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Historical Overview of Domestic Spent Fuel Shipments - Update*

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HISTORICAL OVERVIEW OF DOMESTIC SPENT FUEL SHIPMENTS - UPDATE

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ABSTRACT

The information in this paper summarizes historic data on spent fuel shipments in the United States. The data are updated periodically to keep abreast of changes. Information on shipments is provided for planning purposes; to support program decisions of the U. S. Department of Energy's (DOE's) Office of Civilian Radioactive Waste Management (OCRWM); and to inform interested members of the public, federal, state, and local government, Indian tribes, and the transportation community.

INTRODUCTION

Purpose

The purpose of this paper is to provide available historical 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.

Most of the shipments addressed in this paper 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 provides a comprehensive compilation and analysis of available data on the shipment of spent fuel.

Historical information on the shipment of spent nuclear fuel can be useful in planning future shipments. Such information is useful for (1) anticipating transportation needs, (2) interacting with the public and public officials, and (3) conducting shipments. Experience gained from over 25 years of shipments can provide a framework for understanding and resolving transportation challenges. The historical record also provides a basis for lessons learned.

Data Sources

The data contained in this paper rely primarily on two existing data bases: DOE's Shipment Mobility/Accountability Collection (SMAC) and the U.S. Department of Transportation's (DOT's) Radioactive Material Routing Report (RAMRT). The SMAC data base contains information on unclassified shipments that have been made to and from DOE facilities. It does not include routing data. The RAMRT data base contains historical data (beginning in 1982) on all shipments of highway route-controlled quantities (HRCQ) of radioactive materials by truck, but no 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 require interpretation to determine which shipments involved spent fuel payloads. Although this data base presents an important historical record, delays by carriers of up to 6 months in reporting shipments limit RAMRT's usefulness in addressing current shipments. The data presented in this report have also been supplemented by summary reports prepared by the Nuclear Assurance Corporation,[1,2] the Office of Technology Assessment,[3] the U.S. Nuclear Regulatory Commission's (NRC) Public Information Circular for Shipments of Irradiated Reactor Fuel,[4] and personal interviews with DOE traffic managers and commercial cask suppliers who provided much of the information on rail shipments of commercial spent fuel.

History

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 OCRWM within DOE. 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 (FWMS), spent fuel will be transported from nuclear power plants to either: (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.

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 and, in some cases, by decisions between a state and a utility to move the spent fuel to an alternate storage site.[3] Various research reactors across the United States have shipped spent fuel for reprocessing at government-owned plants. Thus, when fuel is removed from university research reactors, DOE has been responsible for disposal or reprocessing of the fuel under its university assistance program.[5]

During the past 25 years, approximately 2,600 commercial spent fuel rail and truck shipments have taken place domestically. These shipments have been involved in few incidents. There have been no fatalities, radiation injuries, or damage to the environment resulting from the transport of radioactive cargo. 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 specially designed casks that are manufactured to contain and shield the spent fuel during normal shipment. This type of cask must withstand tests designed to verify its containment and shielding of the 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 lb, 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 (approximately 40,000 metric tons of spent fuel) will be in reactor-site storage at utilities by the turn of the century. Storage require that fuel be shipped to an NWPA storage facility at that time. The duration of shipments and their precise number will depend, in part, upon the mix of rail and truck shipments; cask design; future spent fuel generation; and facility development.

SPENT FUEL SHIPMENTS

Although 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 paper, the primary focus of this paper is commercial spent fuel shipments because they comprise over 99% of the tonnage to be transported.

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 the heavy deuterium-enriched form of water used in nuclear research) is used to transfer heat from the fuel. BWRs are LWRs 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 LWRs 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.

LWR 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 to 289 rods for BWRs and PWRs, respectively. 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 (Fig. 1) may contain 4

(PWR) to 9 (BWR) assemblies per cask. Rail casks may accommodate 21 (PWR) to 52 (BWR) assemblies per cask.

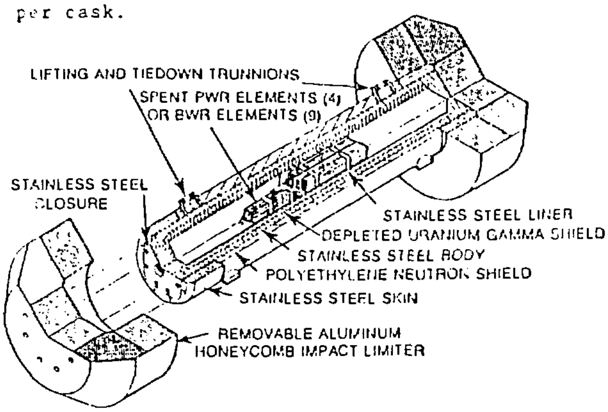

FIGURE 1. GA-4/GA-9 LEGAL-WEIGHT TRUCK SHIPPING CASK

Research reactor fuel, which differs substantially from power reactor fuel, varies widely in form, ^{235}U 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 1/1000 the net weight of a commercial spent fuel element. 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. In contrast, commercial fuel must be cooled for a year or more to qualify for shipment.

Because spent commercial and research reactor fuels vary greatly in form, weight, and activity, information for each type of fuel is presented separately. In the future, the vast majority of spent fuel shipped will be generated by utilities and shipped under NWPA provisions.

History of Shipments of Commercial Spent Fuel

This section provides an overview of domestic, commercial spent nuclear fuel shipments that have traversed U.S. highways or railways during the past 25 years. Commercial shipments contain 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 NWPA, as amended, commercial spent fuel shipped by DOE will also be regulated by the NRC.

Classes of Commercial Spent Fuel Shipments

In the United States, commercial power reactor spent nuclear fuel has resulted from the operation of LWRs and gas-cooled reactors (GCRs). The LWR 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—the Fort St. Vrain reactor owned by Colorado Public Service. The reactor is now permanently shut down. A small commercial GCRF cooled reactor, Peach Bottom 1, owned by the Philadelphia Electric Co., discontinued operation in the early 1970s.

Spent fuel from light-water reactors. The majority of the spent fuel originates from the LWRs (94% of the commercial spent fuel shipped and 99% of the metric tons of uranium [MTU] shipped). As discussed previously, LWRs include PWRs and BWRs. 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, unused uranium and all the plutonium produced would be returned for reuse.) Once the fuel cycle was closed, the fuel was to be shipped to a facility for reprocessing (or recycling) 90 to 120 d after removal from the reactor. As a consequence, 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 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 on-site.

Three commercial spent fuel reprocessing plants were constructed in the United States: (1) Nuclear Fuel Services (NFS), West Valley, New York; (2) General Electric (GE) Nuclear Energy, Morris, Illinois; and (3) Allied General Nuclear Services, Barnwell, South Carolina. Only NFS-West Valley was opened for fuel reprocessing. In 1972, NFS was shut down for modification and 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 or accepted spent fuel for storage and is now closed.

Most spent fuel casks in service in 1989 were originally designed to transport fuel to reprocessing plants for recycling. Although these casks were designed to ship spent fuel that had been cooled for only 90 to 120 d, commercial spent fuel shipped today typically involves fuel that has cooled for several years and is less radioactive.[3]

Most of the recent commercial spent nuclear fuel shipments have been performed 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 research facilities.

GE owned and operated the IF-100, IF-200, and IF-300 casks and used these primarily to service its 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 NFS and 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, spent fuel rods (a portion of a fuel assembly) are shipped 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, owned by the 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 the Idaho National Engineering Laboratory (INEL) for long-term storage. All of these shipments have been by truck using the FSV-1 cask.

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 commercial spent fuel shipments made since 1964 and their weight in MTUs by mode of transportation is given in Table 1. (This table does not cover shipments from Hallem, Path Finder, Elk River, Fermi 1, Shippingport,

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	4706.16	2346	2346	983.343	4255.51	230	312	877.691	8961.67	2576	2658	1861.034

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

and Peach Bottom 1 Reactors due to the difficulty of gathering information.) Almost 2,700 loaded casks of commercial spent fuel were shipped from 1964 through 1989. Based on the number of shipments made 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 by weight because of the larger load capacity of rail casks.

Figure 2 shows the number of loaded casks and fuel quantity (in MTUs) shipped each year from 1964 through September 1989.

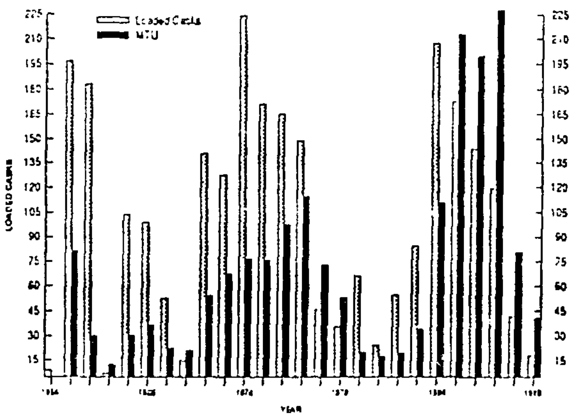

FIGURE 2. COMMERCIAL FUEL SHIPMENT ACTIVITY, 1964 TO 1989, BY LOADED CASKS AND WEIGHT (MTU)

Although the greatest number of fuel assemblies were moved in 1986 (see Table 1), the greatest number of cask shipments were moved in 1974 (Fig. 2). For a combination of reasons (rail versus truck shipments, fewer PWR and more BWR assemblies), assemblies shipped increased from 346 in 1974 to 1027 in 1986, while cask shipments decreased from 224 in 1974 to 144 in 1986. In 1986, the majority of assemblies were the BWR type shipped by rail. If data from Fig. 2 are separated for truck and rail, a shift from small capacity casks to casks carrying greater volumes is evident, for example, due to use of the TN-9 cask from 1984 through 1987. A trend toward larger rail shipment volumes was also seen.

Figure 3 shows fuel quantity shipped by truck and rail, by year. Greater volumes of fuel were moved by truck during the early 1970s and early 1980s. Figure 4 shows the number of cask loads by truck and rail. The rail mode shows three periods of activity corresponding to startup of NFS-West Valley (late 1960s); the movement of Dresden fuel to Morris Operation and transfer of H. B. Robinson fuel to Brunswick (mid- to late 1970s); and the movement of contract fuel from Cooper and Monticello to Morris Operation (mid- to late 1980s).

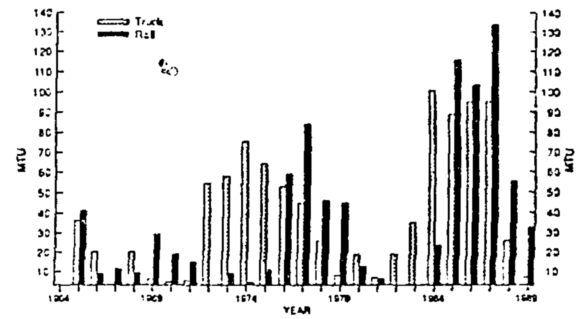

FIGURE 3. COMMERCIAL FUEL QUANTITY BY TRANSPORTATION MODE, 1964 TO 1989, TRUCK AND RAIL

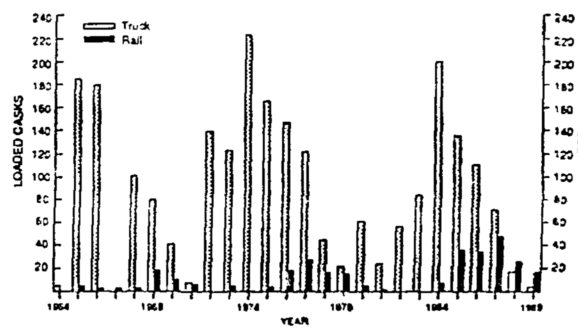

FIGURE 4. TOTAL NUMBER OF LOADED CASKS BY TRANSPORTATION MODE, 1964 TO 1989, TRUCK AND RAIL

Major shipping operations from 1983 through 1989, ranked by number of shipments (listed by facility and state) are:

- NFS-West Valley, NY to Point Beach, WI (114 shipments);
- Oconee, SC to McGuire, NC (111 shipments);
- GE-Morris, IL to Point Beach, WI (109 shipments);
- NFS-West Valley, NY to the R.E. Ginna Power Plant, NY (81 shipments); and
- Fort St. Vrain, CO to the ID Chemical Processing Plant (ICPP), ID (43 shipments).

Rail shipments, not including the Three Mile Island shipments, were concentrated in Illinois.

Iowa, Minnesota, Nebraska, and Wisconsin. The TMI shipments were from Pennsylvania to Idaho. Figures 5 and 6 show these major campaign flows from 1983 to 1989 by highway and rail, respectively.

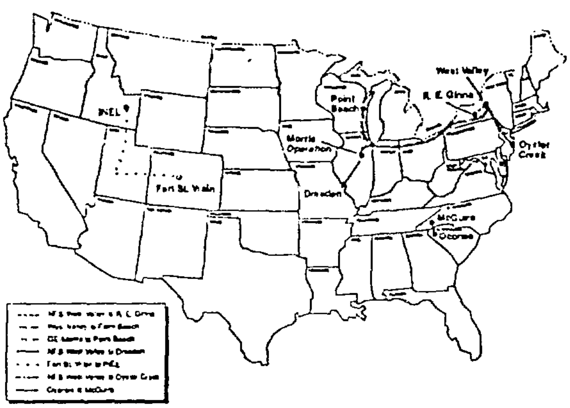

FIGURE 5. MAJOR COMMERCIAL SPENT FUEL SHIPMENTS BY TRUCK, 1983 TO 1989

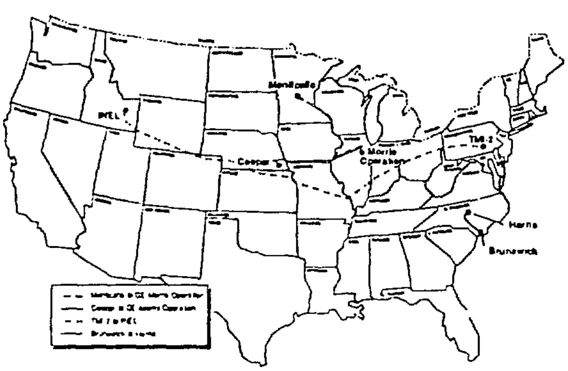

FIGURE 6. MAJOR COMMERCIAL SPENT FUEL SHIPMENTS BY RAIL, 1983 TO 1989

Figure 7 depicts the number of shipments, number of reactors in service, mass in MTU, and number of assemblies shipped from 1964 to 1989.

Interesting trends are reflected in Figure 7. For example, the cumulative amount of spent fuel shipped shows four periods of major activity: the mid-1960s, the late 60s and early 1970s, the mid-1970s, and 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).

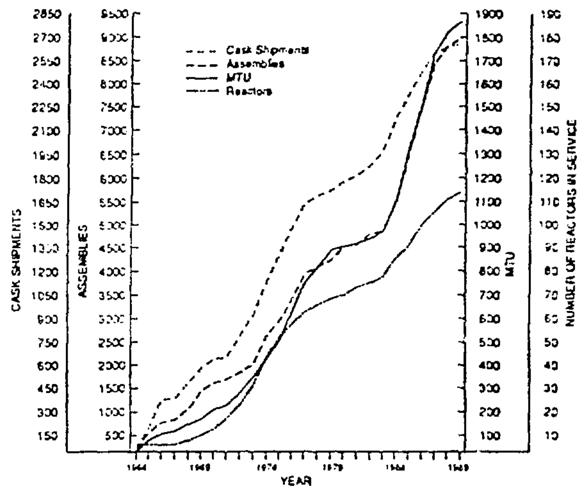

FIGURE 7. COMPARISON OF CUMULATIVE NUMBER OF ASSEMBLIES, CASK SHIPMENTS, AND MTUs MOVED FORM COMMERCIAL REACTORS, 1964 TO 1989

<u>Casks used to ship commercial spent fuel.</u> Table 2 gives an overview of commercial casks used to ship spent fuel from 1964 through September 1989 and their current status.

A relatively small number of casks have been fabricated to move commercial power reactor spent fuel. The IF-100, IF-200, NFS Model-100, M-100, Vandenburg, WECX-300, and NAC-1/NFS-4 have been retired from service for this kind of payload. Only eight commercial cask models are currently in service, including three 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 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 TMI core debris.

History of Shipments of Research Reactor Fuel

In general, shipments of spent fuel discharged from reactors used for research and test purposes are in two main groups:

TABLE 2. 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	LWT[a]	1 (PWR)	50,000	1962	1974
IF-200	3	OWT[b]	1 (PWR)	70,000	1960	1972
IF-300	4	Rail	7/18 (PWR/BWR)	140,000	1973	-
FSV-1[c]	4	LWT	6 (HTGR)	48,000	1980	-
NAC-1/NFS-4[c,d]	6	LWT	1/2 (PWR/BWR)	48,000	1964	1984
NLI-1/2[d]	5	LWT	1/2 (PWR/BWR)	48,000	1975	-
NUPAC-125B[e]	3	Rail	7 canisters	160,000	1984	-
M-100[f]		Rail				
WECX-300	1	Rail	10 (PWR)	150,000	1962	~1974
NFS Model-100[g]	1	Rail	12 & 18 (PWR)	120,000	1968	~1974
TN-8	2	OWT	3 (PWR)	80,000	1979	-
TN-9	2	OWT	7 (BWR)	80,000	1979	-
Vandenburg[f]		Truck				
NAC-LWT[h]	1	LWT	1/2 (PWR/BWR)	48,000	1989	-
TN-REG[i]	1	Rail	45 (PWR)			-
TN BRP[h]	1	Rail	80 (BWR)		1989	-

[a] LWT = legal-weight truck.
[b] OWT = overweight truck.
[c] Not currently certified for LWR fuel.
[d] Currently dedicated for foreign fuel research reactor (metallic) shipment.
[e] Certified for TMI core debris.
[f] Data not available for publication.
[g] Specific to 12 Big Point & 16 Humboldt Bay.
[h] Five casks fabricated; one approved for use at the time of this report.
[i] Special-use casks, not for general service.

(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 research reactor fuel from universities, research facilities, and DOE facilities from 1983 to 1989 was shipped by truck. During this period, 236 shipments carrying a total of 20.29 MTU were made.

The largest number of research reactor fuel shipments was in 1986. The largest campaigns in 1986 were from Brookhaven National Laboratory (BNL) in Brookhaven, New York, to the Idaho Chemical Processing Plant (ICPP) in Idaho; the Oak Ridge National Laboratory (ORNL) 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 ten shipments from universities in California, Michigan, and Missouri.

<u>Casks used to ship research reactor fuel.</u> Casks used to ship research reaches fuel include the NLI-1/2, the HFIR, T-3, GE-700, and the T-2. The HFIR cask was the cask most frequently used. This 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 facilties, but this cask is no longer in use. Restart of these shipments has been delayed pending the certification of a new shipping cask. ORNL used the GE-700 cask for shipments to Savannah River in 1988 and 1989; however, these shipments have been completed.

<u>Motor carriers.</u> Three motor carriers, Tri-State Motor Transport, Home Transportation, and McGil Specialized Carriers, participated in the majority of commercial shipping campaigns involving trucks. 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 this limited market.

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 of casks. With the exception of the NUPAC-125B, which is only certified 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 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 PWR and BWR commercial reactor fuel. The GA-4 will accommodate four PWR spent fuel assemblies; the GA-9 will contain nine 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 and a titanium alloy is planned for the structural material. The cask is capable of carrying three PWR or seven BWR spent fuel assemblies.

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 s[illegible]lding, and a wedge-lock closure mechanism [illegible] 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.

CONCLUSION

The information in this paper covers shipments of spent nuclear fuel in the United States through September 1989. A more comprehensive presentation of this material is being prepared for DOE's OCRWM. This report will be updated periodically to keep abreast of changes.

REFERENCES

1. Nuclear Assurance Corporation, 1986. *Spent Fuel Transportation in the United States: Commercial Spent Fuel Shipments Through December 1984.*

2. Nuclear Assurance Corporation, 1989. Transportation of U. S. LWR Spent Fuel.

3. U. S. Congress, Office of Technology Assessment, 1986. *Transportation of Hazardous Materials*, OTA-SET-304 (Washington, DC: U.S. Government Printing Office).

4. Office of Nuclear Material Safety and Safeguards, 1988. *Public Information Circular for Shipments of Irradiated Reactor Fuel*, United States Nuclear Regulatory Commission, NUREG-0725.

5. U. S. Department of Energy, Office of Civilian Radioactive Waste Management, 1988. *Characteristics of Spent Fuel, High-Level Waste, and Other Radioactive Wastes Which May Require Long-Term Isolation*, DOE/RW-1084, Volume 7.