HOW MANY DID YOU SAY? HISTORICAL AND PROJECTED SPENT NUCLEAR FUEL SHIPMENTS IN THE UNITED STATES, 1964 – 2048

Robert J. Halstead (bearhalstead@aol.com)
State of Nevada Agency for Nuclear Projects
Carson City, NV 80906

Fred Dilger (fcd@co.clark.nv.us)
Clark County Nuclear Waste Division
Las Vegas, NV 89101

ABSTRACT

No comprehensive, up-to-date, official database exists for spent nuclear fuel shipments in the United States. The authors review the available data sources, and conclude that the absence of such a database can only be rectified by a major research effort, similar to that carried out by Oak Ridge National Laboratory (ORNL) in the early 1990s. Based on a variety of published references, and unpublished data from the U.S. Nuclear Regulatory Commission (NRC), the authors estimate cumulative U.S. shipments of commercial spent fuel for the period 1964-2001. The cumulative estimates include quantity shipped, number of cask-shipments, and shipment-miles, by truck and by rail. The authors review previous estimates of future spent fuel shipments, including contractor reports prepared for the U.S. Department of Energy (DOE), NRC, and the State of Nevada. The DOE Final Environmental Impact Statement (FEIS) for Yucca Mountain includes projections of spent nuclear fuel and high-level radioactive waste shipments for two inventory disposal scenarios (24 years and 38 years) and two national transportation modal scenarios ("mostly legal-weight truck" and "mostly rail"). Commercial spent fuel would compromise about 90 percent of the wastes shipped to the repository. The authors estimate potential shipments to Yucca Mountain over 38 years (2010-2048) for the DOE "mostly legal-weight truck" and "mostly rail" scenarios, and for an alternative modal mix scenario based on current shipping capabilities of the 72 commercial reactor sites. The cumulative estimates of future spent fuel shipments include quantity shipped, number of cask-shipments, and shipment-miles, by legal-weight truck, heavy-haul truck, rail and barge.

INTRODUCTION

Recent public discussions of spent nuclear fuel transportation in the United States have frequently included contentious debates over the number, tonnage, and mileage of past and projected shipments. It is difficult to resolve disputes about high-level nuclear waste transportation relying on past shipments data, because there is no regularly updated, comprehensive, official database for historical spent nuclear fuel shipments in the United States. It is difficult to resolve disputes about projected shipments, mainly because of uncertainties about the modal mix of potential shipments to the proposed Yucca Mountain repository site. There are also major technical and legal uncertainties about the amount of high-level nuclear waste that can be emplaced in the proposed geologic

repository. To further complicate matters, there is no generally agreed upon definition of what constitutes a spent nuclear fuel shipment, especially regarding multiple cask-shipments by rail, or cask-shipments that involve more than one transportation mode.

The authors of this paper initially intended to produce updated, year-by-year estimates of spent fuel shipments from civilian nuclear power reactors, civilian research reactors, naval reactors, and other defense-related programs. It turned out that a thorough update was not possible within the scope of this paper. One of the conclusions of this paper is that a major study effort will be required to complete a comprehensive update. The authors' more modest goal here is to review the major published data sources, and based primarily upon these sources, to calculate a best estimate of the cumulative U.S. experience with commercial spent nuclear fuel shipments, 1964-2001. Unpublished shipment data from the U.S. Nuclear Regulatory Commission (NRC) is included as an attachment

This paper also addresses projected shipments of spent fuel and high-level nuclear waste to the proposed Yucca Mountain repository. In February 2002, the Secretary of Energy formally recommended development of a geologic repository at Yucca Mountain in Nevada. The U.S. Department of Energy (DOE) prepared a Final Environmental Impact Statement (FEIS) to accompany the site recommendation. This paper evaluates the range of shipments that could occur under the two disposal inventory scenarios contained in the FEIS, and three transportation modal scenarios. Commercial spent fuel would compromise about 90 percent of the total projected repository inventory.

U.S. COMMERCIAL SPENT FUEL SHIPMENTS, 1964-2001

No comprehensive, up-to-date, official database exists for spent nuclear fuel shipments in the United States. The most-inclusive and best-documented source is a series of reports prepared at Oak Ridge National Laboratory (ORNL) between 1989 and 1992. (1,2) The 1991 ORNL update is especially useful, but it only covers the period 1964-1989. It reports disaggregate data on commercial, DOE, and research spent fuel shipments, excluding shipments from foreign points of origin. There are annual summaries of shipments by mode, number of assemblies shipped, number of shipments, number of loaded casks, and metric tons uranium (MTU) of spent fuel shipped. The ORNL study team utilized all of the major DOE, DOT, and NRC databases, supplemented by personal interviews with shippers, carriers, and equipment suppliers. The report clearly notes instances where data was estimated. All in all, the ORNL reports offer a methodological model for future studies. Unfortunately, the series has not been updated.

For the period 1979 - 1997, the most useful source is the Public Information Circular (NUREG-0725), published by the NRC. (3) It reports information on all domestic and foreign shipments regulated by NRC. Annual summaries are provided, by mode, for number of shipments, quantity of spent fuel (thousands of kilograms), shipment-miles, and kilogram-miles. NUREG-0725 also provides cumulative data on shipments and quantities shipped between specific origins and destinations, and shipping routes used. The NRC primarily utilizes data submitted by shippers. Shipment-miles are estimated based on road atlas mileage. The usefulness of the Circular is limited, however, by the

aggregation of utility, industrial, and research shipments; the absence of data on DOE shipments of commercial reactor spent fuel; and discrepancies in data reported for specific origin-destination pairs. The Circular has not been updated since October 1998.

For the period 1998 to date, the only official data available from NRC is an unpublished summary prepared in response to a congressional request. In April 2002, U.S. Senators Harry Reid and John Ensign of Nevada wrote to NRC Chairman Richard Meserve requesting complete information on all previous U.S. shipments of spent nuclear fuel and high-level radioactive waste by truck, rail, or barge. (4) In May 2002, NRC provided the Nevada Senators an updated cumulative summary of NRC-regulated shipments, 1979-2001. (5) The data was organized by origin-destination pairs, and indicated shipment mode, total number of shipments, and amount shipped (kilograms). NRC noted "no licensed spent fuel shipments by barge were reported for the time period covered by NUREG-0725." Unfortunately, this summary includes data discrepancies from earlier reports. The NRC cumulative summary for 1979-2001 is presented in Attachment A.

Contractor reports prepared for DOE and the State of Nevada provide additional information on historical spent fuel shipments. Reports by Nuclear Assurance Corporation and the University of Nevada, Reno supplement information on pre-1990 movements and document the difficulties resulting from inconsistent DOE, NRC, and DOT databases. (6,7) Reports by E.J. Bentz and Associates, and by the Western Interstate Energy Board, provide details about specific rail shipping campaigns. (8,9) A report prepared by Science Applications International Corporation (SAIC) supplements the ORNL data on cumulative national shipment-miles by mode. (10) A recent publication by Nuclear Assurance Corporation, which purportedly addresses the same topic as this paper, was not made available to the authors. (11)

The absence of a comprehensive, up-to-date, official database can only be rectified by a research effort similar to that previously carried out by ORNL. Such an effort should include the aforementioned published sources, DOE databases such as the Shipment Mobility/Accountability Collection (SMAC) and Central Internet Database (CID), the DOT Radioactive Material Routing Report (RAMRT), and interviews with shippers, carriers, and equipment suppliers. Until such an effort is carried out, interested parties must rely upon estimates.

Table I presents the authors' best estimate of cumulative shipments of U.S. commercial spent nuclear fuel, based on the references cited.

Table I. Estimated Shipments of U.S. Commercial Spent Fuel, 1964-2001

Mode	Quantity Shipped (MTHM)	Shipments	Cask-Shipments (Loaded Casks)	Shipment-Miles (Miles)
Truck	876	2,396	2,396	1,792,000
Rail	1,581	326	479	148,000
Total	2,457	2,722	2,875	1,940,000

Between 1964 and 2001, an estimated 2,457 MTHM of commercial spent fuel was shipped, in 2,722 shipments, comprised of 2,875 cask-shipments, resulting in 1.94 million shipment-miles. About 88 percent of the shipments were made by truck, and these truck shipments accounted for about 89 percent of the estimated shipment-miles. The relatively smaller number of shipments by rail, 12 percent, carried about 64 percent of total commercial spent fuel transported, because of the larger capacity of rail casks, and because the majority of rail shipments were comprised of two or more casks. Rail movements represented only about 11 percent of estimated shipment-miles, and the average rail shipment was less than 500 miles in length.

The totals reported in Table I for quantity shipped, and number of shipments, differ slightly from other estimates based on the same sources (for example, Pope 2000). (12) The authors have adjusted the NRC data for 1979-2001 to include DOE shipments of commercial spent fuel, and DOE shipments of reactor core debris from Three Mile Island. The authors further adjusted this data to eliminate shipments to DOE facilities from university research reactors and foreign points of origin. The authors estimated rail cask-shipments for 1990-2001, and shipment-miles for 1964-1970 and 1998-2001, using methods similar to ORNL and NRC.

PROJECTED HIGH-LEVEL NUCLEAR WASTE SHIPMENTS, 2010-2048

Sandia National Laboratories (SNL) produced one of the first systematic projections of future shipments to a geologic repository in 1986. (13) SNL identified the important study inputs that have been used in most subsequent projection efforts: location specific shipment inventories, radiological characteristics of spent fuel and other wastes requiring disposal, truck/rail modal mix, shipping cask capacities, route-specific distances from originations to destinations, and multiple rail cask-shipment assumptions for dedicated trains. (14) The SNL study was the basis for the projection of potential shipments published in the DOE 1986 Environmental Assessment (EA) for Yucca Mountain: up to 94,200 legal-weight trucks, or up to 14,600 rail casks. (15)

A study by NANP staff and consultants in 1988 projected up to 76,000 truck shipments, or 34,600 truck and rail shipments combined, for a repository limited to 70,000 MTHM. (16) A more-detailed study prepared for NANP by Planning Information Corporation (PIC) in 1996 projected a range of 20,200 to 104,500 truck and rail shipments combined, for a geologic repository only, and for a repository co-located with an interim storage facility. (17) A study prepared for the NRC in 1999 projected 75,000 legal-weight truck shipments of commercial spent fuel to Yucca Mountain, if all currently operating reactors renew their licenses for an additional 20 years of operation. (18)

The DOE Final Environmental Impact Statement (FEIS) for Yucca Mountain offers the most recent projections of future shipments of spent nuclear fuel and high-level radioactive waste. (19) The FEIS considers two approaches to repository development, a Proposed Action and an expanded repository (referred to as Modules 1 and 2). Under the Proposed Action, DOE would transport 70,000 metric tons of heavy metal (MTHM) of spent nuclear fuel and high-level radioactive waste to Yucca Mountain over 24 years (2010-2034). The Proposed Action complies with Section 114(d) of the Nuclear Waste

Policy Act, which limits first repository emplacements to 70,000 MTHM until a second repository is in operation.

The FEIS addresses maximum transportation impacts, if there is no second repository, in an inventory scenario called Module 2. Under Module 2, the FEIS evaluates the impacts of transporting the entire projected national inventory of high-level nuclear wastes, about 119,000 MTHM, in addition to other wastes requiring geologic disposal, to one repository in Nevada, over 38 years (2010-2048). (19)

Commercial spent fuel would compromise 63,000 MTHM (90 percent) of the first 70,000 MTHM shipped to the repository, and 105,000 MTHM (88 percent) of the total projected repository inventory. Commercial spent fuel would compromise about 73 percent of repository cask-shipments. (19)

DOE developed two FEIS national transportation scenarios - "mostly legal-weight truck" and "mostly rail" - in order to estimate the number of shipments required. DOE adopted this approach because "it cannot accurately predict the actual mix of rail and truck transportation that would occur from the 77 sites to the repository. Therefore, the selected scenarios enable the analysis to bound (or bracket) the ranges of legal-weight truck and rail shipments that could occur." [p. J-10] DOE states that the "estimated number of shipments for the mostly legal-weight truck and mostly rail scenarios represents the two extremes in the possible mix of transportation modes." [p. 6-35] Table II summarizes the DOE estimated number of shipments for the various disposal inventory and transportation scenario combinations.

Table II. Projected Shipments to Yucca Mountain for DOE Scenario Combinations

Inventory Scenario	(Mostly Truck) Truck Shipments	(Mostly Truck) Rail Shipments	(Mostly Rail) Truck Shipments	(Mostly Rail) Rail Shipments
Proposed Action (2010-2034)	52,786	300	1,079	9,646
Module 1 (2010-2048)	105,685	300	3,122	18,243
Module 2 (2010-2048)	108,544	355	3,122	18,935

Ref. 19

State of Nevada Agency for Nuclear Projects (NANP) staff and contractors have evaluated the two DOE national transportation scenarios, and a third scenario under which each site ships by its current modal capability. NANP assumed that all projected spent nuclear fuel and other radioactive wastes requiring geologic disposal would be shipped to Yucca Mountain, per inventory scenario Module 2. (19,20,21) The DOE "mostly legal-weight truck" scenario would result in the largest number of shipments, about 108,900 shipments over 38 years, or about 2,865 per year. The Nevada current capabilities scenario would result in 47,300 shipments over 38 years, or about 1,245 per

year. The DOE "mostly rail" scenario, over 38 years, could result in more than 45,000 shipments (about 1,185 per year) or as few as 13,500 (about 355 per year), depending upon the rail service used (general freight or dedicated trains) and the availability of direct rail access to Yucca Mountain. Table III presents the projected shipments, loaded cask-shipments, and shipment-miles calculated by NANP.

Table III. Projected Repository Shipments and Shipment-Miles, 2010-2048.

Repository Transportation Scenario & Modes	Shipments	Cask-Shipments	Shipment-Miles
Mostly Legal-Weight Truck			
Legal-Weight Truck Direct (77 sites)	108,544	108,544	227,735,000
General Freight Rail to NV (1 site)	355	355	181,000
Heavy-Haul Truck in NV	355	355	118,000
Mostly Rail (Maximum)			
Legal-Weight Truck Direct (6 sites)	3,122	3,122	8,657,000
Barge to Rail (17 sites)	3,004	3,004	186,000
Heavy-Haul Truck to Rail (7 sites)	1,061	1,061	19,000
General Freight Rail to NV (77 sites)	18,935	18,935	37,484,000
Heavy-Haul Truck in NV	18,935	18,935	6,267,000
Current Modal Capabilities			
Legal-Weight Truck Direct (25 sites)	27,435	27,435	65,784,000
General Freight Rail to NV (52 sites)	14,886	14,886	28,353,000
Dedicated Rail in NV	4,962	14,886	1,603,000
Mostly Rail (Minimum)			
Legal-Weight Truck (6 sites)	3,122	3,122	8,657,000
Barge to Rail (17 sites)	3,004	3,004	186,000
Heavy-Haul Truck to Rail (7 sites)	1,061	1,061	19,000
Dedicated Rail Direct (77 sites)	6,312	18,935	12,495,000

Estimates of projected shipments to Yucca Mountain must consider a range of modal scenarios and shipment numbers. The DOE "mostly legal-weight truck scenario" is the only national transportation scenario that is currently feasible. All 72 power plant sites and all 5 DOE sites can ship by legal-weight truck. At present, there is no railroad access to Yucca Mountain. Construction of a new rail spur, 99 to 344 miles in length, could take 10 years and cost more than $1 billion. The alternative to rail spur construction, delivery of thousands of large rail casks by 220-foot-long, heavy-haul trucks, over distances of 112 to 330 miles on public highways, is probably not feasible. (20,21)

Maximum utilization of rail for cross-country transportation, as described in the FEIS, appears unlikely. Even if DOE is able to develop rail access to Yucca Mountain, the objective of shipping 90 percent of the commercial SNF by rail is unrealistic. DOE acknowledges that 25 of the 72 power plant sites cannot ship directly by rail. Nevada studies show that number could be up to 32 sites. The "mostly rail" scenario assumes that DOE can ship thousands of casks by barge into the Ports of Boston, New Haven, Newark, Jersey City, Wilmington (DE), Baltimore, Norfolk, Miami, Milwaukee, Muskegon,

Omaha, Vicksburg, and Port Hueneme (CA). Alternately, DOE would have to move thousands of casks from reactors to rail connections using large heavy-haul trucks, which will require special state permits and route approvals. In the end, "mostly rail" could mean moving no more than 60-75 percent of the commercial spent fuel by rail, and moving the remaining 25-40 percent by legal-weight truck. (20,21)

CONCLUSIONS

No comprehensive, up-to-date, official database exists for spent nuclear fuel shipments in the United States. The absence of such a database can only be rectified by a major research effort, similar to that carried out by ORNL under DOE sponsorship in the early 1990s. Cumulative shipments of U.S. commercial spent nuclear fuel can be estimated based on the published references cited and the unpublished NRC data presented in the Attachment. Between 1964 and 2001, an estimated 2,457 MTHM of commercial spent fuel was shipped, in 2,722 shipments, comprised of 2,875 cask-shipments, resulting in 1.94 million shipment-miles.

According to the DOE FEIS, about 70,000 MTHM of spent fuel and high-level nuclear waste could be shipped to Yucca Mountain over 24 years, and about 119,000 MTHM could be shipped over 38 years (2010-2048). The DOE "mostly legal-weight truck" scenario would result in the largest number of shipments, about 108,900 shipments over 38 years, or about 2,865 per year. The DOE "mostly rail" scenario, over 38 years, could result in more than 45,000 shipments (about 1,185 per year) or as few as 13,500 (about 355 per year). Commercial spent fuel would compromise about 88 percent of the wastes shipped to the repository, and about 73 percent of repository cask-shipments.

REFERENCES

1. ORNL, "Historical Overview of Domestic Spent Fuel Shipments - Update," ORO/TOP-5405.0, Prepared by SAIC, Oak Ridge, TN, for DOE (July 1991).

2. R.B. POPE, ET AL, "Historical Overview of Domestic Spent Nuclear Fuel Shipments in the United States," PATRAM'92, Yokohama, Japan (Sept.13-18, 1992).

3. NRC, Office of Nuclear Materials Safety and Safeguards, "Public Information Circular for Shipments of Irradiated Reactor Fuel,"NUREG-0725, Rev. 13 (October 1998).

4. U.S.SENATE, Correspondence, Senators Harry Reid and John Ensign, to Richard A. Meserve, Chairman, U.S. Nuclear Regulatory Commission (April18, 2002).

5. NRC, "Number of Shipments and Quantity of Spent Fuel (Kilograms) Shipped for Origination/Destination Pairs: 1979-2001," Attachment, Correspondence from

R.A. Meserve, NRC Chairman, to Honorable H. Reid, United States Senate (May 10, 2002).

6. NAC, "Commercial Spent Nuclear Fuel Shipments in the United States, 1964 - 1987," NWPO-TN-008-90, Prepared for NANP (December 1990).

7. D.H. SANDERS, "Spent Fuel Shipment Database," Report CIS 92-36, Prepared for NANP, by College of Engineering, University of Nevada, Reno (January 1994).

8. E.J. BENTZ AND ASSOCIATES, "Technical and Institutional Considerations Regarding Near-Term (1998) Spent Fuel Transportation To An Interim Storage Facility," Prepared for NANP (September 1995).

9. WESTERN INTERSTATE ENERGY BOARD, "Rail Primer: Legal, Technical and Business Aspects of Rail Transportation," Revised (November 1995).

10. DOE, Yucca Mountain Site Characterization Project, "Nevada Commercial Spent Nuclear Fuel Transportation Experience," YMP/91-17, Prepared by SAIC for DOE, Las Vegas (September 1991).

11. NAC, "Spent Fuel Shipments: A History of Safety," Nuclear Fuel Cycle Topical Report (Winter 2001/2002).

12. R. POPE, "International Experience with SNF/HLW Transport," Presentation before the U.S. National Academy of Sciences, National Transportation Research Board, Washington, DC (September 11, 2000).

13. J.W. CASHWELL, ET AL, "Transportation Impacts of the Commercial Radioactive Waste Management Program," SAND85-2715, Prepared for DOE by SNL (April 1986).

14. R.J. HALSTEAD, ET AL, "Transportation to Yucca Mountain: Critical Issues," High-Level Radioactive Waste Management, Proceedings of the Second Annual International Conference, Las Vegas, NV, Vol. 1, 647-656 (April 28-May 3, 1991).

15. DOE, "Environmental Assessment: Yucca Mountain Site, Nevada Research and Development Area, Nevada," DOE/RW-0073 (1986)

16. NANP, "A Report on High-Level Nuclear Waste Transportation: Prepared Pursuant to Assembly Concurrent Resolution No. 8 of the 1987 Nevada Legislature" (1988).

17. PIC, "The Transportation of Spent Nuclear Fuel and High-Level Radioactive Waste: A Systematic Basis for Planning and Management at National, Regional

and Community Levels," Prepared for NANP (September 1996). (This and other NANP reports can be accessed on the web at http://www.state.nv/nucwaste/trans.htm.)

18. NRC, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Main Report, Section 6.3 – Transportation: Table 9.1 Summary of Findings on NEPA issues for license renewal of nuclear power plants, Final Report," NUREG-1437, Volume 1, Addendum 1 (August 1999).

19. DOE, "Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada," DOE/EIS-0250 (February 2002). (Available on the web at http://www.ymp/gov/documents/feis_a/index.htm)

20. "A Mountain of Trouble: Report on Impacts of the Proposed Yucca Mountain High-Level Nuclear Waste Program," Prepared for NANP (February 2002).

21. "Testimony of Robert J. Halstead, on Behalf of the State of Nevada, before the Committee on Energy and Natural Resources, United States Senate, May 22, 2002."

ATTACHMENT A

Table AI. Number of Shipments and Quantity of Spent Fuel Shipped for Origination/Destination Pairs, 1979-2001 [Source: NUREG-0725, Rev. 13, Table 3.1, updated through 2001 and reformatted]

Origin	Destination	Shipments	Kilograms Shipped
Alexandria Bay, NY	Savannah River Project, SC	10	227.000
Arkansas One, AR	Portsmouth, VA	1	3.000
Babcock & Wilcox, VA	GE/Vallecitos, CA	2	41.000
Babcock & Wilcox, VA	Oconee, SC	3	558.000
Babcock & Wilcox, VA	Quad Cities, IL	2	499.000
Battelle Columbus, OH	Calvert Cliffs, MD	1	72.000
Battelle Columbus, OH	GE/Morris, IL	2	791.000
Battelle Columbus, OH	GE/Vallecitos, CA	2	28.000
Battelle Columbus, OH	Ginna, NY	5	2632.000
Battelle Columbus, OH	Zion, IL	2	879.000
Big Rock Point, MI	Portsmouth, VA	2	14.000
Byron Station, IL	Alexandria Bay, NY	1	11.000
Brunswick, NC	Battelle Columbus, OH	1	30.000
Brunswick, NC	Shearon Harris, NC	57	322777.800
Calvert Cliffs, MD	Alexandria Bay, NY	1	25.000
Calvert Cliffs, MD	Battelle Columbus, OH	3	64.000
Callaway, MO	Alexandria Bay, NY	1	14.000
Charleston, SC	Savannah River Project, SC	3	22.700
Charleston, SC	Savannah River Project, SC	12	1616.900
Cintichem, NY	Idaho Nat Eng Lab, ID	3	10.000
Cintichem, NY	Savannah River Project, SC	14	41.000
Concord, CA	Idaho Nat Eng Lab, ID	1	0.050

Cooper, NE	GE/Morris, IL	30	194546.000
Derby Lane, VT	Savannah River Project, SC	8	20.000
Dresden Station, IL	Babcock & Wilcox, VA	3	56.000
Dresden Station, IL	Portsmouth, VA	1	9.000
Duane Arnold, IA	GE/Vallecitos, CA	2	19.000
Dundalk, MD	GE/Vallecitos, CA	3	148.000
Dundalk, MD	Port of Oakland, CA	1	302.000
E.I. Hatch, GA	Babcock & Wilcox, VA	1	20.000
E.I. Hatch, GA	GE/Vallecitos, CA	1	14.000
Erie, NY	Savannah River Project, SC	1	5.600
Fort Calhoun, NE	Battelle Columbus, OH	1	1.000
Fort Erie, NY	Savannah River Project, SC	1	3.000
Fort St. Vrain, CO	General Atomics, CA	2	10.000
Fort St. Vrain, CO	Idaho Nat Eng Lab, ID	123	500.000
General Atomics, CA	Idaho Nat Eng Lab, ID	2	6.000
GE/Morris, IL	La Crosse, WI	4	939.000
GE/Morris, IL	Point Beach, WI	108	48382.000
GE/Vallecitos, CA	Argonne Nat Lab, IL	5	29.500
GE/Vallecitos, CA	Hanford, WA	3	102.000
GE/Vallecitos, CA	Idaho Nat Eng Lab, ID	18	71.000
GE/Vallecitos, CA	Port of Oakland, CA	7	57.000
GE/Vallecitos, CA	Portland, OR	1	1.000
GE/Vallecitos, CA	Richmond, CA	3	39.000
GE/Wilmington, NC	Savannah River Project, SC	2	19.000
Georgia Tech, GA	Savannah River Project, SC	1	4.470
Ginna, NY	Dundalk, MD	1	4.000
Haddam Neck, CT	Battelle Columbus, OH	3	1275.000
Hope Creek, NJ	GE/Vallecitos, CA	1	17.000
Idaho Nat Eng Lab, ID	Portland, OR	1	3.000
Limerick, PA	GE/Vallecitos, CA	1	0.020
McGuire, NC	Babcock & Wilcox, VA	1	5.000
McGuire, NC	Dundalk, MD	1	13.100
McMaster University, CN	Savannah River Project, SC	6	6.000
Mich. State Univ., MI	Denver Federal Center, CO	1	8.000
Mich. State Univ., MI	Idaho Nat Eng Lab, ID	2	11.000
Millstone, CT	GE/Vallecitos, CA	3	36.000
M.I.T., MA	Savannah River Project, SC	13	17.000
Monticello, MN	Battelle Columbus, OH	2	67.000
Monticello, MN	GE/Morris, IL	29	195013.000
Monticello, MN	GE/Vallecitos, CA	4	55.000
NIST, MD	Savannah River Project, SC	11	447.000
Newport News, VA	Savannah River Project, SC	4	24.000
Norfolk Int Terminal, VA	Savannah River Project, SC	1	7.000
NFS, West Valley, NY	Battelle Columbus, OH	8	2977.000
NFS, West Valley, NY	Dresden Station, IL	31	20447.000
NFS, West Valley, NY	Ginna, NY	73	32300.000
NFS, West Valley, NY	Oyster Creek, NJ	33	42950.000
NFS, West Valley, NY	Point Beach, WI	114	48450.000

Oconee, SC	Babcock & Wilcox, VA	6	972.000
Oconee, SC	McGuire, NC	138	140094.000
Ogdensburg, NY	Savannah River Project, SC	14	35.000
Oyster Creek, NY	Battelle Columbus, OH	1	33.000
Pembina, ND	Idaho Nat Eng Lab, ID	1	3.000
Portland, OR	Idaho Nat Eng Lab, ID	28	139.000
Portsmouth, VA	GE/Vallecitos, CA	1	9.000
Portsmouth, VA	Idaho Nat Eng Lab, ID	39	200.000
Portsmouth, VA	Savannah River Project, SC	169	1057.000
Port of Oakland, CA	GE/Vallecitos, CA	9	93.000
Port of Savannah, GA	Savannah River Project, SC	5	65.000
Quad Cities, IL	Babcock & Wilcox, VA	2	499.000
Quad Cities, IL	Battelle Columbus, OH	1	18.000
Quad Cities, IL	GE/Vallecitos, CA	4	56.000
R.I. AEC, RI	Savannah River Project, SC	35	16.000
Richmond, CA	GE/Vallecitos, CA	1	12.000
Robinson, SC	Brunswick, NC	18	49725.000
Robinson, SC	GE/Vallecitos, CA	1	28.700
Robinson, SC	Shearon Harris, NC	25	213532.300
San Onofre, CA	GE/Morris, IL	16	6800.000
Savannah River Proj, SC	Idaho Nat Eng Lab, ID	3	0.040
Southport, NC	Savannah River Project, SC	1	22.000
Sunny Point, NC	Savannah River Project, SC	1	14.000
Surry, VA	Battelle Columbus, OH	1	20.000
Three Mile Island, PA	GE/Vallecitos, CA	1	12.800
U of Cal(Berk), CA	Idaho Nat Eng Lab, ID	3	21.000
U of MI, MI	Savannah River Project, SC	17	50.000
U of MO, MO	Idaho Nat Eng Lab, ID	15	81.000
U of MO, MO	Savannah River Project, SC	50	205.400
Univ of Toronto, CN	Savannah River Project, SC	1	0.001
U of VA, VA	Savannah River Project, SC	13	15.000
Virgil Summer, SC	Alexandria Bay, NY	2	35.000
Zion, IL	Battelle Columbus, OH	2	920.000
Total		1429	1334575.381