

NUREG-0725
Rev. 8

Public Information Circular for Shipments of Irradiated Reactor Fuel

U.S. Nuclear Regulatory Commission

Office of Nuclear Material Safety and Safeguards



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Division of Safeguards and Transportation
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
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PREFACE

This circular has been prepared to provide information on the shipment of irradiated reactor fuel (spent fuel) subject to regulation by the U.S. Nuclear Regulatory Commission (NRC). It provides a brief description of spent fuel shipment safety and safeguards requirements of general interest, a summary of data for 1979-1991 highway and railway shipments, and a listing, by State, of recent highway and

railway shipment routes.

The enclosed route information reflects specific NRC approvals that have been granted in response to requests for shipments of spent fuel. This publication does not constitute authority for carriers or other persons to use the routes described to ship spent fuel, other categories of nuclear waste, or other materials.

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1 INTRODUCTION

The Nuclear Regulatory Commission (NRC) is authorized under the Atomic Energy Act of 1954, as amended, to regulate the commercial nuclear industry for the purpose of protecting the public health and safety and the common defense and security of the United States. Included in this authority is the regulation of certain aspects of the transportation of irradiated reactor fuel (spent fuel). NRC's role in this regard is explained in Section 2 of this report. Section 3 provides descriptive statistics on spent fuel shipments in the commercial nuclear industry for the period 1979-1991. Section 4 contains a listing, by State, of highway and railway segments used in each State for transporting spent fuel in recent years (1987-1991).

2 REGULATORY REQUIREMENTS FOR SPENT FUEL SHIPMENTS

Spent fuel shipments are regulated from both the safety and safeguards standpoints. Safety deals with protection of public health and safety during routine transport as well as in the event of handling or transportation accidents, whereas safeguards deals with the protection of shipments against deliberate, malevolent acts by persons.

2.1 Safety Requirements

Federal regulatory responsibility for spent fuel transportation safety is shared by NRC and the U.S. Department of Transportation (DOT). Basically, NRC's safety role is to ensure that the spent fuel packagings meet strict regulatory design rules, and includes approving packaging designs and Quality Assurance Programs, and conducting inspections. NRC packaging requirements are specified in 10 CFR Part 71. The DOT role in regulating spent fuel shipment safety is broad, and covers all aspects of actual transportation, including route selection, vehicle condition and placarding, driver training, package marking, labeling, other shipping documentation, etc. These requirements are specified in 49 CFR Parts 171-178. Of the NRC and DOT safety requirements for spent fuel shipments, NRC's packaging standards and DOT's routing rules have been of most general interest, and are briefly described below.

2.1.1 Packaging Standards

The basic strategy for regulating spent fuel shipments is to rely on the packaging to protect the public health and safety during transportation. The packaging standards that have been established in the regulations provide that a spent fuel packaging (cask) shall prevent the loss or dispersion of the radioactive contents, provide adequate

shielding and heat dissipation, and prevent nuclear criticality under both normal and accident conditions of transportation. The normal conditions of transportation that must be considered are specified in the regulations in terms of hot and cold environments, pressure differential, vibration, water spray, impact, puncture, and compression tests. Accident conditions that must be considered are specified in terms of impact, puncture, fire conditions, and immersion.

The NRC initially reviews the cask design to verify its resistance to accidents. NRC must issue a certificate before a cask fabricated from the reviewed design can be used to transport spent fuel.

The ability of packaging to provide protection has been demonstrated by the responses of packaging during actual traffic accidents. For example, an accident occurred on December 8, 1971, on a major highway near Oak Ridge, Tennessee. In this accident, the driver of a vehicle carrying a spent fuel cask swerved to avoid colliding with an oncoming vehicle, lost control, and overturned off the roadway. The cask assembly was thrown into a ditch, traveling more than 100 feet before coming to rest. No release of contents or release of radiation occurred. The outer surface of the cask sustained minor damage. The spent fuel cask was placed on another trailer and taken to its destination. The cask was returned to service after repair of the minor damage and inspection.

The accident resistance of casks has also been demonstrated in controlled tests. In one test, sponsored by the U.S. Department of Energy (DOE), a truck bearing a cask was deliberately placed in the path of and struck by a 120-ton locomotive traveling about 80 miles per hour. In another DOE test, a cask aboard a truck moving about 80 miles per hour was deliberately crashed into an immovable concrete structure. Subsequent examination in both these tests confirmed that no radioactive material would have been released from the casks had they been loaded with spent fuel. Thus, both field experience and controlled tests have substantiated the strategy of depending on packaging design for safety in transit.

For further information on spent fuel shipment safety, please consult NUREG/BR-0111, *Transporting Spent Fuel-Protection Provided Against Severe Highway and Railroad Accidents*.

2.1.2 Routing Requirements

DOT requirements in 49 CFR 177.825(b) designate the use of the Interstate System of highways and available city beltways as the primary roadways over which radioactive material shipments under an NRC safeguards-approved route plan are to be carried. There is no routing rule for rail shipments. The general designation as preferred

highways is given to roadways, based on their capacity for reducing transit times. Appropriate State routing agencies, following prescribed criteria, may designate an alternate route to the preferred Interstate System. It is the responsibility of spent fuel carriers to abide by the routing rule when they transport spent fuel by highway.

2.1.3 Spent Fuel Shipment Safety Record

The safety record for spent fuel shipments in the U.S. and in other industrialized nations is enviable. Of the thousands of shipments completed over the last 30 years, none has resulted in an identifiable injury through release of radioactive material.

2.2 Safeguards Requirements

In May 1979, NRC adopted new regulations, in 10 CFR 73.37, for strengthening the protection of shipments of spent fuel against radiological sabotage. These regulations were subsequently revised in May 1980, in response to public comments. The regulations require, among other actions, NRC approval of routes for the transportation of spent fuel, to ensure adequate planning for physical protection against actual or attempted acts of radiological sabotage. Physical protection requirements for NRC licensees who transport or deliver spent fuel to a carrier for transport include: shipment prenotification to NRC; procedures for coping with emergencies; a communications center; contact with the communications center every 2 hours; a written log of shipment events; arrangements with local law enforcement agencies (NRC often coordinates this item); avoidance of intermediate stops; surveillance of the shipment vehicle while stopped; armed escorts in heavily populated areas; escort training; onboard communications; immobilization devices on trucks; driver training; and notification of State governors before shipments. Of these safeguards requirements, route approval and State notification have been of most general interest, and are briefly described below.

2.2.1 Route Approval

NRC licensees planning to ship spent fuel are required to submit proposed routes for such shipments to the NRC for approval, from the safeguards standpoint, before the use of a given route. For highway shipments, the licensee must propose a route that conforms with DOT's routing rules. NRC surveys proposed routes for communication reception, location of safe havens, etc. Routes may be approved for a single shipment, or a specified series of shipments. Once a shipment series is approved, the route may be used for all shipments, without reapproval of the route for each shipment, provided that NRC is notified in advance of each shipment. The route approval is for a stated

number of shipments only; any subsequent shipments not part of an approval must be additionally approved. NRC approval authorizes only spent fuel shipments, and does not include other categories of nuclear waste material. From time to time, NRC may authorize alternate routes or detours, as circumstances dictate at the time of shipment. Also, detours may be taken without prior approval, in response to unforeseen circumstances that arise during a shipment. Criteria for determining when and how such detours may be taken are provided in published regulatory guidance (Physical Protection of Irradiated Spent Fuel, NUREG-0561, Rev. 1).

2.2.2 Notification of State Governors

NRC requires its licensees to notify the governor or the governor's designee before the transport of spent fuel within or through the State [10 CFR 73.37 (f)]. Spent fuel is identified in 10 CFR 73.37(a) as "... net weight of irradiated fuel, exclusive of cladding or other structural or packaging material. . . ." The notification must be in writing and postmarked at least 7 days before transport, if mailed, or delivered at least 4 days before transport, if sent by messenger. The notification must include:

- the name, address, and telephone number of the shipper, carrier, and receiver
- a description of the shipment, as specified by DOT
- a listing of the routes to be used within the State
- a statement that NRC requires that shipment schedule information (provided as an enclosure) be protected from unauthorized disclosure.

The enclosure to the notification provides:

- the estimated date and time of departure from the point of origin of the shipment
- the estimated date and time of entry into the governor's State
- a statement that schedule information must be protected from unauthorized disclosure until at least 10 days after the shipment (or 10 days after the last shipment of a series) has entered or originated within the State.

The licensee must also notify the governor of schedule changes that differ by more than 6 hours from the furnished schedule. Subsequent distribution of the schedule information is at the governor's discretion, but NRC regulations require all persons who receive the schedule information to protect it from unauthorized disclosure.

2.2.3 Spent Fuel Shipment Safeguards Record

Safeguards incidents for spent fuel shipments are those that involve attempts at radiological sabotage of spent fuel, or purposeful acts that threaten or result in significant degradation of the safeguards system used to protect the shipment. Licensees are required, under existing regulations, to immediately notify law enforcement authorities upon the occurrence or discovery of a safeguards incident, for the purpose of initiating an appropriate response. In addition, licensees are required to promptly report safeguards incidents to NRC by telephone, followed by a written report. To date, no safeguards incidents involving the shipment of spent fuel have occurred. However, a number of citations have been issued for minor procedural infractions: one in 1986, two in 1987, two in 1990 and one in 1991.

3 DESCRIPTIVE STATISTICS FOR 1979-1991 HIGHWAY AND RAILWAY SPENT FUEL SHIPMENTS

NRC began approving spent fuel shipments in 1979. This section provides descriptive statistics on the shipments that have occurred through 1991. Only shipments of academic, industrial, and utility irradiated reactor fuel subject to NRC regulation are included; DOE shipments are excluded. Figure 3.1 and Table 3.1 provide a geographical perspective for spent fuel shipments. Figure 3.1 shows the highway and railway routes used for spent fuel transport during 1979-1991. Table 3.1 shows the number of shipments and quantity of spent fuel shipped between specific origination/destination pairs for the period.

Table 3.2 and Figures 3.2-3.9 provide more detailed spent fuel shipment information, including mode of shipment (highway or railway) and shipment trends over time. Table 3.2 provides a summary of spent fuel shipment data for the 1979-1991 period. For each year, the table provides four variables that describe shipping activity by mode. Data for shipment miles are taken primarily from road atlases, and have been rounded to the nearest hundred miles for each year. Data on quantity of spent fuel shipped were provided by shippers, and have been rounded to the nearest hundred kilograms for each year. The kilogram-miles data are derived from shipment quantity and distance data, and have been rounded to the nearest hundred thousand.

Table 3.3 shows the pattern of highway and rail shipments throughout the period 1979-1991. The number of domestic highway shipments (except for the year 1981) rose

steadily to a high in 1984 then declined steadily through 1991. Import shipments have generally declined since 1980, with no imports in 1990 and 1991. The number of export shipments has been low (0-3) through the entire period. Also, in 1990-1991 four international shipments have been made in which US ports were transitted.

Figure 3.2 shows that most (91.8 percent) of approximately 1,200 spent fuel shipments during the 1979-1991 period were completed over highways. Figure 3.3 shows that most of the shipping activity occurred during 1980-1987, with a generally decreasing trend in the number of shipments since 1984.

Figure 3.4 shows that the larger quantity (64.0 percent) of spent fuel was shipped by railway, which reflects the greater capacity of rail spent fuel containers versus that for trucks. In addition, a few rail shipments included multiple spent fuel containers, further increasing the rail shipment payload. The figure indicates that 989,500 kilograms, or about 990 metric tons, of spent fuel were shipped. Figure 3.5 shows that greater quantities of spent fuel were shipped during 1984-1987, than before or after those years. The figure also shows that 1985 was the peak year for quantity of spent fuel shipped, and that, since then most spent fuel has been shipped by rail.

Figure 3.6 shows that the highway mode accounted for most (94.8 percent) of the 774,000 spent fuel shipment miles. Figure 3.7 shows that shipment mileage peaked in 1984, with a general decline in subsequent years.

Figure 3.8 shows the cumulative movement of spent fuel, calculated by summing the product of quantity and distance for all shipments, and is expressed in kilogram-miles. This unit is analogous to "ton-miles," a unit commonly used to measure the flow of commodities. The figure shows that the railway mode accounted for the majority (64.8 percent) of the 396.1 million kilogram-miles associated with spent fuel shipments. Figure 3.9 shows the kilogram-miles distribution by year.

Finally, Figures 3.10 and 3.11 provide an operational perspective for the spent fuel shipments. Figure 3.10 shows the distribution of shipments by individual shipment quantity, and the corresponding total quantity shipped. The individual shipment quantities have been grouped into ranges, with highway shipments most frequently falling within the 0-10, 400-500, and 1300-1400 kilogram ranges, and with most railway shipments within the 6000-7000 kilogram range. The smallest quantity range accounts for the largest number of shipments (478, or 39 percent of highway and railway shipments combined), yet comprises only 2,000 kilograms (0.2 percent) of the combined quantity shipped. Conversely, the 54 railway shipments in the 6000-7000 kilogram shipment range comprise only 4.5 percent of the combined total shipments, but 36 percent of the combined quantity of spent fuel

shipped. (All shipments less than 1400 kilograms were shipped by highway, and all shipments greater than 1400 kilograms were shipped by railway.)

Figure 3.11 shows the distribution of shipments by distance range, and the corresponding total quantity of spent fuel shipped. For highway shipments, the number of shipments generally decreases with shipment distance, although a significant number of shipments exceeded 900 miles. Of the 356 metric tonnes shipped by highway, 173 tonnes (49 percent) traveled less than 200 miles. The number of rail shipments was somewhat uniform over the ranges with 400-700 mile shipments accounting for 62 percent of the total quantity shipped by rail.

4 ROUTE SEGMENT LISTING FOR RECENT HIGHWAY AND RAILWAY SPENT FUEL SHIPMENTS

Table 4.1 is a listing of highway and railway routes that have recently been used to transport spent fuel. The table identifies the spent fuel shipments that occurred in each State. The table also lists the highway or railway route segments within the State that were used for each shipment, and when the shipment was completed. The table shows that highway spent fuel shipments were made in or through 26 States, and that railway shipments were made in or through 17 States during the period discussed.



Figure 3.1 Routes Used for Spent Fuel Shipments: 1979 - 1991

Table 3.2 Summary Data for 1979-1991 Spent Fuel Shipment Information

Year	Number of Shipments		Kilograms Spent Fuel Shipped (Thousand)		Shipment Miles (Thousand)		Kilogram-Miles (Million)	
	Highway	Railway	Highway	Railway	Highway	Railway	Highway	Railway
1979	16	11	0.1	30.2	8.0	2.3	0.1	6.2
1980	130	5	10.0	13.6	115.9	1.0	17.2	2.8
1981	81	2	7.9	6.0	38.5	0.4	1.7	1.2
1982	124	0	7.1	0.0	106.8	0.0	1.8	0.0
1983	117	0	36.6	0.0	83.6	0.0	12.7	0.0
1984	245	3	84.5	23.8	181.3	1.6	51.4	12.7
1985	135	18	74.0	119.4	70.9	8.7	28.3	57.8
1986	105	15	40.4	97.5	47.8	8.7	8.8	56.3
1987	107	15	82.3	101.4	41.8	8.4	14.8	56.5
1988	25	7	12.8	41.8	11.4	4.3	2.4	25.7
1989	16	6	0.1	30.8	16.7	1.7	0.1	8.7
1990	2	8	(0.03)*	70.5	1.5	1.6	(0.02)*	13.8
1991	11	10	0.1	98.4	9.6	1.5	0.1	15.0
TOTAL	1114	100	355.9	633.5	733.8	40.2	139.4	256.7

* Entries in parentheses rounded to nearest hundredth: All others rounded to nearest tenth.

Table 3.3 Number of Domestic and International Spent Fuel Shipments: 1979-1991

Year	Domestic		International		
	Highway	Railway	Export	Import	Transient
1979	2	11	0	14	0
1980	73	5	2	55	0
1981	30	2	3	48	0
1982	80	0	1	43	0
1983	92	0	2	23	0
1984	209	3	2	34	0
1985	114	18	0	21	0
1986	88	15	0	17	0
1987	85	15	3	19	0
1988	10	7	0	15	0
1989	11	6	1	4	0
1990	0	8	2	0	3
1991	7	10	4	0	1

TOTAL NUMBER OF SHIPMENTS - 1214

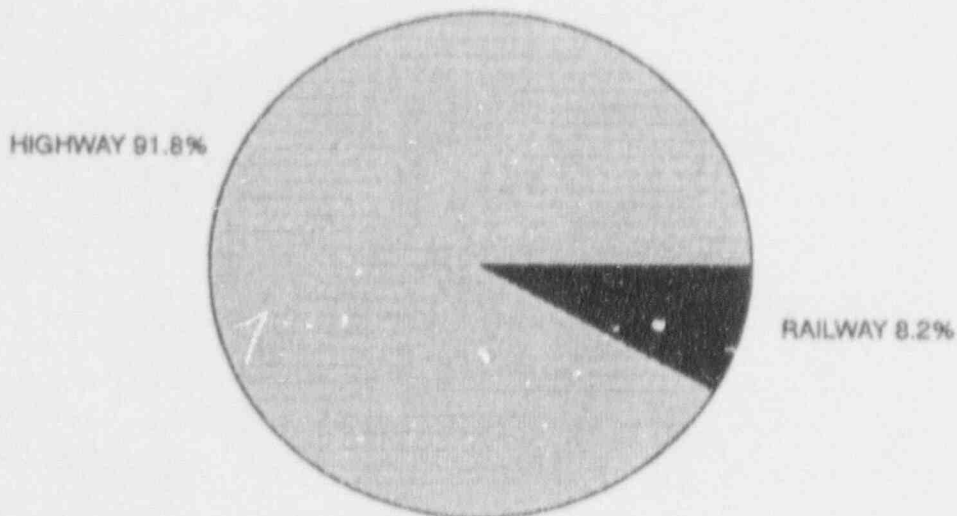


Figure 3.2 Number of Spent Fuel Shipments by Mode: 1979-1991

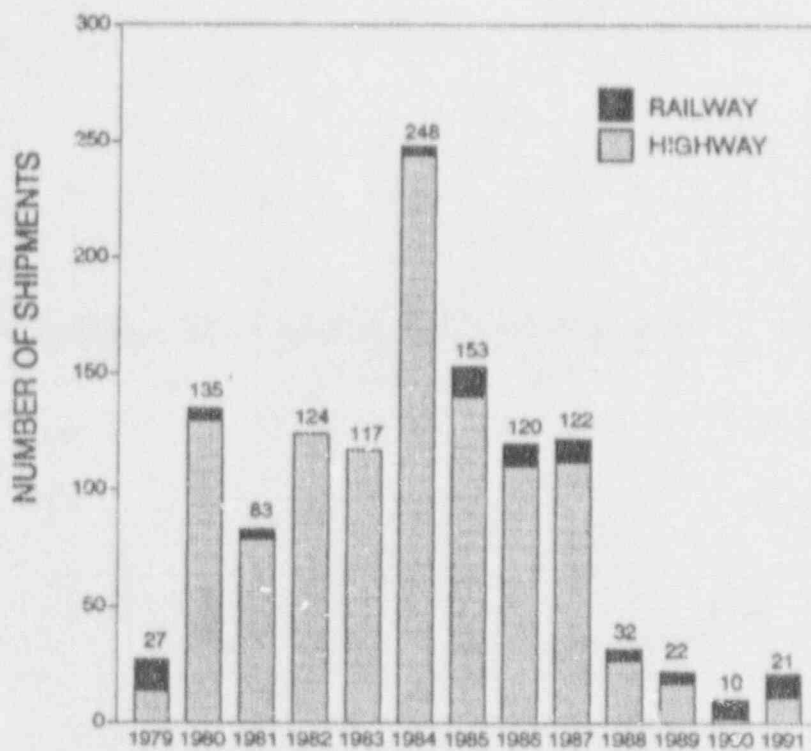


Figure 3.3 Number of Spent Fuel Shipments by Year: 1979-1991

TOTAL KILOGRAMS OF SPENT FUEL SHIPPED - 989.5 THOUSAND

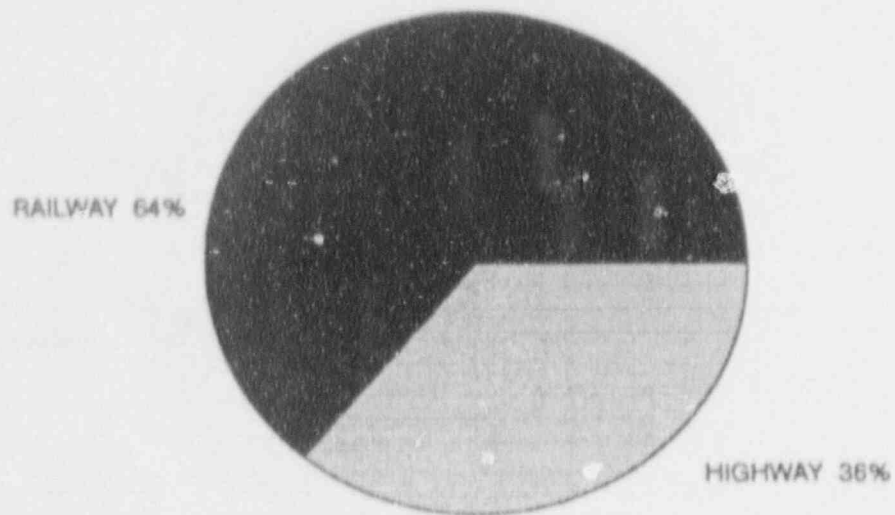


Figure 3.4 Quantity of Spent Fuel Shipped by Mode: 1979-1991

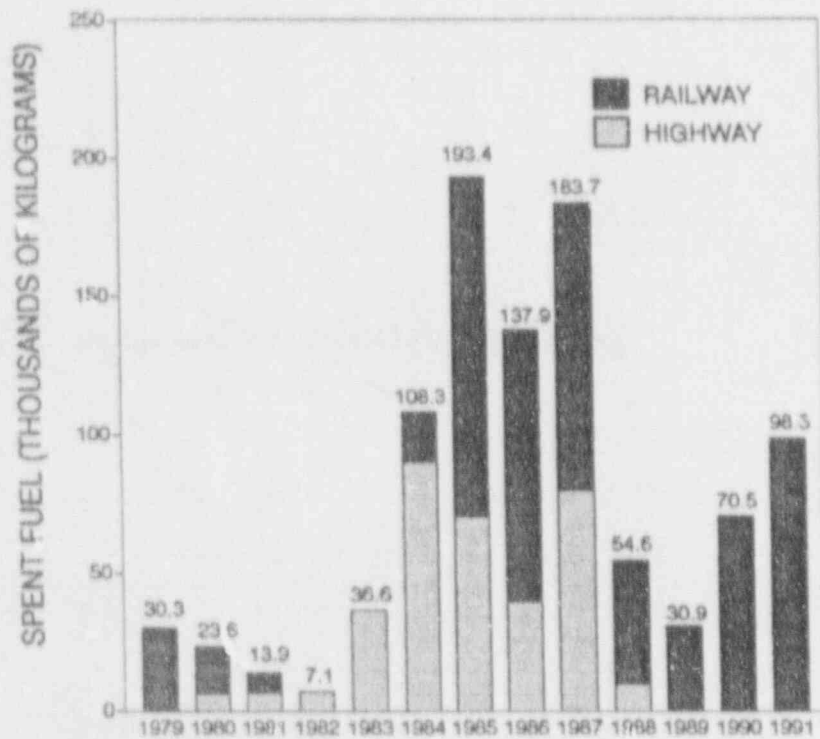


Figure 3.5 Quantity of Spent Fuel Shipped by Year: 1979-1991

TOTAL SHIPMENT MILES - 774,000

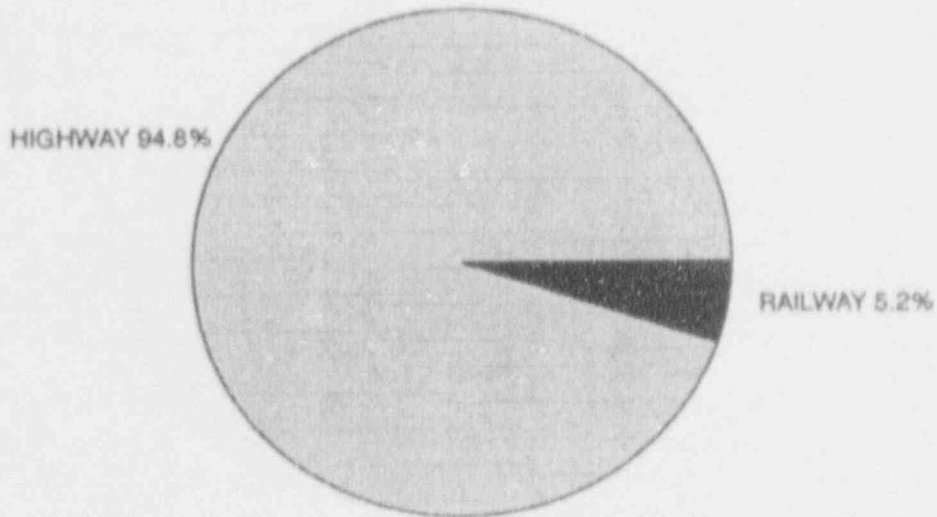


Figure 3.6 Spent Fuel Shipment Miles by Mode: 1979-1991

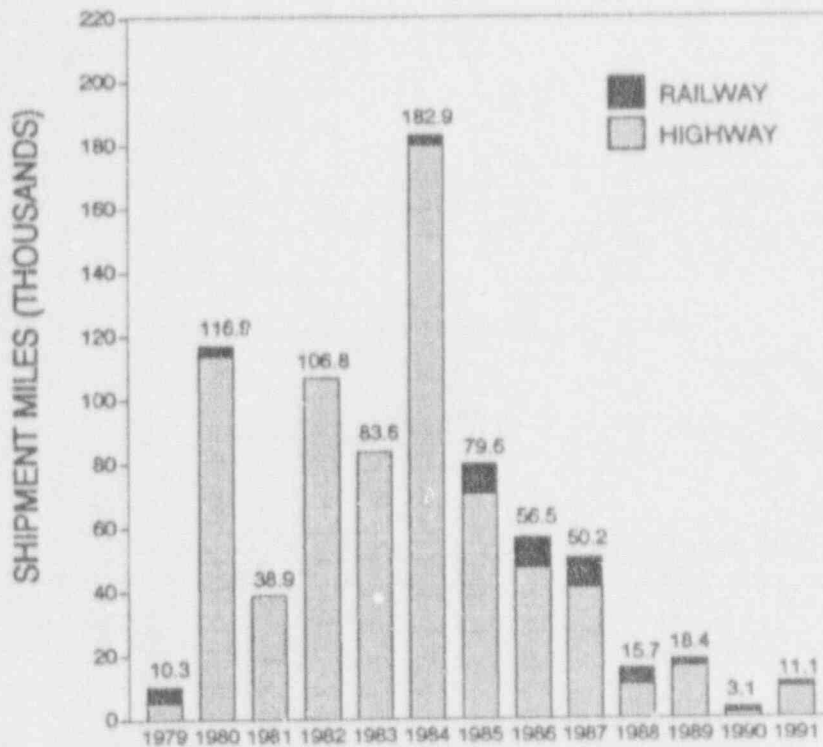


Figure 3.7 Spent Fuel Shipment Miles by Year: 1979-1991

TOTAL KILOGRAM-MILES - 396.1 MILLION

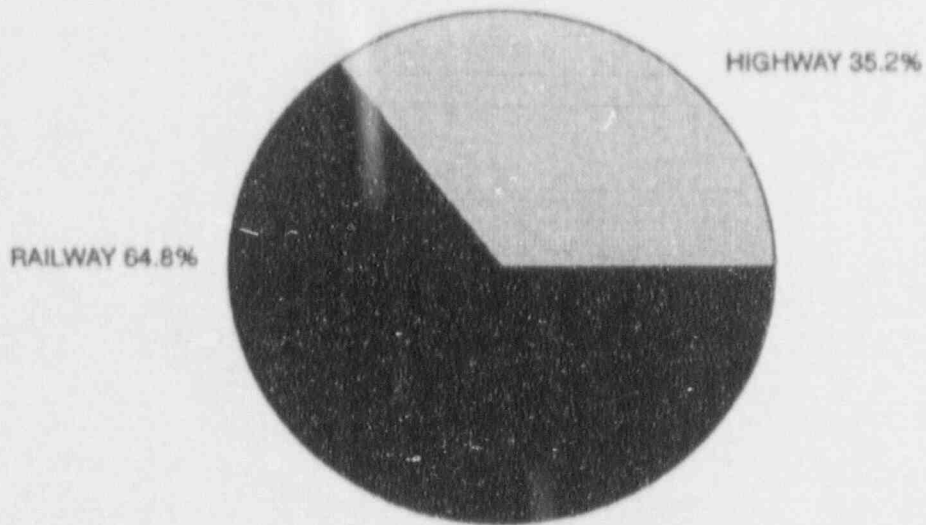


Figure 3.8 Spent Fuel Shipment Kilogram-Miles by Mode: 1979-1991

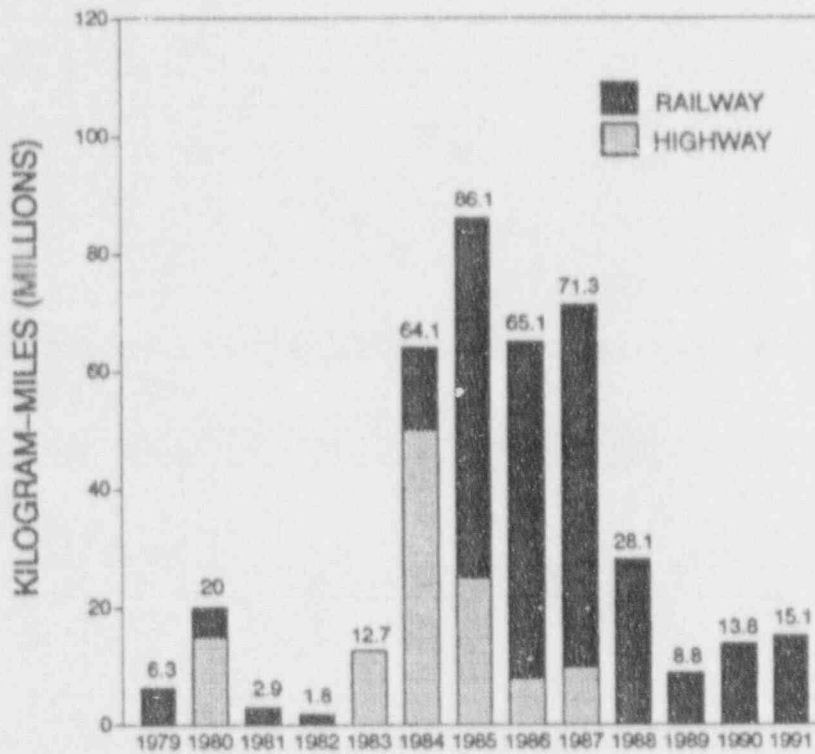


Figure 3.9 Spent Fuel Shipment Kilogram-Miles by Year: 1979-1991

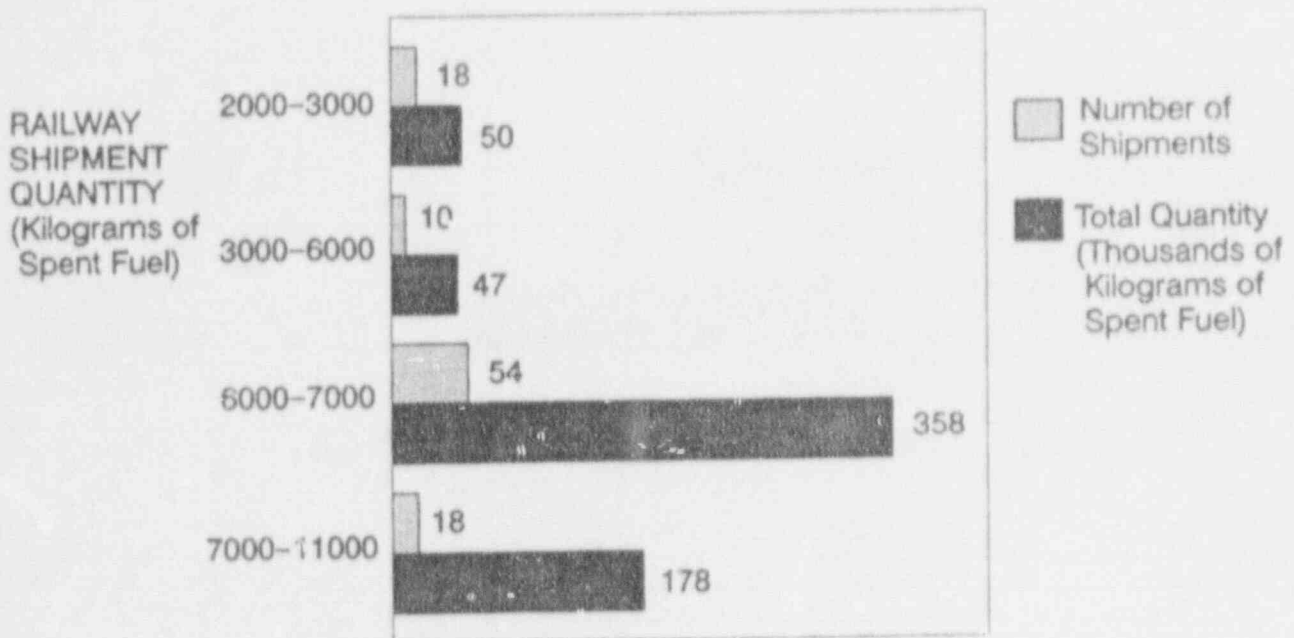
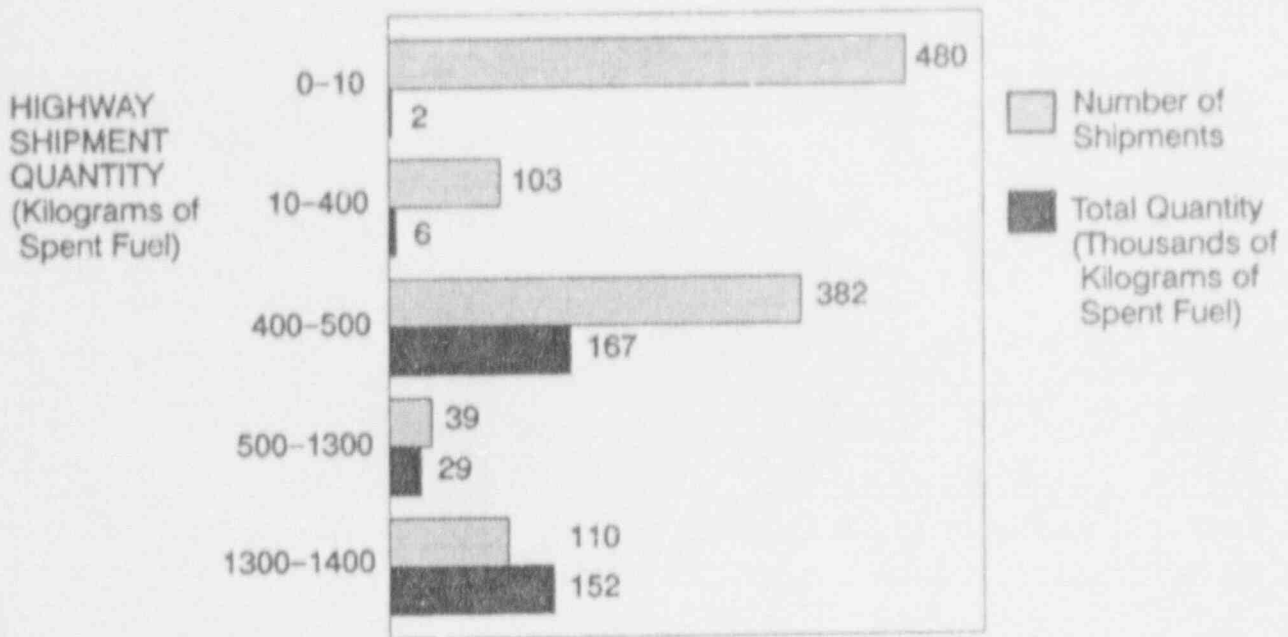


Figure 3.10 Number and Total Quantity of Spent Fuel Shipments by Shipment Quantity Range: 1979-1991

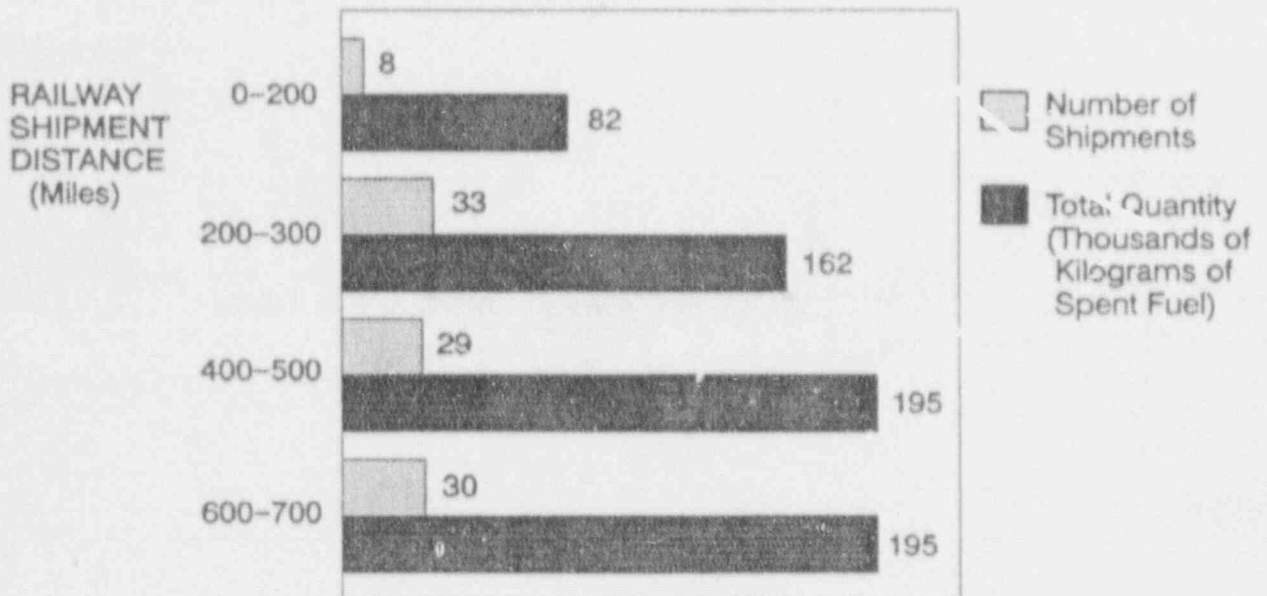
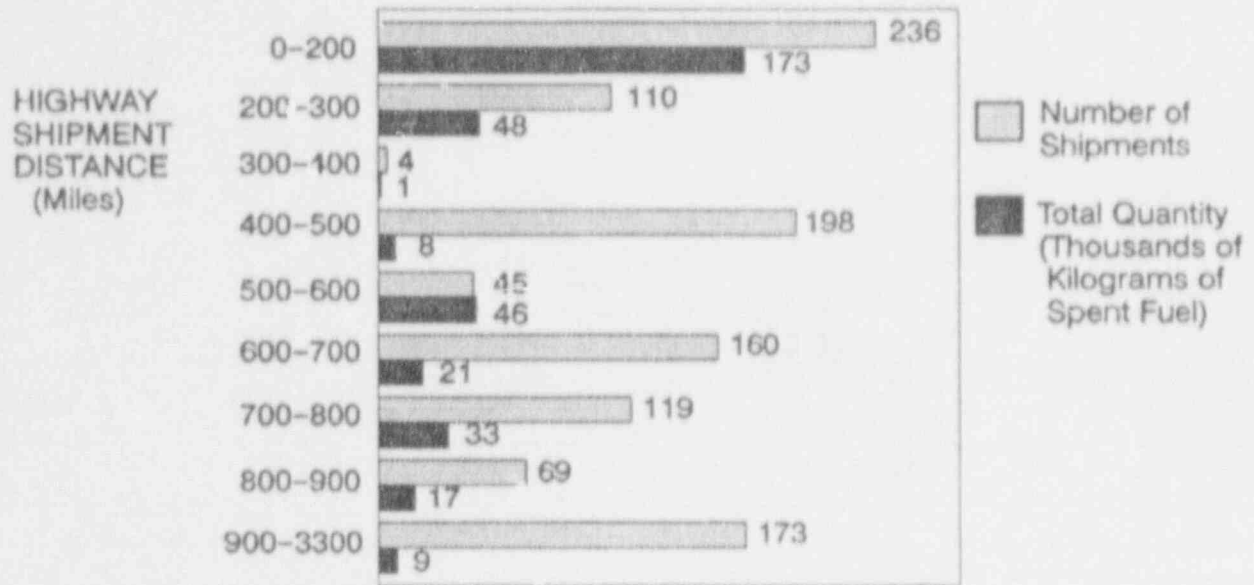


Figure 3.11 Number and Total Quantity of Spent Fuel Shipments by Shipment Distance Range: 1979-1991

Table 4.1 Highway and Railway Spent Fuel Shipment Routes Used in 1987-1991*

State	Shipment	Highway Shipment Route Segment			Shipments Completed
		From:	Route	To:	
AZ	General Atomics to Idaho National Engineering Laboratory (INEL)	NV line	I-15 N	UT line	1987
AR	Arkansas One to Portsmouth, Virginia Marine Terminal	Plant AR-333 US-64 AR-326	AR-333 N US-64 E AR-326 N I-40 E	US-64 AR-326 I-40 TN Line	1991
CA	University of Calif. Berkeley (UCB) to Idaho National Engineering Laboratory	UCB private road I-80 I-880 I-238 I-580 I-205 I-5	private road W I-80 S I-880 S I-238 E I-580 E I-205 E I-5 N I-80 E	I-80 I-880 I-238 I-580 I-205 I-5 I-80 NV Line	1989
	Portsmouth, Virginia, Marine Terminal to GE/Vallecitos	NV line I-8C I-5 I-205 I-580 I-680	I-80 W I-5 S I-205 W I-580 W I-680 E CA-84 E	I-5 I-205 I-580 I-680 CA-84 GE/VAL	1988
	GE/Vallecitos to Portland Marine Terminal	GE/VAL CA-84 I-680 I-580 I-205	CA-84 W I-680 N I-580 E I-205 E I-5 N	I-680 I-580 I-205 I-5 OR line	1988
	GE/Vallecitos to Port of Oakland	GE/VAL CA-84 I-680 I-580 CA-238 I-880 Market St.	CA-84 W I-680 N I-580 W CA-238 W I-880 N Market St. W 3rd St. N.	I-680 I-580 CA-238 I-880 Market St. 3rd St. Middle Harbor Rd.	1987
	Port of Oakland to GE/Vallecitos	Oakland Term. Market St. 5th St. I-880 CA-238 I-580 I-680	Market St. N 5th St. S I-880 S CA-238 E I-580 E I-680 S CA-84 E	5th St. I-880 CA-238 I-580 I-680 CA-84 GE/VAL	1988
		3rd St. Middle Harbor Rd.	Middle Harbor Rd. W 7th St. W	7th St. 5190 7th St. Term.** Berth	

Table 4.1 (Continued)

State	Shipment	Highway Shipment Route Segment			Shipments Completed
		From:	Route	To:	
CA (Cont.)	General Atomics to Idaho National Engineering Laboratory	GA local road I-5 CA-55 CA-91 I-215	local road E I-5 N CA-55 N CA-91 E I-215 N I-15 N	I-5 CA-55 CA-91 I-215 I-15 NV line	1987
	Babcock & Wilcox, Lynchburg, to GE/Vallecitos	NV line I-80 I-5 I-205 I-580 I-680	I-80 W I-5 S I-205 W I-580 W I-680 S CA-84 E	I-5 I-205 I-580 I-680 CA-84 GE/VAL.	1987
CO	Michigan State University (MSU) to Denver Federal Center	WY line I-25	I-25 S 6th Ave. W.	Exit 209 Denver 6th Ave. Denver Fed. Ctr.	1989
	Fort St. Vrain Reactor to Idaho National Engineering Laboratory	Fort St. Vrain WCR 19.5 WCR 34 WCR 19 CO-66	Weld Co. Rd. 19.5 S WCR 34 W WCR 19 CO-66 W I-25 N	WCR 34 WCR 19 CO-66 I-25 WY line	1991
GA	Port of Savannah to Savannah River Project (SRP)	Terminal Port Roads GA-17 GA-21 I-16	Port Roads W GA-17 S GA-21 S I-16 W I-95 N	GA-17 GA-21 I-16 I-95 SC line	1987/88
ID	University of Missouri to Idaho National Engineering Laboratory	UT line I-15 US-26	I-15 N US-26 N US-20 W	US-26 US-20 INEL	1989
	Michigan State University to Idaho National Engineering Laboratory		(same as above route)		1989
	University of Calif. Berkeley to Idaho National Engineering Laboratory		(same as above route)		1989
	General Atomics to Idaho National Engineering Laboratory		(same as above route)		1987
	Fort St. Vrain to Idaho National Engineering Laboratory		(same as above route)		1991

Table 4.1 (Continued)

State	Shipment	Highway Shipment Route Segment			Shipments Completed
		From:	Route	To:	
ID (Cont.)	Idaho National Engineering Laboratory to Portland Marine Terminal	Plant	US-26 E	1-15	1991
		US-26	1-15 S	1-86	
		1-15	1-86 W/S	1-84	
		1-86	1-84 W	OR Line	
IL	Michigan State University to Idaho National Engineering Laboratory	IN line	1-80 W	1-280	1989
		1-80	1-280 W	IA line	
	Michigan State University to Denver Federal Center		(same as above route)		1989
	Callaway to Alexandria Bay	MO line	1-270 E	1-70	1991
		1-270	1-70 E	IN line	
	University of Missouri to Savannah River Project	MO line	1-255 E	1-64	1987
		1-255	1-64 E	1-57	
		1-64	1-57 S	1-24	
		1-57	1-24 S	KY line	
	Dresden Reactor to Portsmouth, Virginia, Marine Terminal	Dresden	Lorenzo Rd. E	1-55	1987
		Lorenzo Rd.	1-55 S	1-74	
		1-55	1-74 E	IN line	
	Dresden Reactor to Babcock & Wilcox, Lynchburg		(same as above route)		1987
	Babcock & Wilcox, Lynchburg, to GE/Vallecitos	IN line	1-74 W	1-274	1987
		1-74	1-274 W	1-74	
		1-274	1-74 W	1-280	
		1-74	1-280 W	IA line	
	Portsmouth, VA, Marine Terminal to GE/Vallecitos		(same as above route)		1988
	Babcock & Wilcox, Lynchburg, to Quad Cities	IN line	1-74 W	1-474	1987
		1-74	1-474 W	1-74	
		1-474	1-74 W	1-80	
		1-74	1-80 N	IL-84	
		IL-80	IL-84 N	Quad Cities	
	Battelle Columbus to GE/Morris	IN line	1-74 W	1-55	1987
		1-74	1-55 N	Lorenzo Rd.	
		1-55	Lorenzo Rd. W	Dresden Rd.	
		Lorenzo Rd.	Dresden Rd. N	GE/Morris	
	Byron Station to Alexandria Bay	Byron	German Church Rd.	IL-64	1991
		German Church Road	IL-64	1-39	
		IL-64	1-39 S	1-80	
		1-39	1-80 E	IN line	

Table 4.1 (Continued)

State	Shipment	Highway Shipment Route Segment			Shipments Completed
		From:	Route	To:	
IN	Michigan State University to Idaho National Engineering Laboratory	MI line	1-69 S	1-80	1989
		1-69	1-80 W	IL line	
	Michigan State University to Denver Federal Center		(same as above route)		1989
	Portsmouth, Virginia, Marine Terminal to GE/Vallecitos	OH line	1-70 W	1-465	1988
		1-70	1-465 N	1-74	
		1-465	1-74 W	IL line	
	Dresden Reactor to Portsmouth, Virginia, Marine Terminal	IL line	1-74 E	1-465	1987
		1-74	1-465 S	1-70	
		1-465	1-70 E	OH line	
	Dresden Reactor to Babcock & Wilcox, Lynchburg		(same as above route)		1987
	Babcock & Wilcox, Lynchburg, to GE/Vallecitos	OH line	1-70 W	1-465	1987
		1-70	1-465 S	1-74	
		1-465	1-74 W	IL line	
Battelle Columbus to GE/Morris		(same as above route)		1987	
Babcock & Wilcox, Lynchburg, to Quad Cities	KY line	1-65 N	1-465	1987	
	1-65	1-465 W	1-74		
	1-465	1-74 W	IL line		
Byron to Alexandria Bay	IL line	1-80E	OH line	1991	
Callaway to Alexandria Bay	IL line	1-70 N/E	1-465	1991	
	1-70	1-465 S/E/N	1-70		
	1-465	1-70E	OH line		
IA	Michigan State University to Idaho National Engineering Laboratory	IL line	1-280 W	1-80	1989
		1-280	1-80 W	1-680	
		1-80	1-680 W	1-29	
		1-680	1-29 S	1-680	
		1-29	1-680 W	NE line	
	Michigan State University to Denver Federal Center		(same as above route)		1989
	Babcock & Wilcox, Lynchburg, to GE/Vallecitos		(same as above route)		1987
	Portsmouth, Virginia, Marine Terminal to GE/Vallecitos		(same as above route)		1988

Table 4.1 (Continued)

State	Shipment	Highway Shipment Route Segment			Shipments Completed
		From:	Route	To:	
KY	University of Michigan to Savannah River Project	OH line I-275	I-275 S I-75 S	I-75 TN line	1987
	University of Missouri to Savannah River Project	IL line	I-24S	TN line	1987
	Babcock & Wilcox, Lynchburg, to Quad Cities	TN line I-75 I-64	I-75 N I-64 W I-65 N	I-64 I-65 IN line	1987
MD	Alexandria Bay to Savannah River Project	PA line	I-81 S	WV line	1988
	CINTICHEM to Savannah River Project		(same as above route)		1987/91
	Summer to Alexander Bay		(reverse of above route)		1990
	Dresden Reactor to Portsmouth, Virginia, Marine Terminal	WV line US-48/US-40 I-70	US-48/US-40 E I-70 E I-81 S	I-70 I-81 WV line	1987
	Dresden Reactor to Babcock & Wilcox Lynchburg		(same as above route)		1987
	Portsmouth, Virginia, Marine Terminal to GE/Vallecitos		(reverse of above route)		1988
	National Institute of Standards and Technology (NIST) to Savannah River Project	NIST local roads I-270 I-70	local roads E I-270 N I-70 W I-81 S	I-270 I-70 US-40/48 WV line	1987
	Babcock & Wilcox, Lynchburg, to GE/Vallecitos	WV line I-81 I-70	I-81 N I-70 W US-40/48 W	I-70 US-40/48 WV line	1987
	Calvert Cliffs to Alexandria Bay	Calvert Cliffs MD-4 I-95 I-495 I-270 I-70	MD 4 N I-95 W I-495 W I-270 N/W I-70 W I-81 N	I-95 I-495 I-270 I-70 I-81 PA line	1990
	MI	Michigan State University to Idaho National Engineering Laboratory	MSU local roads US-27 I-96 Temp. I-69	local roads W US-127 S I-96 W Temp. I-69 S I-69 S	US-127 I-96 Temp. I-69 I-69 IN line
Michigan State University to Denver Federal Center			(same as above route)		1989

Table 4.1 (Continued)

State	Shipment	Highway Shipment Route Segment			Shipments Completed	
		From:	Route	To:		
MI (Cont.)	University of Michigan to Savannah River Project	University of Michigan	Plymouth Rd N	US-23	1987	
		Plymouth Rd	US-23 S	I-94		
		US-23	I-94 E	I-275		
		I-94	I-275 S	I-75		
MO	University of Missouri to Savannah River Project	I-275	I-75 S	OH line	1987	
		University of Missouri	MO-740 W	I-70		
		MO-740	I-70 E	US-40		
		I-70	US-40 S	I-270		
		US-40	I-270 S	I-255 (contin. of I-270)		
	University of Missouri to Idaho National Engineering Laboratory	I-270	I-255 E	IL line	1989	
		University of Missouri	MO-740 W	I-70		
		MO-740	I-70 W	I-435		
		I-70	I-435 N	I-29		
		I-435	I-29 N	IA line		
Callaway to Alexandria Bay	Callaway	MO-CC N	MO-0	1991		
	MO-CC	MO-0 E	MO-D			
	MO-0	MO-D N	I-70			
	MO-D	I-70 E	I-270			
	I-70	I-270 E	IL line			
NE	Michigan State University to Idaho National Engineering Laboratory	IA line	I-680 W	I-80	1989	
		I-680	I-80 W	WY line		
	University of Missouri to Idaho National Engineering Laboratory		(same as above route)		1989	
		Michigan State University to Denver Federal Center		(same as above route)	1989	
	Babecock & Wilcox, Lynchburg, to GE/Vallecitos		(same as above route)		1987	
		Portsmouth, Virginia, Marine Terminal to GE/Vallecitos		(same as above route)	1988	
	NV	University of Calif. Berkeley to Idaho National Engineering Laboratory	CA line	I-80 E	UT line	1989
			Portsmouth, Virginia, Marine Terminal to GE/Vallecitos		(reverse of above route)	1988

Table 4.1 (Continued)

State	Shipment	Highway Shipment Route Segment			Shipments Completed
		From:	Route	To:	
NV (Cont.)	Babcock & Wilcox, Lynchburg, to GE/Vallecitos		(reverse of above route)		1987
	General Atomics to Idaho International Engineering Laboratory	CA line	I-15 N	AZ line	1987
NY	Alexandria Bay to Savannah River Project	Alexandria Bay	I-81 S I-481 S I-81 S	I-481 I-81 PA line	1988
	Summer to Alexandria Bay		(reverse of above route)		1990
	Calvert Cliffs to Alexandria Bay		(reverse of above route)		1990
	Byron to Alexandria Bay	PA line I-90	I-90 E I-81 N	I-81 CD Border	1991
	Callaway to Alexandria Bay		(same as above)		1991
	CINTICHEM to Savannah River Project	CINTICHEM Longmeadow Rd NY-210 NY-17	Longmeadow Rd N NY-210 E NY-17 N I-84 W	NY-210 NY-17 I-84 PA line	1987/91
NC	Oconee Station to Babcock & Wilcox, Lynchburg, Virginia	SC line I-26 I-40	I-26 N I-40 E I-77 N	I-40 I-77 VA line	1988/89
	Oconee Station to McGuire Station	SC line I-85 I-77	I-85 N I-77 N NC-73 E	I-77 NC-73 McGuire	1987/88
	Summer to Alexandria Bay	SC line	I-77 N	VA line	1990
	Alexandria Bay to Savannah River Project	VA line I-77 I-40	I-77 S I-40 W I-26 S	I-40 I-26 SC line	1988
	NIST to Savannah River Project		(same as above route)		1987
	University of Virginia to Savannah River Project		(same as above route)		1987/88
	Babcock & Wilcox, Lynchburg, to Oconee		(same as above route)		1987
	Portsmouth, Virginia, Marine Terminal to Savannah River Project	VA line	I-95 S	SC line	1987/88

Table 4.1 (Continued)

State	Shipment	Highway Shipment Route Segment			Shipments Completed
		From:	Route	To:	
NC (Cont.)	Norfolk Int'l Term. to Savannah River Project		(same as above route)		1987
	Newport News to Savannah River Project		(same as above route)		1989
	University of Michigan to Savannah River Project	TN line I-40	I-40 E I-26 E	I-26 SC line	1987
	CINTICHEM to Savannah River Project		(same as above route)		1987
	University of Missouri to Savannah River Project		(same as above route)		1987
	CINTICHEM to Savannah River Project	VA line	I-77 S	SC line	1991
OH	Portsmouth, Virginia, Marine Terminal to GE/Vallecitos	WV line I-470 I-70 I-270	I-470 W I-70 W I-270 N I-70 W	I-70 I-270 I-70 IN line	1988
	Dresden Reactor to Portsmouth, Virginia, Marine Terminal		(reverse of above route)		1987
	Dresden Reactor to Babcock & Wilcox Lynchburg		(reverse of above route)		1987
	University of Michigan to Savannah River Project	MI line I-75 I-475 I-75	I-75 S I-475 S I-75 S I-275 E	I-475 I-75 I-275 KY line	1987
	Babcock & Wilcox, Lynchburg, to GE/Vallecitos	WV line I-470 I-70 I-270	I-470 W I-70 W I-270 S I-70 W	I-70 I-270 I-70 IN line	1987
	Battelle Columbus to GE/Morris	Site OH-142 US-40 US-29	OH-142 N US-40 N US-29 N I-70 W	US-40 US-29 I-7 IN line	1987
	Byron to Alexandria Bay	IL line	I-80 E	PA line	1991
	Callaway to Alexandria Bay	IN line I-70 I-270 I-70	I-70 E I-270 S/E/N I-70 E I-470 E	I-270 I-70 I-470 WV line	1991

Table 4.1 (Continued)

State	Shipment	Highway Shipment Route Segment			Shipments Completed
		From:	Route	To:	
OR	GE/Vallecitos to Portland Marine Terminal	CA line	I-5 N	I-205 (Exit 288)	1989
		I-5	I-205 N	Exit 24B Airport Way 122nd Ave. Marine Dr. Portland Rd. N. Marine Dr. Term. No. 6	
	Idaho National Engineering Laboratory to Portland Marine Terminal	IO Line	I-84 W/N	Marine Dr.	1991
		I-84 Marine Dr.	Marine Dr. W Exit road	Term. No. 6 Exit Term. No. 6	
PA	Alexandria Bay to Savannah River Project	NY line	I-81 S	MD line	1988
	Calvert Cliffs to Alexandria Bay		(reverse of above route)		1990
	Summer to Alexandria Bay		(reverse of above route)		1990
	Byron to Alexandria Bay	OH line	I-80 E	I-79	1991
		I-80	I-79 N	I-90	
		I-79	I-90 N/E	NY line	
	CINTICHEM to Savannah River Project	NY line	I-84 W	I-380	1987/91
		I-84	I-380 S	I-80	
		I-380	I-80 W	I-81	
		I-80	I-81 S	MD line	
Callaway to Alexandria Bay	WV line	I-70 E	I-79	1991	
	I-70	I-79 N	I-90		
	I-79	I-90 E	NY line		
Dresden Reactor to Portsmouth, Virginia, Marine Terminal	WV line	I-70 E	I-79	1987	
	I-70	I-79 S	WV line		
Dresden Reactor to Babcock & Wilcox Lynchburg		(same as above route)		1987	
Portsmouth, Virginia, Marine Terminal to GE/Vallecitos		(reverse of above route)		1988	
Babcock & Wilcox, Lynchburg to GE/VAL		(reverse of above route)		1987	
SC	Oconee Station to Babcock & Wilcox, Lynchburg	Oconee	SC-130 S	US-123	1988/89
		SC-130	US-123 E	US-76	
		US-123	US-76 S	I-85	
		US-76	I-85 N	I-26	
		I-85	I-26 N	NC line	

Table 4.1 (Continued)

State	Shipment	Highway Shipment Route Segment			Shipments Completed	
		From:	Route	To:		
SC (Cont.)	Portsmouth, Virginia, Marine Terminal to Savannah River Project	NC line	I-95 S	US-301	1987/88	
		I-95	US-301 W	SC-70		
		US-301	SC-70 W	SC-64		
		SC-70	SC-64 W	SRP		
		Norfolk Int'l Terminal to Savannah River Project		(same as above route)		1987
		Newport News to Savannah River Project		(same as above route)		1989
		Oconee Station to McGuire Station	Oconee	SC-130 S	US-123	1987/88
			SC-130	US-123 E	US-76	
			US-123	US-76 S	I-85	
			US-76	I-85 N	NC line	
		Alexandria Bay to Savannah River Project	NC Line	I-26 S	SC-121	1988
			I-26	SC-121 S	SC-19	
			SC-121	SC-19 S	SC-118	
			SC-19	SC-118 W	SC-19	
			SC-118	SC-19 S	SRP	
	University of Michigan to Savannah River Project		(same as above route)		1987	
	CINTICHEM to Savannah River Project		(same as above route)		1987	
	CINTICHEM to Savannah River Project	NC line	I-77 S	I-20	1991	
		I-77	I-20 W	SC-19		
		I-20	SC-19 S	SRP		
	University of Missouri to Savannah River Project	NC line	I-26 S	SC-121	1987	
		I-26	SC-121 S	SC-19		
		SC-121	SC-19 S	SRP		
	University of Virginia to Savannah River Project		(same as above route)		1987/88	
	NIST to Savannah River Project		(same as above route)		1987	
	Port of Savannah to Savannah River Project	GA line	I-95 N	I-26	1987/88	
		I-95	I-26 W	US-301		
		I-26	US-301 W	SC-70		
		US-301	SC-70 W	SC-64		
		SC-70	SC-64 W	SRP		
	Babcock & Wilcox, Lynchburg, to Oconee Station	NC line	I-26 S	I-85	1987	
		I-26	I-85 SW	SC-153		
		I-85	SC-153 N	US-123		
		SC-153	US-123 SW	SC-130		
		US-123	SC-130 N	Oconee Station		

Table 4.1 (Continued)

State	Shipment	Highway Shipment Route Segment			Shipments Completed
		From:	Route	To:	
SC (Cont.)	Virgil C. Summer Nuclear Generating Station to Alexandria Bay	Summer	SC-215 N	SC-213	1990
		SC-215	SC-213 E	SC-34	
		SC-213	SC-34 E/N	I-77	
		SC-34	I-77 N	NC line	
TN	University of Michigan to Savannah River Project	KY line	I-75 S	I-640	1987
		I-75	I-640 E	I-40	
		I-640	I-40 E	NC line	
	University of Missouri to Savannah River Project	KY line	I-24 S	I-65	1987
		I-24	I-65 S	I-40	
		I-65	I-40 E	I-640	
		I-40	I-640 E	I-40	
	CINTICHEM to Savannah River Project	I-640	I-40 E	NC line	1987/91
		VA line	I-81 S	I-40	
		I-81	I-40 S	NC line	
	Babcock & Wilcox, Lynchburg, to Quad Cities	VA line	I-81 S	I-40	1987
		I-81	I-40 W	I-75	
I-40		I-75 N	KY line		
Arkansas One to Portsmouth, Virginia Marine Terminal	AR Line	I-40 E	I-240	1991	
	I-40	I-240 SE	I-40		
	I-240	I-40 E	I-81		
	I-40	I-81 N	VA Line		
UT	University of Missouri to Idaho National Engineering Laboratory	WY line	I-80 W	I-84	1989
		I-80	I-84 N	I-15	
		I-84	I-15 N	ID line	
	General Atomics to Idaho National Engineering Laboratory	AZ line	I-15 N	ID line	1987
	Michigan State University to Idaho National Engineering Laboratory	WY line	I-80 W	I-84	1989
		I-80	I-84 N	I-15	
		I-84	I-15 N	ID line	
	Fort St. Vrain to Idaho National Engineering Laboratory		(same as above)		1991
	University of Calif. Berkeley to Idaho National Engineering Laboratory	NV line	I-80 E	I-215	1989
		I-80	I-215 N	I-15	
		I-215	I-15 N	ID line	
Portsmouth, Virginia, Marine Terminal to GE/Vallecitos	WY line	I-80 W	NV line	1988	
Babcock & Wilcox, Lynchburg, to GE/Vallecitos		(same as above route)		1987	

Table 4.1 (Continued)

State	Shipment	Highway Shipment Route Segment			Shipments Completed
		From:	Route	To:	
VA (Cont.)	Oconee to Babcock & Wilcox, Lynchburg,	NC line	I-77 N	I-81	1988/89
		I-77	I-81 N	I-581	
		I-81	I-581 E	US-460	
		I-581	US-460 E	Mt. Athos Road	
		US-460	Mt. Athos Rd. E	B&W	
	Newport News Terminal to Savannah River Project	Term.	US-66 N	US-17	1989
		US-60	US-17 S	VA-32	
		US-17	VA-32 S	US-58	
		VA-32	US-58 W	I-95	
		US-58	I-95 S	NC line	
	Portsmouth, Virginia Marine Terminal to Savannah River Project	Portsmouth	US-58 W	US-17	1987/88
		US-58	US-17 S	I-264	
		US-17	I-264 W	US-58	
		I-264	US-58 W	I-95	
		US-58	I-95 S	NC line	
	CINTICHEM to Savannah River Project	WV line	I-81 S	TN line	1987
	CINTICHEM to Savannah River Project	WV line	I-81 S/W	I-77	1991
	I-81	I-77 S	NC line		
	University of Virginia to Savannah River Project	UVA	Alderman Rd. N	US-250	1987/88
Alderman Rd.		US-250 W	US-29		
US-250		US-29 S	I-64		
US-29		I-64 W	I-81		
I-64		I-81 S	I-77		
I-81		I-77 S	NC line		
Norfolk Int'l Term. to Savannah River Project	Term.	Port roads E	Term.	1987	
	Port roads	Term. Blvd. E	Blvd.		
	Term. Blvd	I-564 S	I-564		
	I-564	I-64 S	US-58		
	I-64	US-58 W	I-95		
	US-58	I-95 S	NC line		
Alexandria Bay to Savannah River Project	MD line	I-81 S	I-77	1988	
	I-81	I-77 S	NC line		
Portsmouth, Virginia, Marine Terminal to GE/Valleccitos	Ports. Marine Term	US-58 S	VA-17	1988	
	US-58	VA-17 S	I-264		
	VA-17	I-264 S	US-460		
	I-264	US-460 W	VA-32		
	US-460	VA-32 N	US-258		
	VA-32	US-258 N	I-64		
	US-258	I-64 W	I-295		
	I-64	I-295 W	I-64		
	I-295	I-64 W	I-81		
	I-64	I-81 N	WV line		

Table 4.1 (Continued)

State	Shipment	Highway Shipment Route Segment			Shipments Completed
		From:	Route	To:	
VA (Cont.)	Dresden Reactor to Portsmouth, Virginia Marine Terminal		(reverse of above route)		1987
	Arkansas One to Portsmouth Marine Terminal	TN Line I-84 I-81/I-64 I-64 I-295 I-64 US-258 VA-82 US-460 I-264 VA-17	I-84 N I-81/I-64 N/E I-64 E I-295 E I-64 E US-258 S VA-32 E US-460 E I-264 E VA-17 N US-58	I-81/I-64 I-64 I-295 I-64 US-258 VA-82 US-460 I-264 VA-17 US-58 Portsmouth Marine Terminal	1991
	NIST to Savannah River Project	WV line I-81	I-81 S I-77 S	I-77 NC line	1987
	Babcock & Wilcox, Lynchburg, to Oconee Station	Site W Mt. Athos Rd. US-460 I-581 W I-81	Mt. Athos Rd. W US-460 W I-581 W I-81 W I-77 S	US-460 I-581 I-81 I-77 NC line	1987
	Babcock & Wilcox, Lynchburg, to GE/Vallecitos	Site VA-726	VA-726 S US-460 W	US-460 VA-220 Alt.	1987
		US-460 VA-220 Alt. US-11	VA-220 Alt. N US-11 N I-81 N	US-11 I-81 WV line	
	Dresden Reactor to Babcock & Wilcox, Lynchburg	WV line I-81	I-81 S US-11 S	US-11 VA-220 Alt.	1987
		US-11 VA-220 Alt.	VA-220 Alt. S US-460 E	US-460 Mt. Athos Road	
		US-460	Mt. Athos Rd. E	B&W	
	Babcock & Wilcox, Lynchburg, to Quad Cities	Site Mt. Athos Rd. US-460 I-581	Mt. Athos Rd. W US-460 W I-581 W I-81 S	US-460 I-581 I-81 TN line	1987
	Summer to Alexandria Bay	NC line I-77	I-77 N I-81	I-81 WV line	1990
WV	Alexandria Bay to Savannah River Project	MD line	I-81 S	VA line	1988
	CINTICHEM to Savannah River Project	MD line	I-81 S	VA line	1987/91

Table 4.1 (Continued)

State	Shipment	Highway Shipment Route Segment			Shipments Completed	
		From:	Route	To:		
WV (Cont.)	Dresden Reactor to Portsmouth, Virginia, Marine Terminal	OH line	I-470 E	I-70	1987	
		I-470	I-70 E	PA Line		
		PA line	I-79 S	US-48		
		I-79	US-48 E	MD line		
		MD line	I-81 S	VA line		
		Dresden Reactor to Babcock & Wilcox, Lynchburg		(same as above route)		1987
		Portsmouth, Virginia, Marine Terminal to GE/Vallecitos		(reverse of above route)		1988
		Callaway to Alexandria Bay	OH line I-470	I-470 E I-70 E	I-70 PA line	1991
		Babcock & Wilcox, Lynchburg, to GE/Vallecitos		(reverse of above route)		1987
		NIST to Savannah River Project	MD line	I-81 S	VA line	1987
	Summer to Alexandria Bay		(reverse of above)		1990	
WY	University of Missouri to Idaho National Engineering Laboratory	NE line	I-80 W	UT line	1989	
	Michigan State University to Idaho National Engineering Laboratory		(same as above route)		1989	
	Babcock & Wilcox, Lynchburg, to GE/Vallecitos		(same as above route)		1987	
	Fort St. Vrain to Idaho National Engineering Laboratory	CO line I-25	I-25 N I-80 W	I-80 UT line	1991	
	Portsmouth, Virginia, Marine Terminal to GE/Vallecitos		(same as above route)		1988	
	Michigan State University to Denver Federal Center	NE line I-80	I-80 W I-25 S	I-25 CO line	1989	

Table 4.1 (Continued)

State	Shipment	Railway Shipment Route Segment			Shipments Completed
		From:	Route	To:	
IL	Cooper Reactor to GE/Morris	IA line	Burlington Northern	EOLA	1987/88/89
		EOLA	Elgin, Joliet, Eastern	GE/Morris	
	Monticello to GE/Morris		(Same as above route)		1987
IA	Cooper Reactor to GE/Morris	NE line	Burlington Northern	IL line	1987/88/89
MN	Monticello to GE/Morris	Monticello	Burlington Northern	WI line	1987
NE	Cooper Reactor to GE/Morris	Cooper	Burlington Northern	IA line	1987/88/89
NC	Brunswick to Shearon Harris	Brunswick	Military Ocean Term. track	Leland	1989
		Leland Hamlet	CSX CSX	Hamlet Bonsal (Shearon Harris)	
	Robinson to Shearon Harris	SC line Hamlet	CSX CSX	Hamlet Bonsal (Shearon Harris)	1990/91
	Robinson to Brunswick	SC line	Seaboard Coast Line (SCL)	Brunswick	1979/80/81
SC	Robinson to Shearon Harris	Robinson	CSX	NC line	1990/91
	Robinson to Brunswick	Robinson	SCL	NC line	1979/80/81
WI	Monticello to GE/Morris	MN line	Burlington Northern	IL line	1987

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11. ABSTRACT (200 words or less)

This circular has been prepared to provide information on the shipment of irradiated reactor fuel (spent fuel) subject to regulation by the Nuclear Regulatory Commission (NRC), and to meet the requirements of Public Law 96-295. The report provides a brief description of NRC authority for certain aspects of transporting spent fuel. It provides descriptive statistics on spent fuel shipments regulated by the NRC from 1979 to 1991. It also lists detailed highway and railway segments used within each state from October 1, 1987 through December 31, 1991.

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