times a year.

Spent Fuel from High-Temperature Gas-Cooled Reactors

The other type of commercial, nuclear power reactor used in the United States is the high-temperature gas-cooled reactor (HTGR). There are many differences between HTGRs and LWRs. One important difference is that HTGRs use helium gas instead of water as a coolant. The only commercial HTGR in the United States is the Fort St. Vrain Reactor, which is owned by Public Service Company of Colorado, in Platteville. This reactor was permanently shut down in the Summer of 1989. Since 1980, there have been 722 assemblies containing 33.21 MTU shipped to INEL for long-term storage. All of these shipments have been by truck using the FSV-1 cask. These shipments are summarized in the Appendix.

A schedule for shipping the remaining fuel assemblies from the Fort St. Vrain reactor has not been established.

Statistical Summary of Shipments of Commercial Spent Fuel

An overview of the number of commercial spent fuel shipments that have been made since 1964 and the weight in metric tons of uranium (MTU) by mode of transportation is given in Table 1. (This table does not cover all commercial shipments ever completed due to difficulty in gathering information. Included in this category are the shipments from Hallem, Path Finder, Elk River, Fermi 1, Shippingport, and Peach Bottom 1 Reactors.) Almost 2,700 loaded casks of commercial spent fuel were shipped from 1964 through 1989. Based on the number of shipments during this period, 91% were truck shipments. However, only 52% of the MTU were shipped by truck. Rail shipments, while accounting for only 9% of the number of shipments, transported nearly half of the spent fuel. The larger load capacity of rail casks explains this result.

Figure 4 shows the number of loaded casks and fuel quantity (in MTU) shipped each year from 1964 through September 1989.

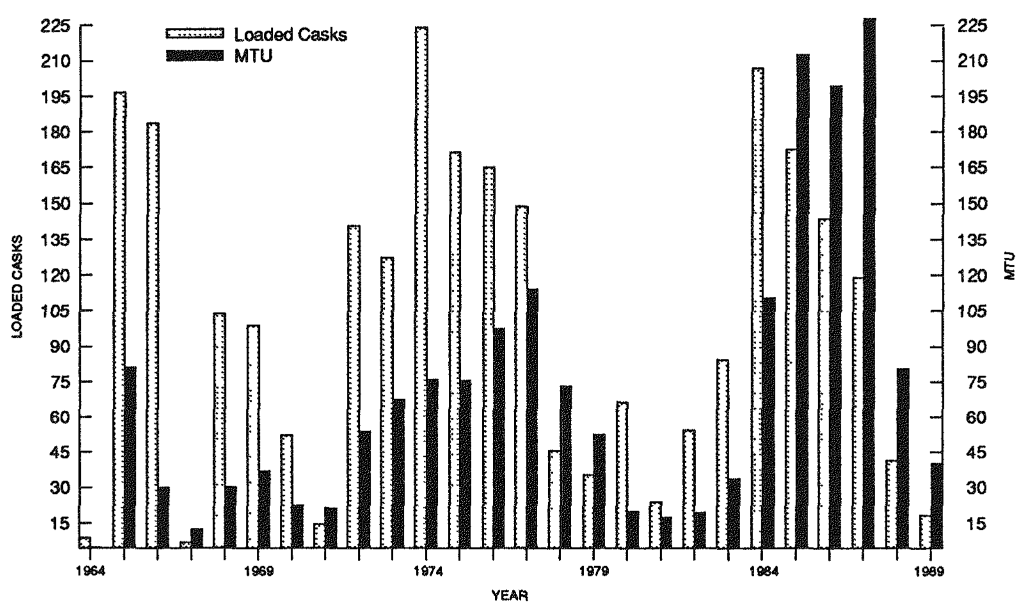

Figure 4. Commercial Fuel Shipment Activity, 1964 to 1989
No. of Loaded Casks and Weight (MTU)

TABLE 1. SUMMARY OF COMMERCIAL SPENT FUEL SHIPMENTS, 1964 THROUGH SEPTEMBER 1989

Year	Motor				Rail				Total			
	No. of Assemb.[a]	No. of Shipments	No. of Loaded Casks	Weight (MTU)	No. of Assemb.[a]	No. of Shipments	No. of Loaded Casks	Weight (MTU)	No. of Assemb.[a]	No. of Shipments	No. of Loaded Casks	Weight (MTU)
1964	9.00	5	5	0.918	0.00	0	0	0.000	9.00	5	5	0.918
1965	370.00	185	185	37.740	150.00	12	12	40.950	520.00	197	197	78.690
1966	235.00	180	180	20.746	32.00	3	3	8.736	267.00	183	183	29.482
1967	0.00	0	0	0.000	39.00	3	3	10.647	39.00	3	3	10.647
1968	202.00	101	101	20.604	36.00	3	3	9.828	238.00	104	104	30.432
1969	80.00	80	80	6.080	302.00	18	18	29.256	382.00	98	98	35.336
1970	41.00	41	41	3.148	142.00	10	10	18.460	183.00	51	51	21.608
1971	16.00	8	8	4.368	80.00	6	6	15.405	96.00	14	14	19.773
1972	139.00	139	139	54.263	0.00	0	0	0.000	139.00	139	139	54.263
1973	389.00	123	123	58.798	72.00	5	5	9.360	461.00	128	128	68.158
1974	333.15	223	223	75.260	13.00	1	1	1.690	346.15	224	224	76.950
1975	198.00	166	166	64.149	64.00	4	4	11.712	262.00	170	170	75.861
1976	145.18	147	147	54.703	324.00	18	18	59.292	469.18	165	165	113.995
1977	123.00	122	122	45.895	407.00	27	27	84.771	530.00	149	149	130.666
1978	43.08	45	45	25.921	112.00	16	16	47.936	155.08	61	61	73.857
1979	24.20	21	21	8.183	105.00	15	15	44.940	129.20	36	36	53.123
1980	256.00	61	61	19.296	32.00	5	5	13.696	288.00	66	66	32.992
1981	23.59	23	23	7.607	13.00	2	2	5.564	36.59	25	25	13.171
1982	250.07	56	56	18.084	0.00	0	0	0.000	250.07	56	56	18.084
1983	94.16	84	84	34.693	0.00	0	0	0.000	94.16	84	84	34.693
1984	463.00	200	200	100.852	126.00	3	7	22.842	589.00	203	207	123.694
1985	355.16	135	135	96.541	648.00	18	36	116.748	1003.16	153	171	213.289
1986	485.80	110	110	96.788	541.25	18	34	103.554	1027.05	128	144	200.342
1987	262.27	71	71	95.240	629.14	25	48	133.692	891.41	96	119	228.932
1988	121.00	16	16	26.168	262.16	11	25	55.392	383.61	27	41	81.560
1989	48.00	4	4	7.298	125.01	7	14	33.220	173.01	11	18	40.518
Total	4706.66	2346	2346	983.343	4255.01	230	312	877.691	8961.67	2576	2658	1861.034

[a]Decimal values represent the shipment of partial assemblies, typically individual fuel rods.

Although the greatest number of fuel assemblies were moved in 1986 (as shown in Table 1), the greatest number of cask shipments were moved in 1974 (Figure 4). Due to a combination of reasons (use of rail versus truck shipments and the predominance of smaller numbers of PWR versus larger numbers of BWR assemblies), the total number of assemblies shipped increased from 346 in 1974 to 1,027 in 1986, while the total number of cask shipments decreased from 224 in 1974 to 144 in 1986. In 1986, the majority of assemblies were BWR type shipped by rail. Figures 4a and 4b break down the data from Figure 4, separately for truck and rail. Both truck and rail shipments show groups of activity: mid-1960s, early 1970s, mid-1970s and 1984 through 1989. These groups are more prominately defined with rail shipment activity. A trend showing a shift from small capacity casks to casks carrying greater volumes is easily seen in the truck shipment activity in Figure 4a. This is due to the use of the TN-9 cask during the period of 1984 through 1987. A trend toward larger rail shipment volumes during activity periods can be seen in Figure 4b.

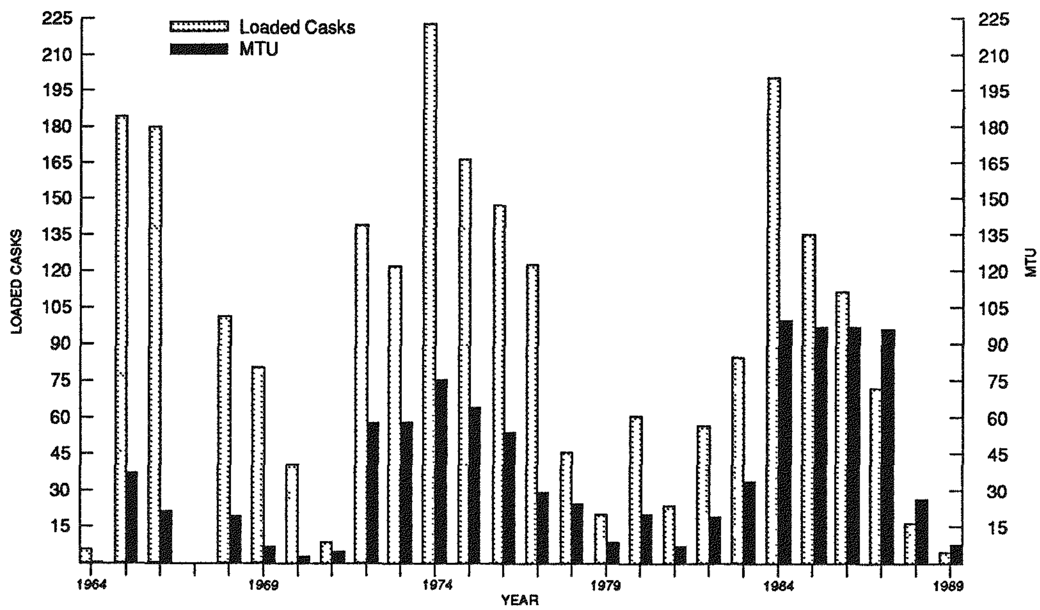

Figure 4a. Truck Shipment Activity, 1964 to 1989
Loaded Casks and Weight (MTU)

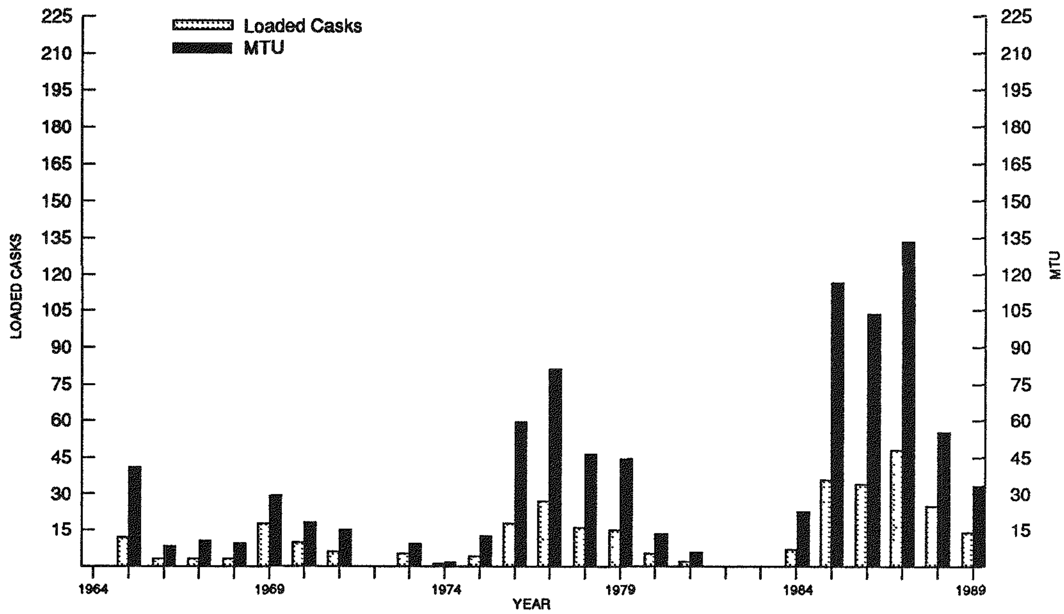

Figure 4b. Rail Shipment Activity, 1964 to 1989
Loaded Casks and Weight (MTU)

Figure 5 shows fuel quantity shipped by truck and rail, by year, for the corresponding period. Greater volumes of fuel were moved by truck during the early 1970s and early 1980s. Figure 5a shows the number of cask loads by truck and rail. Rail mode shows 3 periods of activity corresponding to startup of NFS-West Valley (late 1960s); movement of Dresden fuel to Morris Operation and transfer of H. B. Robinson fuel to Brunswick (mid- to late 1970s); and movement of contract fuel from Cooper and Monticello to Morris Operation (mid- to late 1980s).

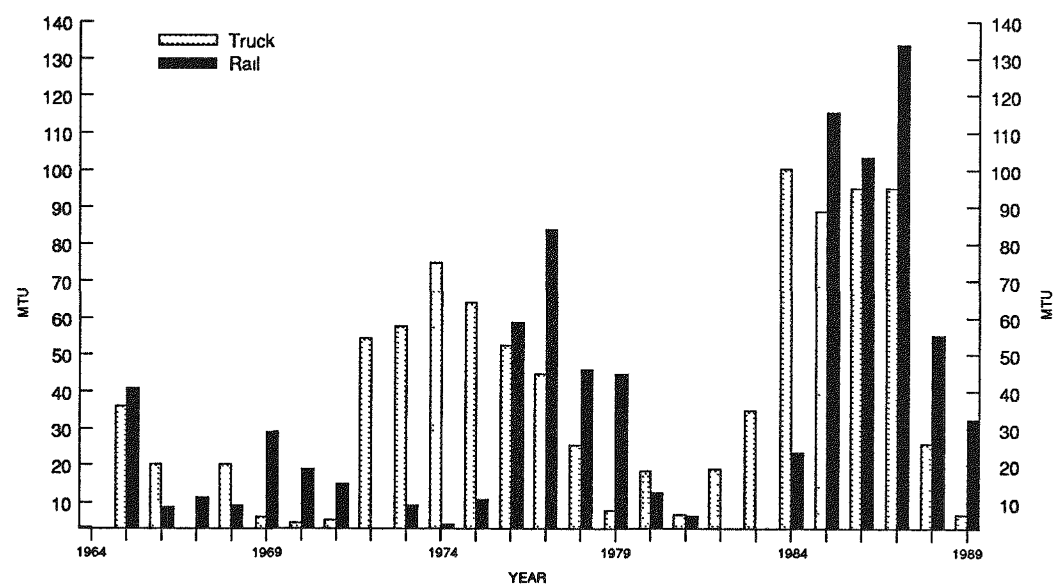

Figure 5. Commercial Fuel Quantity by Transportation Mode, 1964 to 1989
Truck and Rail

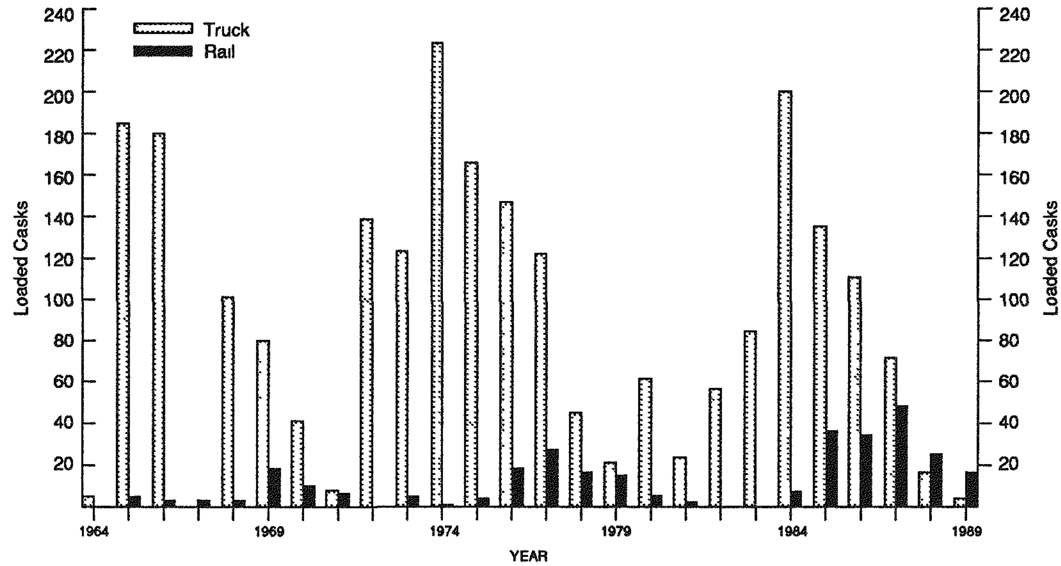

Figure 5a. Total Number of Loaded Casks by Transportation Mode, 1964 to 1989
Truck and Rail

Table 2 lists major shipping operations, or campaigns, by year from 1983 through 1989. The major campaigns, ranked in descending number of shipments (listed by facility and State), were:

NFS-West Valley, New York to Point Beach, Wisconsin (114 shipments);
Oconee, South Carolina to McGuire, North Carolina (111 shipments);
GE-Morris, Illinois to Point Beach, Wisconsin (109 shipments);
NFS-West Valley, New York to the R.E. Ginna Power Plant, New York (81 shipments);
Fort St. Vrain, Colorado to the Idaho Chemical Processing Plant (ICCP), Idaho (43 shipments);
NFS-West Valley, New York to the Oyster Creek Power Plant, New Jersey (32 shipments);
NFS-West Valley, New York to the Dresden Power Plant, Illinois (31 shipments);
Cooper Station, Nebraska to GE-Morris, Illinois (30 shipments);
Monticello Nuclear Generating Station, Minnesota to GE-Morris, Illinois (29 shipments).

The decommissioning of the NFS-West Valley facility required that all of the commercially owned spent fuel in storage be removed. The lack of alternative storage space forced the affected utilities to ship spent fuel back to their own storage pools. This explains the large number of shipments made to Dresden 2 and Point Beach 1 Power Plants in 1984, and the R.E. Ginna and Oyster Creek Power Plants in 1985. A further discussion of the GE-Morris and West Valley shipments is provided in the Appendix.

In May and June of 1986, six shipments containing a total of 17 spent fuel assemblies were transported from the Engine Maintenance, Assembly, and Disassembly Facility (EMAD) at the Nevada Test Site to Idaho National Engineering Laboratory (INEL). These were pressurized-water reactor fuel assemblies originally from the Turkey Point Power Plant in Florida that were shipped to EMAD for research and development activities. The assemblies were shipped from EMAD to INEL for use in a dry storage fuel demonstration project.

Table 2. Shipments of Commercial Spent Fuel by Year, 1983 to 1989

Origin	Destination	Reactor Type	No. of Fuel Assemblies*	No. of Shipments*	Weight (MTU)**	Shipment Mode
1983						
Battelle, OH	Zion 1, IL	PWR	1.00	1	0.457	Truck
Battelle, OH	Fort Calhoun, NE	PWR	0.12	1	0.038	Truck
Monticello, MN	Battelle, OH	BWR	1.00	1	0.180	Truck
GE-Morris , IL	Point Beach 1, WI	PWR	60.00	60	23.940	Truck
NFS-West Valley, NY	Point Beach 1, WI	PWR	13.00	13	5.187	Truck
NFS-West Valley, NY	Dresden 2/3, IL	BWR	14.00	2	2.562	Truck
Oconee 3, SC	McGuire 1, NC	PWR	4.00	4	1.852	Truck
Surry, VA	Battelle, OH	PWR	0.04	1	0.020	Truck
Zion 1, IL	Battelle, OH	PWR	1.00	1	0.457	Truck
Annual Total			94.16	84	34.693	
1984						
Battelle, OH	Calvert Cliffs, MD	PWR	1.00	1	0.072	Truck
Battelle, OH	Zion 1, IL	PWR	1.00	1	0.457	Truck
Cooper, NE	GE-Morris, IL	BWR	54.00	1	9.882	Rail
Fort St. Vrain, CO	INEL, ID	HTGR	120.00	20	5.520	Truck
Monticello, MN	GE-Morris , IL	BWR	72.00	2	12.960	Rail
GE-Morris , IL	Point Beach 1, WI	PWR	49.00	49	19.551	Truck
NFS-West Valley, NY	Point Beach 1, WI	PWR	101.00	101	40.299	Truck
NFS-West Valley, NY	Dresden 2/3, IL	BWR	191.00	28	34.953	Truck
Annual Total			589.00	203	123.694	
1985						
Calvert Cliffs, MD	PNL, WA	PWR	0.03	1	0.013	Truck
Cooper, NE	GE-Morris , IL	BWR	36.00	1	6.588	Rail
Dresden 2, IL	B&W, Lynchburg, VA	BWR	0.12	1	0.018	Truck
Fort Calhoun, NE	Battelle, OH	PWR	1.00	1	0.357	Truck
Monticello, MN	Morris SF, IL	BWR	612.00	17	110.160	Rail
NFS-West Valley, NY	Battelle, OH	PWR	1.00	1	0.367	Truck
NFS-West Valley, NY	Dresden 2/3, IL	BWR	1.00	1	0.175	Truck
NFS-West Valley, NY	R. E. Ginna, NY	PWR	66.00	66	24.420	Truck
NFS-West Valley, NY	Oyster Creek, NJ	PWR	224.00	32	42.950	Truck
Oconee, SC	McGuire, NC	PWR	13.00	13	6.019	Truck
Point Beach , WI	PNL, WA	PWR	3.00	3	1.200	Truck
R. E. Ginna, NY	Battelle, OH	PWR	1.00	1	0.367	Truck
Surry 1/2, VA	INEL, ID	PWR	45.00	15	20.655	Truck
Annual Total			1,003.15	153	213.289	
1986						
Battelle, OH	Fort Calhoun, NE	PWR	1.00	1	0.357	Truck
Battelle, OH	R. E. Ginna, NY	PWR	5.00	5	2.632	Truck
Cooper, NE	GE-Morris, IL	BWR	378.00	11	69.174	Rail
EMAD, NV	INEL, ID	PWR	17.00	6	8.082	Truck
Fort St. Vrain, CO	INEL, ID	HTGR	134.00	23	6.160	Truck
Monticello, MN	GE-Morris, IL	BWR	144.00	4	25.920	Rail
GE-Morris, IL	PNL, WA	BWR	2.00	1	0.360	Truck
NFS-West Valley, NY	Battelle, OH	PWR	5.00	5	1.835	Truck
NFS-West Valley, NY	R. E. Ginna, NY	PWR	15.00	15	5.550	Truck
Oconee, SC	McGuire, NC	PWR	57.00	27	26.391	Truck
Quad Cities, IL	B&W, Lynchburg, VA	BWR	3.00	2	0.540	Truck
Savannah River, SC	Rocketdyne, CA	Fermi	222.80	17	33.865	Truck
Surry 1/2, VA	INEL, ID	PWR	24.00	8	11.016	Truck
TMI, PA	INEL, ID	PWR/Debris	19.25	3	8.460	Rail
Annual Total			1,027.05	128	200.342	

Table 2. Shipments of Commercial Spent Fuel by Year, 1983 to 1989 (continued)

Origin	Destination	Reactor Type	No. of Fuel Assemblies*	No. of Shipments*	Weight (MTU)**	Shipment Mode
1987						
Arkansas Nuclear 1, AR	B&W, Lynchburg, VA	PWR	0.06	1	0.003	Truck
Battelle, OH	INEL, ID	PWR	3.00	1	1.110	Truck
Battelle, OH	GE-Morris, IL	PWR	2.00	2	0.791	Truck
B&W, Lynchburg, VA	Oconee, SC	PWR	0.01	1	0.005	Truck
B&W, Lynchburg, VA	Quad Cities, IL	BWR	3.08	2	0.591	Truck
Cooper, NE	GE-Morris, IL	BWR	324.00	9	59.292	Rail
Dresden 3, IL	B&W, Lynchburg, VA	BWR	0.12	1	0.018	Truck
Monticello, MN	GE-Morris, IL	BWR	230.00	6	41.400	Rail
Oconee, SC	McGuire, NC	PWR	174.00	58	80.562	Truck
Rocketdyne, CA	INEL, ID	Fermi	80.00	5	12.160	Truck
TMI, PA	INEL, ID	PWR/Debris	75.14	10	33.000	Rail
Annual Total			891.41	96	228.932	
1988						
Cooper, NE	GE-Morris, IL	BWR	234.000	7	42.822	Rail
Oconee, SC	B&W, Lynchburg, VA	PWR	0.002	1	0.001	Truck
Oconee, SC	McGuire, NC	PWR	25.000	9	11.575	Truck
Rocketdyne, CA	INEL, ID	Fermi	96.000	6	14.592	Truck
TMI, PA	INEL, ID	PWR/Debris	28.610	4	12.570	Rail
Annual Total			383.612	27	81.560	
1989						
Brunswick 2, NC	Shearon Harris, NC	BWR	54.000	3	9.720	Rail
Cooper, NE	GE-Morris, IL	BWR	30.000	1	5.490	Rail
Oconee, SC	B&W Lynchburg, VA	PWR	0.004	1	0.002	Truck
Rocketdyne, CA	INEL, ID	Fermi	48.000	3	7.296	Truck
TMI, PA	INEL, ID	PWR/Debris	41.010	3	18.010	Rail
Annual Total			173.014	11	40.518	

* Information on numbers of shipments or numbers of assemblies was unavailable for some campaigns. In these cases, estimates were made, based on known data. For example, the number of shipments was estimated, based on the total number of assemblies shipped and the cask type used. Likewise, for those cases where the number of assemblies shipped was not available, but the number of shipments and type of cask was, the assemblies shipped were estimated, based on the number of shipments and type of cask used. A fraction of an assembly shipped indicates individual fuel rod shipments.

**MTU are estimated using data on numbers of shipments and/or numbers of assemblies and information on cask type.

During the years 1983-1989, spent fuel shipments by truck were concentrated in nine States, with the number of shipments ranging from 190 to 303. These States were Illinois, Indiana, New York, Ohio, Pennsylvania, Wisconsin, Idaho, Utah and Colorado.

Rail shipments, not including the TMI shipments, were concentrated in Illinois, Iowa, Minnesota, Nebraska, and Wisconsin. The TMI shipments were made from Pennsylvania to Idaho. Figures 6 and 7 show these major campaign flows from 1983 to 1989 by highway and rail, respectively. Figure 8 depicts the cumulative number of shipments, number of reactors (in service), mass (in MTU), and number of assemblies shipped from 1964 to 1989.

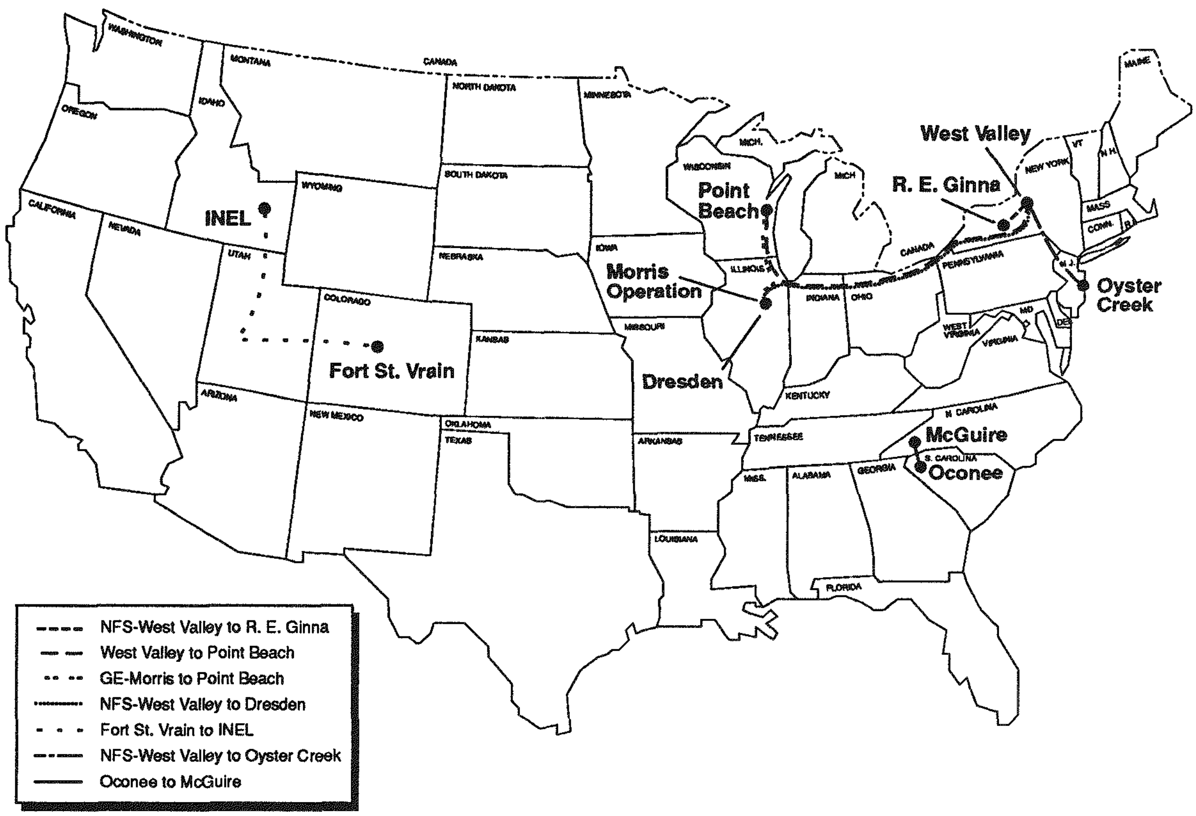

Figure 6. Major Commercial Spent Fuel Shipments by Truck, 1983 to 1989

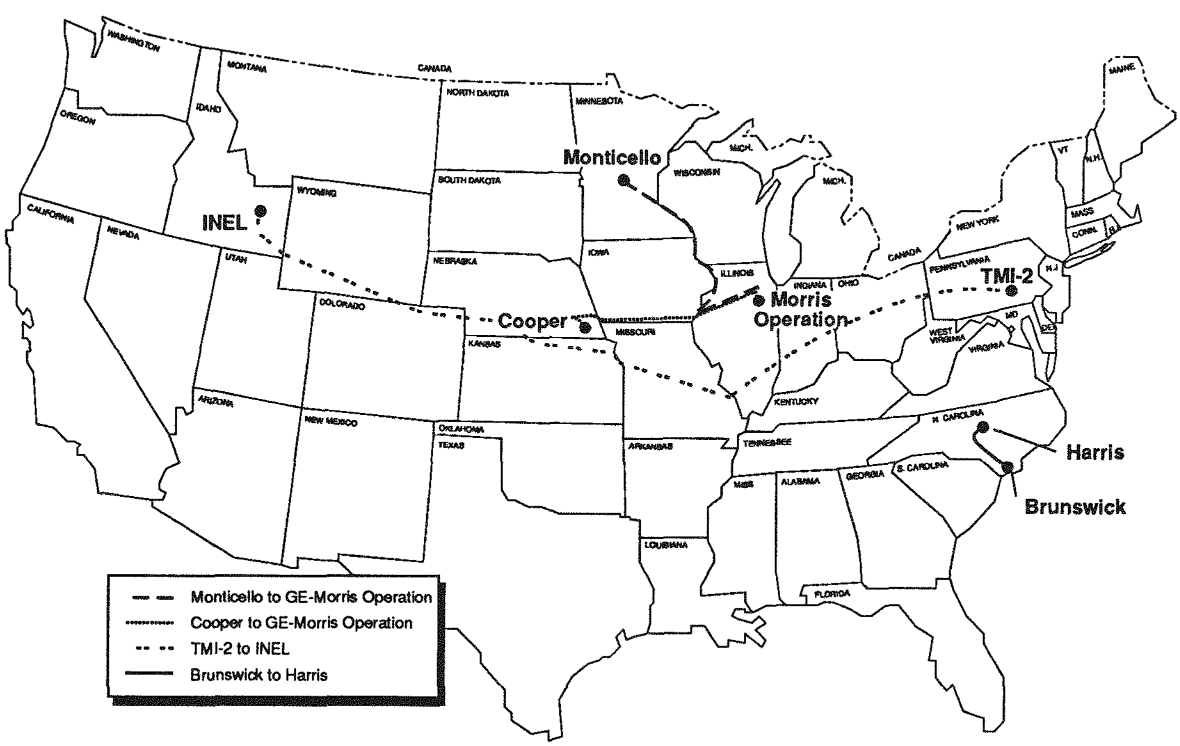

Figure 7. Major Commercial Spent Fuel Shipments by Rail, 1983 to 1989

Interesting trends are reflected in Figure 8. For example, the cumulative amount of spent fuel shipped shows four periods of major activity. The first period occurred in the mid-1960s, the second during the late 60s and early 1970s, the third during the mid-1970s, and the fourth from 1984 through 1987. These periods correspond with the startup of the NFS-West Valley reprocessing facility (1964-1966) in New York, the additional commercial reprocessing at NFS-West Valley (1971-1974), storage at GE-Morris, Illinois (mid-1970s), and the decommissioning of NFS-West Valley (1984-1986) and GE-Morris shipments (1984-1989).

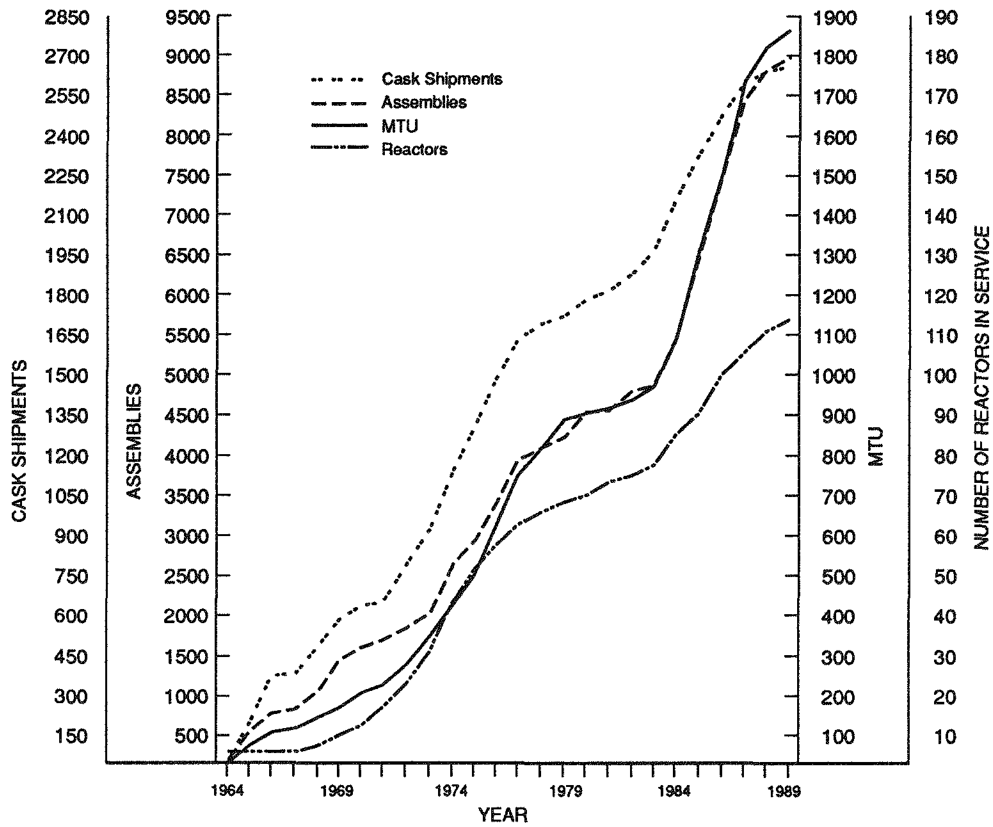

Figure 8. Comparison of Cumulative Number of Assemblies, Number of Cask Shipments, and Number of MTU Moved from Commercial Reactors in Past 25 Years

Casks Used to Ship Commercial Spent Fuel

Table 3 displays information on cask usage for commercial spent fuel shipments that have occurred from 1964 through September 1989. Table 4 gives an overview of commercial casks used to ship spent fuel and their current status.

Table 3. Commercial Shipments By Cask Model

Cask	Mode	No. of Loaded Casks	No. of Assemblies	Total (MTU)
IF-100	Truck-LW	442	787.0	105.449
IF-200	Truck-OW	324	324.0	51.906
IF-300	Rail	208	3225.0	661.319
FSV-1	Truck-LW	121	722.0	33.208
NAC-1/NFS-4	Truck-LW	795	1012.6[3]	288.269
NLI-1/2	Truck-LW	446	842.0	229.060
NUPAC-125B	Rail	43	164.0	72.040
M-100	Rail	19	272.0	35.360
WECX-300	Rail	27	324.0	88.452
NFS Model-100[1]	Rail	15	270.0	20.520
TN-8	Truck-OW	112	333.0	153.835
TN-9	Truck-OW	62	429.0	80.465
Vandenburg[2]	Truck-OW	9	18.0	4.704

[1] Also known as NFS-X2
[2] Current model designation is CNS-3-55.
LW - Legal Weight Truck
OW - Overweight Truck
[3] A fraction of an assembly shipped indicates individual fuel rods or equivalent.

A relatively small number of casks have been fabricated for the purpose of moving commercial power reactor spent fuel. The IF-100, IF-200, NFS Model-100, M-100, Vandenburg, WECX-300, and the NAC-1/NFS-4 have been retired from service in moving this kind of payload. Only eight commercial cask models are currently in service, of which three are rail casks (IF-300, TN-BRP, and NUPAC-125B).

Trans Nuclear has built two new special purpose casks: the TN-REG cask, a rail cask designed to ship R.E. Ginna fuel from the NFS-West Valley facility to INEL, and the TN-BRP also for one-time use in shipments from West Valley to INEL. The TN-BRP cask has received NRC approval. The TN-REG is awaiting approval. The NUPAC-125B cask was designed for shipments of Three Mile Island core debris.

The NAC-1/NFS-4 and the NLI-1/2 are legal-weight truck casks. The NAC-1/NFS-4 is only certified for transporting metallic fuel elements, rather than light-water reactor fuels. The Vandenburg is currently not certified for spent fuel transportation but can still be used for transporting radioactive wastes. The NLI-1/2 casks use external neutron shielding and are still in service. The TN-8, TN-9, and the IF-300 casks also use external neutron shielding and are capable of moving more fuel per shipment because of their larger size. The TN-8 and the TN-9 are overweight truck casks, and the IF-300 is a rail cask.

Nuclear Assurance Corporation (NAC) has designed, obtained an NRC certification for, and built five new, legal-weight truck casks (the NAC-LWT).

Table 4. Inventory of Commercial Spent Fuel Shipping Casks

Cask	No. of Casks	Transport Mode	Cask Capacity	Cask Weight (lb.)	Year Put In Service	Year Retired From Service
IF-100	3	Truck-LW	1 (PWR)	50,000	1962	1974
IF-200	3	Truck-OW	1 (PWR)	70,000	1960	1972
IF-300	4	Rail	7/18 (PWR/BWR)	140,000	1973	-
FSV-1[1]	4	Truck-LW	6 (HTGR)	48,000	1980	-
NAC-1/NFS-4[1, 2]	6	Truck-LW	1/2 (PWR/BWR)	48,000	1964	1984
NLI-1/2[2]	5	Truck-LW	1/2 (PWR/BWR)	48,000	1975	-
NUPAC-125B[3]	3	Rail	7 canisters	160,000	1984	-
M-100*		Rail				
WECX-300	1	Rail	10(PWR)	150,000	1962	~1974
NFS Model-100[4]	1	Rail	12 & 18(PWR)	120,000	1968	~1974
TN-8	2	Truck-OW	3 (PWR)	80,000	1979	-
TN-9	2	Truck-OW	7 (BWR)	80,000	1979	-
Vandenburg*		Truck				
NAC-LWT[5]	1	Truck-LW	1/2 (PWR/BWR)	48,000	1989	-
TN-REG[6]	1	Rail	45(PWR)			-
TN-BRP[6]	1	Rail	80 (BWR)		1989	-

[1] Not certified for light water reactor fuel
[2] Currently dedicated for foreign fuel research reactor (metallic) shipment
[3] Certified for Three Mile Island core debris
LW- Legal-Weight Truck
OW-Overweight Truck

[4] Specific to 12 Big Rock Point & 16 Humboldt Bay
[5] Five casks fabricated, one approved for use at the time of this report
[6] Special use casks, not for general service
* Data not available for publication

Research Reactor Fuel

Shipments of Research Reactor Fuel

This section provides information on shipments that were made of spent fuel discharged from reactors used for research and test purposes. In general, these shipments can be categorized into two main groups:

(1) shipments from reactors used for educational purposes and research at universities and other educational institutions and

(2) shipments from DOE reactors.

Historic data on research reactor spent fuel shipments have not been documented as well as commercial spent fuel shipment activity. This section summarizes research fuel reactor shipments from 1983 to August 1989. The weight (in MTU) of fuel transported in these shipments was estimated using cask capacity information.

All the research reactor fuel from universities, research facilities, and DOE facilities from 1983 to 1989 was shipped by truck. Table 5 provides an annual summary of these shipments.

Table 5. Summary of Annual Research Reactor Spent Fuel Shipments, 1983 to August 1989

Year	Number of Shipments	Weight (MTU)
1983	24	0.4440
1984	43	2.2490
1985	52	1.1607
1986	53	13.5501
1987	32	2.4837
1988	5	0.1102
1989	27	0.2956
Total	236	20.2933

The largest number of research reactor fuel shipments was in 1986. The largest campaigns in 1986 were from Brookhaven National Laboratory in Brookhaven, New York, to the Idaho Chemical Processing Plant (ICPP) in Idaho; the Oak Ridge National Laboratory High Flux Isotope Reactor (HFIR) in Tennessee to the Receiving Basin for Offsite Fuels (RBOF) at Savannah River in South Carolina; and the Rockwell International Reactor in California to RBOF. In 1986, Rockwell International shipped eleven NLI-1/2 casks loaded with Experimental Breeder Reactor-2 (EBR-2) fuel to Savannah River by truck. Each cask contained 24 assemblies and approximately 1,139 kg. of uranium. The largest quantity of fuel was also shipped in 1986. DOE facilities in Idaho Falls (INEL and ICPP) and the RBOF in South Carolina were the major recipients. Several universities have shipped to Savannah River and to INEL. In 1989, INEL received 10 shipments from the universities in California, Michigan, and Missouri. Figure 9 shows the principal shipment flows.

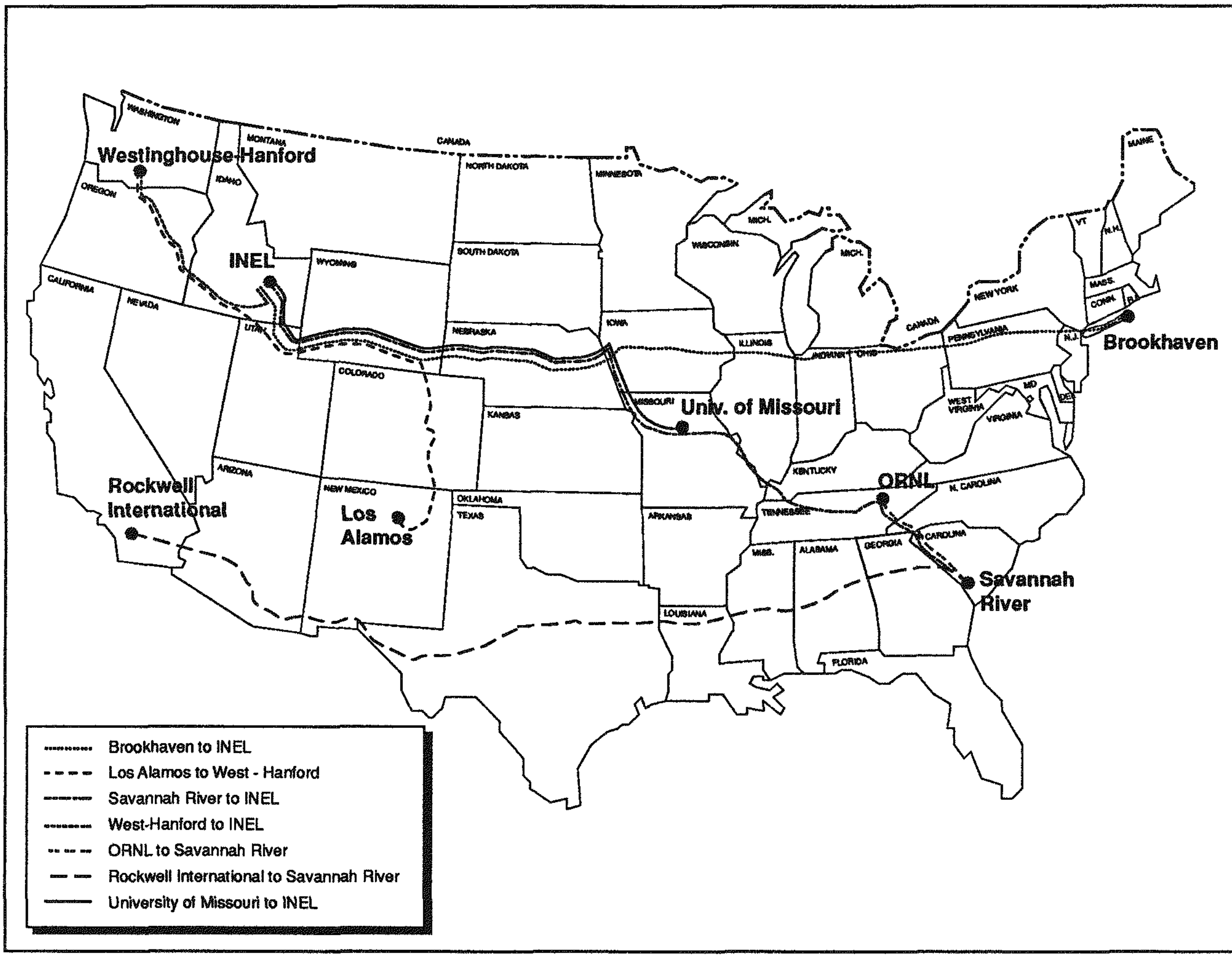

Figure 9. Principal Research Reactor Spent Fuel Shipments, 1983-1989

Casks Used to Ship Research Reactor Fuel

Table 6 provides a summary of the spent fuel casks used for research reactor shipments. Table 6 shows that the HFIR cask was the cask most frequently used. This use is attributable to large numbers of HFIR shipments from Oak Ridge to Savannah River and Oak Ridge to INEL. The HFIR cask was also used by other DOE facilities, but this cask is no longer in use. Restart of these shipments is being delayed pending the certification of a new shipping cask. Oak Ridge National Laboratory (ORNL) used the GE-700 cask for shipments to Savannah River in 1988 and 1989; however, these shipments have been completed.

Table 6. Major Cask Usage by Originating Sites, 1983 to September 1989

Cask	Origin		No. of Shipments	Weight (MTU)
NLI-1/2	Rockwell International		13	14.8070
		Total	13	14.8070
HFIR	ORNL		84	2.6700
	Savannah River		8	0.7600
	Los Alamos		1	0.0950
		Total	93	3.5250
T-3	Westinghouse-Hanford		7	0.1820
	INEL		1	0.0260
	Los Alamos		8	0.2080
		Total	16	0.4160
GE-700	Brookhaven		22	0.1298
	ORNL		9	0.0558
	Univ of Missouri		15	0.0600
		Total	46	0.2456
T-2	INEL		17	0.0510
	Los Alamos		1	0.0030
		Total	18	0.0540

Motor Carriers

Three motor carriers, Tri-State Motor Transport, Home Transportation, and McGil Specialized Carriers, participated in the majority of commercial shipping campaigns involving truck shipments. Over the 25 years addressed in this report, Tri-State has moved the most spent fuel shipments by truck. With the majority of commercial shipments concentrated in a few large campaigns, it is not surprising to find that the majority of the truck shipments were carried out by only three carriers. It should be noted that spent fuel shipments are inherently dominated by a select group of motor carriers because few carriers can afford to provide, or choose to provide, the driver training, specialized equipment, and communications operation needed to support a limited market.

FUTURE SHIPMENTS

Up to this point this report has presented information on the history of domestic shipments of spent nuclear reactor fuel. But, shipments of spent fuel will continue to occur and the experience gained will continue to be of interest and use to many individuals and organizations. This section summarizes future shipments of commercial and research reactor spent fuel.

Two time frames are of interest for future shipments of spent nuclear fuel; (1) the near-term, or next few years, for which shipment plans are already made or being formulated, and (2) the more distant future, near to the turn of the century, when shipments of spent nuclear fuel to federal waste management facilities will begin. The following sections discuss planned and forecast shipment operations for these two time periods.

Near-Term Shipments of Spent Fuel

Commercial Shipments

Projections for near-term commercial shipments of spent nuclear fuel indicate that these will be very limited. These projections and the projected cask type and transportation mode are shown in Table 7.

Table 7. Possible Near-Term Commercial Spent Fuel Shipment Campaigns

	Origin and Destination	Number of Shipments	Cask Projected	Projected Mode
1.	West Valley, NY to DOE Idaho Falls, ID	2	TN-RGE TN-BRP	Rail Rail
2.	Fort St. Vrain, CO to DOE Idaho Falls, ID	206	FSV-1	Truck
3.	Brunswick, Southport, NC to Shearon Harris, New Hill, NC	55	IF-300	Rail
4.	H. B. Robinson, Hartsville, SC to Shearon Harris, New Hill, NC	25	IF-300	Rail

Only two major fuel shipping campaigns are planned for the near future:

- Carolina Power and Light (owner of two IF-300 casks) plans to move fuel from the H.B. Robinson and Brunswick Nuclear Plants to the Shearon Harris Nuclear Plant to provide for additional long-term storage at the Robinson and Brunswick plants. The Brunswick to Harris campaign started in 1989.

- Fort St. Vrain, a high-temperature gas-cooled reactor, has tentative plans to make shipments of its remaining spent fuel in the Fort St. Vrain (FSV-1) cask to INEL.

The number of spent fuel shipments is expected to remain small in the near future, but is projected to increase significantly after an integrated system is developed by DOE's Office of Civilian Radioactive Waste Management. In the future, spent fuel will be moved from temporary storage at nuclear reactors to DOE's waste management facilities. An estimated 90,000 commercial spent fuel assemblies will be in reactor storage at utilities by the turn of the century. If 3,000 MTU are shipped, as identified in DOE's 1990 *Annual Capacity Report*, it is estimated that up to 250 rail and 725 truck shipments may be required annually to move this spent fuel from the reactors to a permanent repository or a monitored retrievable storage facility. The duration of shipments and their precise number will depend, in part, upon the mix of rail and truck shipments, the type of casks designed, future spent fuel generation, and facility development.

Transportation of spent fuel to either a permanent, nuclear waste repository or a monitored retrievable storage facility will only begin when the facilities are licensed and operating. Disposal of spent fuel in the permanent repository is projected to begin in the year 2010. DOE is currently planning to begin shipping spent fuel in 1998 from power plants to an interim storage facility.

Research Reactor Shipments

Research reactor shipments are expected to continue as in previous years. The University of Washington is planning to make five shipments to INEL in 1990. HFIR shipments are scheduled to resume when the new cask becomes available.

Shipments to Future Waste Management Facilities

Shipping spent fuel at the turn of the century will differ considerably from the shipments reported herein. One of the major differences will be the age of the fuel. Future casks are being designed to move much older fuel (fuel that has been cooled for 10 years) and will have almost three times the capacity of the present-generation casks. With the exception of the NUPAC-125B which is certified only for core debris, only nine commercial cask models currently in service are certified for the shipment of spent nuclear fuel; four of these are rail cask models.

Cask design activity is currently focusing on "from-reactor" casks that will constitute a major part of the first cask fleet used to transport spent fuel under provisions of the NWPA. It is expected that other designs will be developed that will meet anticipated shipping needs over the life cycle of the program. It is estimated that truck and rail shipments will constitute the majority of these spent fuel shipments. Contractors are developing cask designs to support this effort.

Babcock & Wilcox is developing the BR-100 cask for rail and barge shipments. The cask design calls for lead shielding and a borated, concrete neutron shield. The current design of the cask will accommodate 21 PWR spent fuel assemblies, or 52 BWR assemblies.

General Atomics Corporation is developing the GA-4 and GA-9 spent fuel shipping casks for legal-weight truck shipments. Both will utilize depleted uranium in their shielding. The two casks are being designed to accommodate both types of commercial reactor fuel: PWR and BWR. Based on current design, the GA-4 will accommodate 4 PWR spent fuel assemblies; the GA-9 will contain 9 BWR assemblies.

Westinghouse Electric Corporation initiated studies, under a limited scope, on the Titan spent fuel shipping cask for legal-weight truck shipments. The design will utilize depleted uranium for the cylindrical cask; a titanium alloy is planned for the structural material.

Nuclear Assurance Corporation is developing, also under a limited scope, the NAC-CTC spent fuel shipping cask for rail and barge shipments. Depleted uranium will provide shielding, and a wedge-lock closure mechanism will secure the cask lid.

All casks are being designed to make the best possible use of current technology and, to the extent practicable, minimize the number of shipments needed. To provide for the safety of the public, all designs will comply fully with the most recent NRC regulations.

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APPENDIX

CASE HISTORIES

Two sites originally intended as reprocessing plants for commercial spent fuel were Nuclear Fuel Services in West Valley, NY (NFS-West Valley), and General Electric in Morris, IL (GE Morris). Storage facilities at commercial nuclear power plants were originally designed on the assumption that spent fuel would be stored under water for about 5 months and then shipped away for reprocessing and final disposal. About 515 metric tons, 6% of all spent fuel rods from commercial sources currently in storage, have been shipped and "temporarily" stored in deepwater pools at NFS-West Valley and GE-Morris. The NFS-West Valley facility did reprocess some commercial spent fuel before it closed in 1972, but the GE-Morris plant never operated. It has, however, continued operation as a storage facility.

This section summarizes the shipment activity between commercial nuclear power plants and the NFS-West Valley and GE-Morris facilities. The combined shipments to and from these facilities make up approximately 75% of the total commercial shipments that have taken place since 1964. In addition, a summary of the Three Mile Island shipments to Idaho is discussed.

Nuclear Fuel Services, West Valley Facility

The West Valley facility, built and operated by Nuclear Fuel Services Inc., was the first commercial reprocessing plant. In its 6 years of operation (1966 to 1972), it produced about 600,000 gal. of high-level waste from the reprocessing of commercial spent fuel and spent fuel from the Hanford production reactors. NFS-West Valley handled and processed spent fuel originating from nine different reactors, transported to the facility in 28 campaigns. These campaigns shipped 2,000 spent fuel assemblies in 341 shipments. From 1973 to 1974, although reprocessing activities had been discontinued, an additional 756 assemblies (containing 165 MTU) were shipped to NFS-West Valley. The cumulative record of spent fuel receipt and storage over the years reveals that over 2,756 spent fuel assemblies were shipped in 756 caskloads to the West Valley facility, over a total of approximately 730,000 cask miles (West Valley, March 1987).

Reprocessing at West Valley was discontinued in 1972, and Nuclear Fuel Services formally withdrew from the reprocessing business in 1976. At that time, the 756 spent fuel assemblies that had been received from 1973 to 1974 were stored in the West Valley storage pool. In 1978, six assemblies were moved from what was now called West Valley Fuel Receiving and Storage (FRS) and shipped to Battelle Pacific Northwest Laboratory. This reduced the fuel storage inventory to 750 spent fuel assemblies with a weight of 163 MTU. By the end of 1986, all utility-owned spent fuel assemblies had been returned to the originating reactors or shipped to another storage facility. These were shipped from West Valley in the four shipping campaigns identified in Table A-1.

The DOE has taken possession of the 125 assemblies remaining at West Valley. Present and future shipments of these assemblies require NRC certification of the special shipping casks used for West Valley waste. The shipments are planned to be made to INEL as part of a DOE transportable storage cask demonstration program.

The destinations for the NFS-West Valley shipments were (1) Commonwealth Edison Company, Dresden Nuclear Power Stations in Morris, IL (Dresden), (2) Wisconsin Electric Power, Point Beach, Two Rivers, WI (Point Beach), (3) GPU Nuclear, Oyster Creek Power Plant, Toms River, NJ (Oyster

Creek), and (4) Rochester Gas and Electric, (R.E. Ginna) Ontario, NY . The Dresden and Point Beach campaigns were conducted simultaneously. Both legal weight and overweight truck shipments were used for these campaigns. In addition, major parts of the Oyster Creek and R.E. Ginna campaigns were undertaken at the same time. The 33 shipments (representing approximately 160 BWR fuel assemblies) of the Oyster Creek campaign used overweight trucks. Fully loaded, each of these shipments weighed approximately 115,000 lbs.

Table A-1. Nuclear Fuel Services Assembly Removal Campaigns

Destination/ Time frame	Mode/ Type	Weight (MTU)	No. of Assemblies	No. of Shipments	Cask Capacity
Point Beach Two Rivers, WI 10/83 - 10/84	Truck PWR	43	114	114	NLI-1/2 1 PWR
Dresden Morris, IL 12/83 - 11/84	Truck BWR	20	206	30	TN-9 7 BWRs
	Truck BWR	0.2	*	1	NLI-1/2 1 BWR
Oyster Creek Toms River, NJ 1/85 - 7/85	Truck BWR	43	224	32	TN-9 7 BWRs
R. E. Ginna Ontario, NY 6/85 - 5/86	Truck PWR	31	81	81	NLI-1/2 1 PWR

* Twisted assembly, not counted in total.

General Electric Morris Operation

The number of shipments made to and from GE-Morris facility is comparable to the number to and from the NFS-West Valley facility. General Electric built the Midwest Fuel Reprocessing Plant in Morris, Illinois, to reprocess commercial light-water reactor fuel. The facility began receiving spent fuel shipments in 1972. In 1974, GE decided not to reprocess spent fuel but kept its Morris facility open as a storage facility. In 1975, GE reracked the Morris storage pool to increase storage capacity from less than 200 to 750 MTU. BWR fuel shipments to the facility began in 1975 when Commonwealth Edison Co. returned fuel to GE from the Dresden 2 reactor. This campaign marked the first use of the IF-300 rail cask for transporting spent fuel. A total of 753 assemblies were shipped to GE-Morris from the Dresden 2 reactor during the period 1975 to 1977.

The period 1975 through 1976 was the busiest for receipts at GE-Morris. During this 2-year period, a total of 171 shipments was received from Dresden 2 in Illinois, Point Beach in Wisconsin, and San Onofre in California. In 1979, eight fuel assemblies were received from La Crosse, Wisconsin, for temporary storage. These assemblies were subsequently returned to La Crosse in 1981.

In 1983, Wisconsin Electric decided to discontinue its use of the Morris facility for spent fuel storage. This resulted in 109 assemblies being returned to Point Beach in 109 shipments from 1983 through 1984. The NLI-1/2 legal weight truck cask was used for these shipments.

Beginning in 1984 and continuing through January 1989, the Cooper Nuclear Station and the Monticello Plant shipped spent nuclear fuel to GE-Morris by rail.

To date, GE-Morris has received 3,336 assemblies; 119 have been shipped out. Remaining in storage are 3,217 assemblies (352 PWR assemblies and 2,865 BWR assemblies). Because the pool is over 95% full, GE has no current plans for additional fuel receipt. Also, there are no near-term plans to ship fuel out of GE-Morris.

GE has handled fuel in five cask models at Morris: IF-100, IF-200, IF-300, NAC-1/NFS-4, and NLI-1/2. GE also performed dry cask storage studies at Morris using the REA-2023 cask. Table A-2 shows the shipments and receipts from the GE-Morris Operation.

Table A-2. Summary of Spent Fuel Shipments Involving GE-Morris Operation

Reactor Time Period	Mode/Type	Weight (MTU)	No. of Assemblies	No. of Loaded Casks	Cask Type	Capacity
Haddam Neck	Truck/PWR	33.362	80	80	IF-200	1
1972-1987	Truck/PWR	0.791	2	2	NLI-1/2	1
San Onofre	Truck/PWR	35.150	95	95	IF-100	1
1972-1980	Truck/PWR	64.750	175	175	NAC-1	1
Point Beach						
1975-1977	Truck/PWR	43.491	109	109	NAC-1	1
1983-1984[1]	Truck/PWR	43.491	109	109	NLI-1/2	1
La Crosse						
1979	Truck/BWR	0.912	8	4	NAC-1	2
1981[1]	Truck/BWR	0.912	8	4	NAC-1	2
Dresden						
1975-1977	Rail/BWR	130.270	753	42[3]	IF-300	18
Cooper						
1984-1989	Rail/BWR	193.248	1056	59[3]	IF-300	18
1987[2]	Truck/BWR	0.366	2	1	NLI-1/2	2
Monticello						
1984-1987	Rail/BWR	184.092	1058	59[3]	IF-300	18

[1] Returned to reactor from Morris Operation
[2] Sent to Pacific Northwest Laboratory
[3] Some casks partially loaded

A schedule for shipping the remaining fuel assemblies from the Fort St. Vrain reactor has not been established.

Three Mile Island

On March 29, 1979, water flow to the core of the Three Mile Island (TMI) power plant in Middletown, Pennsylvania, was inadvertently cut off. As a consequence, part of the core became damaged. Cleanup activities began immediately. Once cleanup at TMI was well underway, it was decided that the INEL facility in Idaho would perform research on, and provide interim storage for, the TMI core debris.

Rail shipments of the core debris from TMI to INEL began in July 1986. Rail was chosen as the mode of transportation for a number of reasons. One of the most obvious was that the materials could be transported in 25 to 45 shipments, while as many as 250 truck shipments would have been required. Two rail carriers, Conrail, from TMI to St. Louis, Missouri, and Union Pacific, from St. Louis to INEL, were selected to provide the service.

The TMI core debris was packaged for transport in special containers, then loaded into NUPAC-125B casks designed specifically for this campaign. Each of these three casks is 280-in. long and 120 in. in diameter and provides double containment. These casks are transported on heavy-duty flatcars. Two cars with casks are owned by DOE, and the third is leased from Nuclear Packaging Inc., designer of the casks. The rail cars and casks are designed to be operated in normal train service, but the use of dedicated trains is believed to have enhanced cask utilization. A trip from TMI to INEL normally takes 5 to 6 days. Through August 1989, 43 TMI casks had been transported in 20 shipments. Since 1987, three loaded casks at a time have been transported by dedicated train from TMI to INEL. Prior to this time, TMI shipments to INEL contained only one or two casks.

A summary of the amount of material shipped through August 1989 is provided in Table A-3. All core debris has been shipped to INEL.

Table A-3 Summary of Three Mile Island Shipments, through August 1989

Year	No. of Equivalent Fuel Assemblies[1]	No. of Shipments	No. of Loaded Casks	Weight[2] (MTU)
1986	19.25	3	5	8.46
1987	75.14	10	17	33.00
1988	28.61	4	12	12.57
1989	41.01	3	9	18.01

[1] Assemblies from core debris estimated as 36,667 curies per assembly
[2] Estimated at 83,485 curies per MTU

There have been two nonroutine incidents during the TMI movements. On March 24, 1987, a TMI train with two casks hit a car stalled on a grade crossing in St. Louis, injuring the driver of the car. The casks were not affected by the collision. The second incident happened in February 1988. An empty, covered hopper car being used as a buffer car in the dedicated train (a train reserved for the shipment) was discovered to be displaying a hazardous materials placard in error. Although no damage resulted, the incident violated DOT regulations regarding placarding and the placement of placarded cars within a train.

The TMI campaign has provided an opportunity to learn valuable lessons in the transport of spent nuclear fuel. On the operations level, the campaign demonstrated that railroads can be relied on for efficiently carrying heavy loads of nuclear materials. From an institutional point of view some of the most important issues raised by State and local officials and the public included environmental impact; rail accident risk; train routing; notification, inspection, and escorts; and emergency response capability.

To address the institutional concerns, DOE, GPU Nuclear, and INEL responded with an extensive public information program. Efforts were made to inform citizen's advisory groups, display transportation hardware, invite public officials to inspect shipments themselves, and distribute public information documents to interested citizens. For this outreach program, the Federal Government, carriers, and originators exchanged information and addressed potential concerns prior to the shipment campaigns.

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