HISTORICAL OVERVIEW OF DOMESTIC SPENT NUCLEAR FUEL SHIPMENTS IN THE UNITED STATES

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ABSTRACT

The information in this paper summarizes historical data on spent nuclear fuel shipments in the United States (U.S.) from the period from 1964 to 1991. Information on shipments has been developed to establish a basis for developing a transportation system in the U.S. for initiating shipments of spent nuclear fuel beginning in 1998. The paper shows that approximately 2700 power reactor spent nuclear fuel rail and truck casks have been shipped within the U.S. during the past 28 years. In total, approximately 2000 metric tonnes of uranium (MTU) have been shipped to date, which compares with projected shipping rates of from 3000 to greater than 6000 MTU per year when the U.S. Civilian Radioactive Waste Management System is in full operation.

INTRODUCTION

In 1982, the U.S. Congress passed the Nuclear Waste Policy Act (NWPA), establishing a national policy for deep, geologic disposal of spent nuclear fuel (SNF) and high-level radioactive waste. The legislation established the Office of Civilian Radioactive Waste Management (OCRWM) within the Department of Energy (DOE). This office was charged with developing an integrated Civilian Radioactive Waste Management System (CRWMS) for accepting, transporting, storing, and permanently disposing the waste. The CRWMS is currently planned to begin operations in 1998, transporting SNF from generating sites or other storage sites to a monitored retrievable storage (MRS) facility for temporary storage and, possibly, packaging SNF for repository emplacement. Later, the SNF will be transported to a licensed geologic repository for permanent disposal.

As the transportation system and the other components of the CRWMS are placed into operation and brought to full capacity, it is expected that shipments of SNF may reach levels exceeding 3000 metric tonnes of uranium (MTU) per year, and the operation of this system will extend over more than three decades. If the MRS is used as a staging point for shipments to the repository, as is envisioned under some planning scenarios, at full capacity, shipments could exceed 6000 MTU per year. Ultimately, this waste management system is expected to receive and handle more than 63,000 MTU of SNF. During its first year of operation, the CRWMS is expected to have a shipping rate of 400 MTU (U.S. DOE 1991).

While CRWMS SNF shipments will take place in the future, it is important to note that SNF has been shipped safely in the U.S. for years. Recently, power reactor SNF 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 SNF to an alternate storage site (U.S. Congress 1986). In addition, various research reactors across the country have shipped SNF to government-owned plants for reprocessing. When fuel is removed from university research reactors, DOE has been responsible for disposal or reprocessing of that fuel under its university assistance program (U.S. DOE 1988).

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*Managed by Martin Marietta Energy Systems, Inc. for the U.S. Department of Energy under contract DE-AC05-84OR21400.

Historic information on the shipment of SNF can be useful in developing the transportation system needed and in generally planning for future shipments. Such information will be useful for:

(1) anticipating transportation needs,
(2) interacting with public and public officials,
(3) placing the scope of planned activities into perspective, and
(3) preparing the system needed to conduct shipments.

Indeed, the experience gained from almost three decades of shipments in the U.S. can provide a framework for understanding and resolving transportation challenges which may be expected in the future; and the historic record can provide a basis for lessons learned.

A previous document (ORNL 1991) was recently issued which summarized the history of U.S. SNF shipments for the period 1964 to 1989. This paper provides a summary update to that document, expanding the dates considered to include 1964 through the end of 1991; and it provides a limited discussion on the issue of multiple-shipment SNF campaigns which are expected to predominate in the CRWMS operation. Where the previous document provided information on both power reactor and research reactor SNF shipments, this paper is limited to providing information only on power reactor SNF shipments because it comprises over 99% of the tonnage of uranium which has been transported in the U.S. to date. The information provided includes data on the originating sources of SNF shipments, the types of shipping casks used, the number of fuel assemblies shipped, and the number of shipments 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 or based on estimates or anecdotal information. This document provides, within the constraints of the data available, a comprehensive compilation and analysis of data on the shipment of U.S. power reactor SNF from 1964 to the present.

DATA SOURCES

The data contained in this paper rely primarily on two existing databases:

(1) DOE's Shipment Mobility/Accountability Collection (SMAC), and
(2) U.S. Department of Transportation's (DOT's) Radioactive Material Routing Report (RAMRT).

The SMAC data base, operated and maintained in Oak Ridge, Tennessee, for DOE, 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 historic 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. Shipment of HRCQ of radioactive materials include SNF. 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 SNF payloads. Although it presents an important historic record, delays of up to 6 months by carriers in reporting shipments limit RAMRT's usefulness in addressing current shipments.

The data presented in this paper have also been supplemented by and correlated with other summary reports (NAC 1986; NAC 1989), the Office of Technology Assessment's evaluation (U.S. Congress 1986), a U.S. Nuclear Regulatory Commission (NRC) Public Information Circular (U.S. NRC 1988), and personal interviews conducted with DOE traffic managers and commercial cask suppliers who provided much of the information on rail shipments of power reactor SNF.

METHODS FOR TRANSPORTATION OF SPENT NUCLEAR FUEL IN THE U.S.

Throughout the world, SNF is, and has been, shipped in casks that are specially designed and manufactured to contain and shield the SNF during normal shipment. In addition, a cask must be designed to withstand tests which have been specified in regulatory documents (e.g., see IAEA 1990) to ensure that a cask will contain and continue to shield its SNF payload during and following severe accidents. The U.S. requirements for design and operation of SNF casks are found in the regulations promulgated by the NRC and the Department of Transportation (DOT). SNF casks are shipped primarily by road (truck) and rail (train). Currently, there is a small fleet of legal-weight and overweight truck casks and rail casks for commercial SNF shipments. The "overweight" shipments are specially approved and permitted by each state traversed because they exceed a gross vehicle weight of 36,281 kg (80,000 lb) or do not meet weight distribution (bridge formula) requirements.

During train shipments, SNF casks are transported on heavy-duty flat cars. General freight trains and trains dedicated to fuel shipments have both been used. Casks designed for carriage by train are capable of carrying more SNF than those designed for carriage by truck.

Most power reactor fuel is discharged from light-water reactors (LWRs), either boiling-water reactors (BWRs) or pressurized-water reactors (PWRs). Present U.S. truck casks can carry between 1 and 3 (PWR) and between 2 and 7 (BWR) assemblies. These casks, when loaded, weigh between 22 and 36 tonnes (24 and 40 tons). Only one rail cask design is currently in service in the U.S.; it can carry 7 (PWR) or 18 (BWR) assemblies and weighs approximately 63.5 tonnes (70 tons) when loaded.

Future casks being considered by OCRWM for shipping power reactor SNF are expected to have greater capacity than existing casks. Truck casks may contain as many as 4 (PWR) or 9 (BWR) assemblies per cask. Rail casks may accommodate as many as 21 (PWR) or 52 (BWR) assemblies per cask.

HISTORY OF SHIPMENTS OF POWER REACTOR SPENT NUCLEAR FUEL

This section provides an overview of most of the power reactor SNF shipments that have traversed U.S. highways or railways during the past 28 years. Power reactor shipments contain fuel assemblies discharged from a commercial, NRC-licensed power reactor. Shipping of SNF by an NRC licensee is accomplished according to regulations published in Title 10, Code of Federal Regulations. In accordance with the NWPA, as amended, power reactor SNF shipped by DOE will also be regulated by the NRC.

Classes of Power Reactor Spent Nuclear Fuel Shipments

In the U.S., power reactor SNF has resulted from the operation of LWRs and gas-cooled reactors (GCRs). The LWR is the principal reactor type in commercial use in the U.S. Only two gas-cooled commercial power reactors have operated. A small, commercial, demonstration, gas-cooled reactor, Peach Bottom 1, owned by the Philadelphia Electric Co., discontinued operation in the early 1970s. The Fort St. Vrain reactor, owned by Colorado Public Service, had operated during the 1980s, and was permanently shut down in September 1989.

Spent Nuclear Fuel from Light-Water Reactors

The majority of the SNF in the U.S. has originated from the LWRs. For example, 94% of the power reactor SNF shipments made to date, and 99% of the metric tons of uranium [MTU] shipped to date, have originated from LWRs. The remainder of the shipments have originated from the two gas-cooled reactors discussed above.

The first reactors built and put into service in the U.S. were designed with the intention that the SNF would eventually be recycled. 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 many early reactors was not designed to accommodate long-term storage needs. Since reprocessing is no longer considered a nuclear fuel cycle alternative in the U.S., many reactor operators in the U.S. have modified 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 SNF discharges on-site.

Three commercial SNF reprocessing plants have been constructed in the U.S. Only Nuclear Fuel Services (NFS), West Valley, New York, was opened for fuel reprocessing. In 1972, recycling was discontinued at NFS and never restarted. General Electric (GE), Morris, Illinois, was completed but never reprocessed SNF. Morris has received SNF, has shipped some SNF back out, and presently has in storage approximately 3200 SNF assemblies. Allied General Nuclear Services, Barnwell, South Carolina, never reprocessed SNF or accepted SNF for storage.

Most LWR SNF casks in service in the U.S. in 1991 were originally designed to transport fuel to reprocessing plants for recycling. Although these casks were designed to ship SNF that was cooled for only 90 to 120 d, power reactor SNF shipped today typically involves fuel that has cooled for several years and is less radioactive (U.S. Congress 1986). Most of the recent power reactor SNF shipments have been performed to return fuel to the generating reactors from NFS-West Valley, to ship SNF from reactors to GE-Morris under contracts between General Electric Company and utilities, to provide SNF to research facilities, or to transship SNF between generating reactors owned by a single utility.

Occasionally, LWR SNF rods (a portion of a fuel assembly) have been shipped to a commercial testing facility by fuel manufacturers for research and development work. Many of these LWR fuel rod shipments went to Battelle Columbus Laboratories in Ohio or to Babcock & Wilcox in Virginia. These shipments usually involved only a part of an assembly (several fuel rods) and occurred only a few times a year.

Spent Nuclear Fuel from High-Temperature Gas-Cooled Reactors

The other type of commercial nuclear power reactor used in the U.S. is the high-temperature gas-cooled reactor (HTGR). All the fuel has been shipped from the Peach Bottom 1 reactor and, since 1980, there have been 722 assemblies containing 33.21 MTU shipped from the Fort St. Vrain reactor to the Idaho National Engineering Laboratory (INEL) for long-term storage. All of the Fort St. Vrain shipments were made by truck using a legal-weight cask system. The Fort St. Vrain reactor has been shut down, but a schedule for shipping the remaining fuel assemblies, which are currently in temporary dry storage, has not yet been established.

SUMMARY OF SHIPMENTS

An overview of power reactor SNF shipments made in the U.S. since 1964 is given in Table 1, which lists, by year: (1) the number of assemblies shipped, (2) the number of shipments made, (3) the number of loaded casks involved, and (4) the total tonnage of uranium shipped. This table does not cover shipments from the Hallem, Path Finder, Elk River, Fermi 1, Shippingport, and Peach Bottom 1 reactors due to the difficulty of gathering information on these old reactors. The data show that almost 2700 loaded casks of power reactor SNF were shipped from 1964 through 1991. It is also noted that few incidents have occurred with these shipments; and there are no known fatalities due to the radioactive nature of the cargo, nor has there been any known radiation injury or damage to the environment.

The total amount of uranium shipped in the U.S. is less than 2000 MTU. Note, that this is less than the annual shipping rate envisioned for the CRWMS when fully operational. The maximum shipped in any single year is 229 MTU (in 1987), which is less than envisioned for the first year of CRWMS operation.

It can be seen that there were 100 more loaded casks than shipments, which results from multicar rail shipments of SNF. Multicar shipments by rail is one important operating option being considered by the OCRWM.

Although some shipments have occurred in all years considered, there are three periods of significant shipments:

(1) 1965-1970, corresponding to the startup of NFS-West Valley;
(2) 1972-1980, corresponding to movement of Dresden SNF to Morris and the transfer of H.B. Robinson fuel to Brunswick; and
(3) 1984-1990, corresponding to a number of movements of SNF including those from Cooper and Monticello to Morris, from NFS-New York to Point Beach and Dresden, from Three Mile Island to Idaho, and from Brunswick and Robinson to Shearon Harris.

The greatest number of cask shipments occurred in 1974; however, the most fuel assemblies were moved in 1986. This resulted from a transition of emphasis from truck to rail shipments from the 1970s to the 1980s. Specifically, the trend in number of assemblies shipped increased from 96 in 1974 to a maximum of 1027 in 1986 and then dropped off to 98 in 1991. Concurrently, the number of loaded casks shipped decreased from 224 in 1974, to 144 in 1986, and then to 16 in 1991. Again, this is evidence of the transition with time from truck to rail shipments.

A summary breakdown of the shipments by mode of carriage is shown in Table 2. Based on the number of loaded cask shipments made, 87% were shipped by truck and only 13% were shipped by rail; however, the loaded cask rail shipments accounted for half of the tonnage of uranium moved. This results from the larger load capacity of rail casks.

One of the major concerns in getting the CRWMS operating as planned is developing the ability to stage large shipping campaigns from specific facilities — where a campaign is viewed as multiple, essentially sequential, shipments between specific facilities using one or more casks of the same design. Although limited in number and scope, there have been such campaigns in the U.S. Examples of 18 such campaigns that have occurred since 1975 are tabulated in Table 3. These 18 campaigns account for 42% of all loaded cask shipments, and for all of the 100 multiple-car shipments by rail that have occurred. The duration of these campaigns varied from 1 to 8 years in length, the average being 3.4 years. It can be seen from this that, with the exception of the one rail campaign from Robinson to Brunswick, all of the campaigns from 1975 through 1983 were with truck casks. Significant rail campaigns occurred from 1984 onward. It is noted that the majority of the other shipments were in 13 earlier campaigns. These campaigns began in 1965; four were by rail and nine were by truck.

One of the issues concerning the high shipping rates of the CRWMS when operating at full capacity is whether facilities designed with limited cask-handling stations would be capable of handling large shipping rates in a short time period. The data for the Point Beach Nuclear Power Station provide evidence that, in at least one case, a high throughput of casks within an area having limited cask-handling capability is possible. During a 2-year period, Point Beach received and unloaded 223 truck cask shipments of PWR fuel.

CONCLUSIONS

The information in this paper covers shipments of SNF in the U.S. through September 1991. The data were developed, in part, to assess the experience present in the U.S. which can be utilized in the preparations for, the startup of, and the operation of the transportation system to support the Civilian Radioactive Waste Management System. The CRWMS, which is scheduled to initiate operations in 1998, will have a first-year SNF acceptance and shipping rate (of 400 MTU) which is greater than the annual shipping rate at any time during the past 28 years in the U.S. In addition, it is projected that once the system is at full operation, it will have an annual SNF acceptance and shipping rate (of 3000 MTU or greater) well in excess of the total SNF shipped during the past 28 years. Thus, a great deal of effort is needed, in the U.S., to be able to transition from the current shipping capability to that needed to support the CRWMS. Extensive work has been undertaken and continues to support the development of this capability.

One issue that is raised concerning the full operations of the CRWMS is whether a facility designed with limited cask-handling capability could sustain a large number of shipments over a short period of time. In at least one case, it has been shown that a large number of SNF shipments to an operating reactor occurred over a 2-year period. During 1983 and 1984, 223 truck cask shipments were made from both the GE-Morris and NFS-New York facilities to the Point Beach Nuclear Power Plant.

Finally, it is clear that shipments with rail casks, in either single-car or multiple-car trains, are feasible and are desirable in terms of the increased quantity of SNF carried per cask load. During the latter part of the 28-year period considered in the U.S., a significant portion of the SNF transportation occurred in rail casks. Over the 28-year period, half of the metric tonnes of uranium were shipped by rail, while this only accounted for 13% of the loaded cask shipments. This further substantiates the basis for the OCRWM's emphasis on the development of a rail cask for the CRWMS.

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Table 1. Summary of Commercial Spent Nuclear Fuel Shipments in the U.S. from 1964 Through 1991 by both Road (Truck) and Rail (Train).

Year	Number of Assemblies[a]	Number of Shipments	Number of Loaded Casks	Weight (MTU)
1964	9.00	5	5	0.918
1965	520.00	197	197	78.690
1966	267.00	183	183	29.482
1967	39.00	3	3	10.647
1968	238.00	104	104	30.432
1969	382.00	98	98	35.336
1970	183.00	51	51	21.608
1971	96.00	14	14	19.773
1972	139.00	139	139	54.263
1973	461.00	128	128	68.158
1974	346.15	224	224	76.950
1975	262.00	170	170	75.861
1976	469.18	165	165	113.995
1977	530.00	149	149	130.666
1978	155.08	61	61	73.857
1979	129.20	36	36	53.123
1980	288.00	66	66	32.992
1981	36.59	25	25	13.171
1982	250.07	56	56	18.084
1983	94.16	84	84	34.693
1984	589.00	203	207	123.694
1985	1,003.16	153	171	213.289
1986	1,027.05	128	144	200.342
1987	891.41	96	119	228.932
1988	383.61	27	41	81.560
1989	222.70	14	23	46.508
1990	271.20	11	20	62.970
1991	98.06	9	16	41.980
Total	9,380.64	2,599	2,699	1,971.974

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

Table 2. Summary of Commercial SNF Shipments, by Mode, in the U.S. from 1964 through 1991.	Road (Truck)	Rail (Train)	Totals
Number of Assemblies	4,706.93	4,673.71	9,380.64
Percentage of Assemblies	50	50	100
Number of Shipments	2,351	248	2,599
Percentage of Shipments	90	10	100
Number of Loaded Casks	2,351	348	2,699
Percentage of Loaded Casks	87	13	100
Tonnage of SNF (MTU)	983.473	988.501	1,971.974
Percentage of Tonnage	50	50	100
Average Tonnage of SNF per Loaded Cask (MTU/Cask Load)	0.42	2.84	N/A

Table 3. Major Shipping Campaigns in the U.S. for the Period 1975 to 1991.

Years	Origin[a]	Destination[a]	Number of Shipments	Number of Loaded Casks	Mode of Transport
1975-1980	San Onofre NPP	GE - Morris	196	196	Truck
1977-1980	Robinson NPS	Brunswick NPS	42	42	Rail
1979	Turkey Point NPP	EMAD - Nevada	13	13	Truck
1981-1988	Oconee NPS	McGuire NPS	138	138	Truck
1980-1986	Ft. St. Vrain	Idaho Nat. Eng. Lab.	121	121	Truck
1983-1984	GE - Morris	Point Beach NPS	109	109	Truck
1983-1984	NFS - New York	Point Beach NPS	114	114	Truck
1983-1985	NFS - New York	Dresden NPS	31	31	Truck
1984-1987	Monticello NPS	GE - Morris	29	59	Rail
1984-1989	Cooper NPS	GE - Morris	30	59	Rail
1985	NFS - New York	Oyster Creek	32	32	Truck
1986	Savannah River Plant	Rockwell International	17	17	Truck
1985-1986	NFS New York	R. E. Ginna NPS	81	81	Truck
1985-1986	Surry NPS	Idaho Nat. Eng. Lab.	23	23	Truck
1986-1990	Three Mile Island[b]	Idaho Nat. Eng. Lab.	22	49	Rail
1987-1989	Rockwell International	Idaho Nat. Eng. Lab.	14	14	Truck
1989-1990	Brunswick NPS	Shearon Harris NPS	11	17	Rail
1990-1991	Robinson NPS	Shearon Harris NPS	8	16	Rail
TOTALS			1031	1131	N/A

[a] NPP = Nuclear Power Plant; NPS = Nuclear Power Station.
[b] Core debris from TMI.

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