AN ASSESSMENT OF SPENT NUCLEAR FUEL SHIPPING CASK HANDLING CAPABILITIES OF COMMERCIAL LIGHT WATER REACTORS

P. M. Daling
Pacific Northwest Laboratory
Richland, Washington 99352

ABSTRACT

This paper describes an assessment of the spent nuclear fuel shipping cask handling capabilities and limitations of commercial light water reactors. This information was used to develop realistic truck/rail modal fractions in support of design and environmental assessments of federal Monitored Retrievable Storage (MRS) and repository facilities. A computerized data base of reactor-specific cask handling parameters was developed from data obtained from the literature and from contacts with utility personnel knowledgeable about their reactor's cask handling systems. The data base includes information regarding each reactor's in-plant capabilities and limitations, such as cask handling crane capacity, loading pool dimensions, etc., as well as availability of highway, rail, and water access routes to the site. The capability of each reactor to receive and handle the existing spent fuel shipping casks was then evaluated. Modal fractions, which are defined here as the fraction of spent fuel that will be received by truck and rail transport modes, were then calculated based on the quantity of spent fuel that is projected to be discharged from commercial LWRs through 1998.

The results of the cask handling capability indicated that over 90% of the reactors are capable of receiving and handling rail casks if the maximum capability of each facility is utilized. This assumes that current restrictions, such as derated crane capacities, availability of rail access, and technical specification limitations, will be overcome where appropriate. Design and analysis efforts and physical modifications to some reactors and sites would be needed to achieve this high rail percentage. The percentage of reactors that receive and handle rail casks in the near-term (i.e., assuming current limitations are not removed), would be reduced to about 64%. The primary reason for reactor to be judged to be limited to truck transport in the near-term was a lack of rail access.

The modal fraction calculations indicated that up to 93% of the spent fuel discharged from reactors through 1998 could be transported in rail casks, based on each reactor's maximum capabilities. If the near-term capabilities are assumed, the rail percentage would be reduced to about 62%.

INTRODUCTION

The Department of Energy (DOE) will become a major shipper of commercially-generated spent nuclear fuel in the future as federal spent fuel storage and disposal facilities become operational. The DOE is currently involved in long-range waste management system planning activities and are developing designs of spent fuel handling, transportation, storage, and disposal systems. One parameter that affects the design of all of these systems is the fraction of spent fuel that will be shipped by the truck and rail transport modes, or the modal fraction. This parameter affects the design of spent fuel shipping cask receiving and handling systems, cask fleet requirements, and the overall costs, risks, and environmental impacts of the waste management system.

Realistic truck/rail modal fractions are specifically needed to support the advanced conceptual designs of the Monitored Retrievable Storage (MRS; if approved by Congress) and repository facilities. This information is also needed for the environmental documentation to be prepared for these facilities. This paper describes a study that was performed to develop realistic truck/rail modal fractions based on a reactor-by-reactor evaluation of spent fuel shipping cask handling capabilities at operating and planned commercial light water reactors (LWRs). This study was performed for the DOE through the Transportation Technology Center (TTC) at Sandia National Laboratories.

Scope and Approach

The scope of this study includes all U.S. commercial LWRs that are either currently operating, shutdown, or under construction. The cask handling evaluation for each reactor includes consideration of both in-plant cask handling capabilities and limitations as well as access routes (roadways and railspurs) onto the reactor site and into the cask handling area. The existing commercial spent fuel shipping cask designs were used as the basis for the reactor-by-reactor evaluations. Calculation of modal fractions were based on the projected inventories of spent fuel discharged from reactors in the year 1998. Reactor-by-reactor inventories were obtained from Ref. 1 which consists of utility-supplied data that has been modified to match the DOE-Energy Information Administration (EIA) projections for installed capacity and nuclear energy generation. The EIA middle-case projections were used.

The approach to this study consisted of the following steps:

- collect cask handling parameter data through literature reviews and contacts with utility personnel who are knowledgeable about their plant's cask handling systems
- input the cask handling parameter data into a computerized data base to facilitate the analysis
- evaluate the cask handling capabilities and limitations of each reactor based on their ability to handle the existing spent fuel shipping casks
- calculate truck/rail modal fractions

The cask handling parameter data collected in this study included cask handling crane capabilities (design and derated capacity, where applicable), dimensions of cask loading pools, structural limits, availability of rail service, past experience with spent fuel shipments, and any other conditions which could impede or preclude use of a particular shipping cask. These data were obtained through literature reviews, including reviews of plant-specific Safety Analysis Reports (SARs) and the PNL Spent Fuel Data Base. These data were verified and information gaps were filled via the contacts with utility personnel.

The next step was to input the cask handling parameter data into a computerized data base to facilitate the analysis. Commercially-available data base management software was used. The data base currently consists of a "page" of cask handling parameter data for each reactor. The format for each of these pages of data is illustrated in Table I.

TABLE I

Format for Cask Handling Parameter Data "Pages"

PLANT NAME:
UTILITY:
NEAREST TOWN:
NRC DOCKET NUMBER:
REACTOR TYPE:
RATING (MWe):

IN-PLANT HANDLING PARAMETERS

Share Pool: (Y or N)
Preferred Cask:
Cask Experience:
Cask Crane Capacity:
Crane Height:
Pool Depth:
Pool Width:
Pool Length:
COMMENTS:

RAIL/BARGE ACCESS DATA

Rail Spur Onsite: (Y or N)
Nearest Railroad:
Distance From Rail Spur to Site:
Source of Cooling Water:
Barge Feasibility: (Y or N)
COMMENTS:

After the data base was completed, a reactor-by-reactor evaluation was performed to determine which types of existing shipping casks could potentially be received and handled at each reactor. The types of shipping casks considered and their nominal physical dimensions are shown in Table II. The physical dimensions of the cask-types were compared with the handling capabilities and limitations of each reactor to estimate reactor-specific handling capabilities. As shown, two sizes of truck casks (legal-weight [LWT] and overweight [OWT]) and two sizes of rail casks (light and heavy) were considered. Two evaluations were performed for each reactor. The first evaluates the "current capabilities" of each reactor; i.e., determines which shipping casks could be handled at each plant in the near future. The evaluation of current capabilities includes consideration of derated crane capacities, access limitations, and plant technical specifications. Current capabilities represents the types of shipping casks that could be handled <u>without</u> major modifications to the reactor's cask handling facilities. The second evaluation determines the types of shipping casks that could be handled at each plant based on the maximum capabilities of cask handling facilities. The results of this evaluation, designated "in-plant capabilities", did not consider currently-imposed technical specifications, rail access limitations, or derated crane capacities because it was assumed that restrictions based on these parameters could potentially be overcome. The costs to overcome these limitations were not addressed.

TABLE II

Nominal Physical Dimensions of Existing

Types of Spent Fuel Shipping Casks

Primary Transport Mode	Cask Empty Weight (kg)	External Dimensions (m)
Legal-weight Truck	22,000	1.3D x 5.4L
Overweight Truck	36,000	1.7D x 5.8L
Light Rail	64,000	1.6D x 5.3L
Heavy Rail	83,000	2.4D x 5.2L

The final step was to estimate the fraction of the fuel discharged through the year 1998 that could potentially be shipped via each type of shipping cask. It was assumed that all reactors that can ship by the rail mode will do so; thus, the rail modal fraction represents an upper limit. The LWT and OWT modal fractions represents only the amount of fuel that is required to be shipped by these modes, based on access or handling limitations at the reactors. Thus, LWT and OWT modal fractions represent lower limits. This was done because plants that are capable of handling rail casks are also capable of handling LWT and OWT casks but the converse is not necessarily true. The actual modal fractions will depend upon the types of shipping casks that are selected by the reactors that have rail capabilities. Other considerations which were not evaluated here include economics, radiation exposure reduction, and carrier willingness to transport spent fuel.

TABLE III

Spent Fuel Shipping Cask Handling Capabilities

of Commercial Nuclear Power Plants (a)

PLANT NAME (b)	IN-PLANT CAPABILITIES (c) LWT	OWT	RAIL	RAIL (b) ACCESS	BARGE (e) FEASIBILITY	INTERMODAL (f) FEASIBILITY	CURRENT CAPABILITIES (g) LWT	OWT	RAIL
Arkansas Nuclear One - 1 (PWR)*	X	X	X	X			X	X	X
Arkansas Nuclear One - 2 (PWR)*	X	X	X	X			X	X	X
Arnold (BWR)*	X	X	X	X			X	X	X
Beaver Valley - 1 (PWR)*	X	X	X	X	X		X	X	X
Beaver Valley - 2 (PWR)*	X	X	X	X	X		X	X	X
Bellefonte - 1 (PWR)	X	X	X	X	X		X	X	X
Bellefonte - 2 (PWR)	X	X	X	X	X		X	X	X
Big Rock Point (BWR)*	X			X	X		X		
Braidwood - 1 (PWR)	X	X	X	X			X	X	X
Braidwood - 2 (PWR)	X	X	X	X			X	X	X
Browns Ferry - 1 (BWR)*	X	X	X		X	X	X	X	
Browns Ferry - 2 (BWR)*	X	X	X		X	X	X	X	
Browns Ferry - 3 (BWR)*	X	X	X		X	X	X	X	
Brunswick - 1 (BWR)*	X	X	X	X			X	X	X
Brunswick - 2 (BWR)*	X	X	X	X			X	X	X
Byron - 1 (PWR)*	X	X	X	X			X	X	X
Byron - 2 (PWR)	X	X	X	X			X	X	X
Callaway - 1 (PWR)*	X	X	X		X	X	X	X	
Calvert Cliffs - 1 (PWR)*	X	X	X		X	X	X		
Calvert Cliffs - 2 (PWR)*	X	X	X		X	X	X		
Catawba - 1 (PWR)	X	X	X	X			X	X	X
Catawba - 2 (PWR)	X	X	X	X			X	X	X
Clinton - 1 (BWR)	X	X	X	X			X	X	X
Comanche Peak - 1 (PWR)	X	X	X	X			X	X	X
Comanche Peak - 2 (PWR)	X	X	X	X			X	X	X
Cooper (BWR)*	X	X	X	X	X		X	X	X
Crystal River - 3 (PWR)*	X	X	X		X	X	X	X	
D.C. Cook - 1 (PWR)*	X	X	X	X	X		X	X	X
D.C. Cook - 2 (PWR)*	X	X	X	X	X		X	X	X
Davis Besse (PWR)*	X	X	X	X	X		X	X	X
Diablo Canyon - 1 (PWR)*	X	X	X		X	X	X	X	
Diablo Canyon - 2 (PWR)	X	X	X		X	X	X	X	
Dresden - 1 (BWR)	X	X		X	X		X	X	
Dresden - 2 (BWR)*	X	X	X	X	X		X	X	X
Dresden - 3 (BWR)*	X	X	X	X	X		X	X	X
Farley - 1 (PWR)*	X	X	X	X	X		X	X	X
Farley - 2 (PWR)*	X	X	X	X	X		X	X	X
Fermi - 2 (BWR)	X	X	X	X	X		X	X	X
Fitzpatrick (BWR)*	X	X	X	X	X		X	X	X
Fort Calhoun (PWR)*	X	X					X	X	
Ginna (PWR)*	X						X		
Grand Gulf - 1 (BWR)*	X	X	X	X	X		X	X	X
Grand Gulf - 2 (BWR)	X	X	X	X	X		X	X	X
Haddam Neck (PWR)*	X	X	X		X		X	X	
Harris - 1 (PWR)	X	X	X	X			X	X	X
Hatch - 1 (BWR)*	X	X	X	X			X	X	X
Hatch - 2 (BWR)*	X	X	X	X			X	X	X
Hope Creek (BWR)	X	X	X		X	X	X	X	
Humboldt Bay (BWR)	X	X	X	X			X	X	
Indian Point - 1 (PWR)	X	X			X		X		

TABLE III

(Continued)

PLANT NAME (b)	IN-PLANT CAPABILITIES (c)			RAIL (d)	BARGE (e)	INTERMODAL (f)	CURRENT CAPABILITIES (g)		
	LWT	OWT	RAIL	ACCESS	FEASIBILITY	FEASIBILITY	LWT	OWT	RAIL
Indian Point - 2 (PWR)	X				X		X		
Indian Point - 3 (PWR)	X	X	X		X		X		
Kewaunee (PWR)*	X	X	X		X	X	X	X	
La Crosse (BWR)*	X			X	X		X		
La Salle - 1 (BWR)*	X	X	X	X	X		X	X	X
La Salle - 2 (BWR)*	X	X	X	X	X		X	X	X
Limerick - 1 (BWR)	X	X	X	X			X	X	X
Limerick - 2 (BWR)	X	X	X	X			X	X	X
Maine Yankee (PWR)	X	X	X	X	X		X	X	X
Marble Hill - 1 (PWR)	X		X	X			X		X
Marble Hill - 2 (PWR)	X		X	X			X		X
McGuire - 1 (PWR)*	X	X	X	X			X	X	X
McGuire - 2 (PWR)*	X	X	X	X			X	X	X
Millstone - 1 (BWR)*	X	X	X	X	X		X	X	X
Millstone - 2 (PWR)*	X	X	X	X	X		X	X	X
Millstone - 3 (PWR)	X	X	X	X	X		X	X	X
Monticello (BWR)*	X	X	X	X			X	X	X
Nine Mile Point - 1 (BWR)*	X	X	X	X	X		X	X	X
Nine Mile Point - 2 (BWR)*	X	X	X	X	X		X	X	X
North Anna - 1 (PWR)*	X	X	X	X			X	X	X
North Anna - 2 (PWR)*	X	X	X	X			X	X	X
Oconee - 1 (PWR)*	X	X	X			X	X		
Oconee - 2 (PWR)*	X	X	X			X	X		
Oconee - 3 (PWR)*	X	X	X			X	X	X	
Oyster Creek (BWR)*	X	X	X		X	X	X	X	
Palisades (PWR)*	X				X		X		
Palo Verde - 1 (PWR)	X	X	X	X			X	X	X
Palo Verde - 2 (PWR)	X	X	X	X			X	X	X
Palo Verde - 3 (PWR)	X	X	X	X			X	X	X
Peach Bottom - 2 (BWR)*	X	X	X		X	X	X	X	
Peach Bottom - 3 (BWR)*	X	X	X		X	X	X	X	
Perry - 1 (BWR)	X	X	X	X	X		X	X	X
Perry - 2 (BWR)	X	X	X	X	X		X	X	X
Pilgrim - 1 (BWR)*	X	X			X		X	X	
Point Beach - 1 (PWR)*	X	X	X		X	X	X	X	
Point Beach - 2 (PWR)*	X	X	X		X	X	X	X	
Prairie Island - 1 (PWR)*	X	X	X	X	X		X	X	X
Prairie Island - 2 (PWR)*	X	X	X	X	X		X	X	X
Quad Cities - 1 (BWR)*	X	X	X	X			X	X	X
Quad Cities - 2 (BWR)*	X	X	X	X			X	X	X
Rancho Seco (PWR)*	X	X	X	X			X	X	X
River Bend - 1 (BWR)	X	X	X	X	X		X	X	X
Robinson - 2 (BWR)*	X	X	X	X			X	X	X
Salem - 1 (PWR)*	X	X	X		X	X	X	X	
Salem - 2 (PWR)*	X	X	X		X	X	X	X	
San Onofre - 1 (PWR)*	X	X	X			X	X	X	
San Onofre - 2 (PWR)*	X	X	X			X	X	X	
San Onofre - 3 (PWR)*	X	X	X			X	X	X	
Seabrook - 1 (PWR)	X	X	X	X			X	X	X
Seabrook - 2 (PWR)	X	X	X	X			X	X	X

TABLE III

(Continued)

PLANT NAME[b]	IN-PLANT CAPABILITIES[c] LWT	OWT	RAIL	RAIL[d] ACCESS	BARGE[e] FEASIBILITY	INTERMODAL[f] FEASIBILITY	CURRENT CAPABILITIES[g] LWT	OWT	RAIL
Sequoyah - 1 (PWR)*	X	X	X	X	X		X	X	X
Sequoyah - 2 (PWR)*	X	X	X	X	X		X	X	X
Shoreham (BWR)	X				X		X		
South Texas - 1 (PWR)	X	X	X	X			X	X	X
South Texas - 2 (PWR)	X	X	X	X			X	X	X
St. Lucie - 1 (PWR)*	X	X	X		X	X	X		
St. Lucie - 2 (PWR)*	X	X	X		X	X	X		
Summer (PWR)	X	X	X	X			X	X	X
Surry - 1 (PWR)*	X	X	X		X	X	X	X	
Surry - 2 (PWR)*	X	X	X		X	X	X	X	
Susquehanna - 1 (BWR)*	X	X	X	X			X	X	X
Susquehanna - 2 (BWR)	X	X	X	X			X	X	X
Three Mile Island - 1 (PWR)	X	X	X	X			X	X	X
Three Mile Island - 2 (PWR)	X	X	X	X			X	X	X
Trojan (PWR)*	X	X	X		X		X	X	
Turkey Point - 3 (PWR)*	X	X	X		X	X	X		
Turkey Point - 4 (PWR)*	X	X	X		X	X	X		
Vermont Yankee (BWR)*	X	X	X	X			X	X	X
Vogtle - 1 (PWR)	X	X	X	X	X		X	X	X
Vogtle - 2 (PWR)	X	X	X	X	X		X	X	X
WNP - 1 (PWR)	X	X	X	X	X		X	X	X
WNP - 2 (BWR)*	X	X	X		X	X	X	X	
WNP - 3 (PWR)	X	X	X	X	X		X	X	X
Waterford - 3 (PWR)	X	X	X	X			X	X	
Watts Bar - 1 (PWR)	X	X	X	X	X		X	X	X
Watts Bar - 2 (PWR)	X	X	X	X	X		X	X	X
Wolf Creek (PWR)	X	X	X	X			X	X	X
Yankee (PWR)*	X						X		
Zion - 1 (PWR)*	X	X	X	X	X		X	X	X
Zion - 2 (PWR)*	X	X	X	X	X		X	X	X
TOTALS									
PWR's	86	79	79	54	47	22	86	68	52
BWR's	44	41	39	34	26	9	44	41	31
ALL PLANTS	130	120	118	88	73	31	130	109	83

(a) LWT = Legal-weight truck; OWT = Overweight truck. See glossary for definitions of terms.

(b) Asterisk (*) denotes operating plants

(c) "X"indicates in-plant handling conditions are such that casks of specified transport modes (LWT, OWT, or rail) could be handled. Technical specifications are not considered; i.e., only the plants physical capabilities, as reported by utilities were considered.

(d) "X"indicates servicable rail spur extends into cask loading facilities.

(e) "X"indicates plant is located on navigable waterway.

(f) Refers to the potential capability of loading a large rail or OWT cask at a plant that does not have rail access and then shipping the loaded cask by a short-distance heavy-haul truck mode to an off-site rail siding. Intermodal feasibility is not indicated for plants with rail access.

(g) "X"indicates the cask transport modes that can currently be received and loaded; single mode shipments are considered. Technical specification limitations, if applicable, are also considered.

Results and Conclusions

The results of this assessment included: 1) a directory of cask handling parameter data for each reactor; 2) the results of the evaluation of each reactor's cask handling capabilities and limitations; and 3) an estimate of the modal fractions for which the repository and potential MRS facilities should be designed. For more information on the facilities directory.[2]

The results of the evaluations for each reactor are shown in Table III. A total of 86 pressurized water reactors (PWRs) and 44 boiling water reactors (BWRs) were examined. As shown, all of the reactors were determined to be capable of handling LWT casks. According to the in-plant capabilities (i.e., neglecting technical specification limitations and rail access availability), ten plants could not handle OWT casks and twelve could not handle the light rail cask. Therefore, based on in-plant capabilities, approximately 90% of the reactors could potentially receive and handle a rail cask.

Under the "current capabilities" columns of Table III, it is shown that 83 reactors, or approximately 64% of all reactors, could potentially receive and handle a rail cask. The predominant reason that individual reactors were determined to lack rail cask capability is a lack of rail access. Lack of rail access is shown in Table III for 42 reactors (32 PWRs and 10 BWRs). Other limitations were due to inadequate cask loading pool dimensions (7 reactors) and inadequate crane capacities (15 reactors). Some reactors were limited to truck casks for more than one reason so these results should not be added together.

A further review of the results was performed to determine which reactors could potentially receive and handle the light rail cask but not the heavy version (see Table II). It was determined that a total of 19 reactors are in this category. These additional limitations are due primarily to the larger outside diameter of the heavy rail cask which restricts it from being placed in a number of cask loading pools. Other limitations are caused by inadequate lifting capabilities for the heavy rail cask. Note that the results presented in Table III indicate whether or not each plant can receive and handle the light rail cask. Because of this, it should be recognized that some plants listed in Table III are shown as having rail cask handling capabilities but they are not capable of handling the heavy rail cask.

Modal fractions were estimated by adding together the cumulative spent fuel discharges (given in units of MTU) for plants that could receive and handle each type of shipping cask. The rail modal fraction represents an upper limit because it was assumed that all reactors capable of receiving and handling rail casks would do so. LWT and OWT fractions are lower limits. The results of the calculations are presented in Table IV.

Calculations revealed that a total of approximately 38,900 MTU of spent fuel will have been discharged from the reactors listed in Table III by 1998. Of this amount, approximately 36,300 MTU, or about 93%, could potentially be shipped in light rail casks. This means that only about 7% of the fuel would be required to be transported in LWT and OWT casks.

When current capabilities and limitations are considered, the amount of spent fuel that could potentially be shipped in light rail casks is reduced to about 24,100 MTU, or about 62% of the spent fuel available in 1998. The remaining 38% would be required to be transported in truck casks. This is about a 30% reduction in the quantity of spent fuel that could potentially be transported in rail casks relative to in-plant capabilities. This difference represents about 12,200 MTU of spent fuel. Since the primary difference between in-plant and current cask handling capabilities is the availability of rail service to the reactor site, the bulk of this difference could be transported using intermodal shipments. Intermodal shipments are combinations of two or more transport modes, such as truck and rail. For example, it is possible to transport a rail cask by highway between a reactor and the nearest rail siding. Thus, if a reactor is limited to truck shipments only because of a lack of direct rail service, a rail cask can be brought to and leave the reactor site in this manner. Another type of intermodal shipment would be a barge/rail shipment in which a rail cask is delivered to and departs from a reactor site via a barge shipment. As shown in Table III, a total of 73 plants have barge feasibility, which is based primarily on the reactor being located on a navigable waterway.

TABLE IV

Design Basis Modal Fractions for
Repository and MRS Facilities[a]

	Modal Fractions		
	PWRs	BWRs	All Plants
In-Plant Capabilities			
LWT	0.06	0.02	0.05
OWT	0.01	0.03	0.02
Light Rail	0.93	0.95	0.93
Current Capabilities			
LWT	0.21	0.02	0.14
OWT	0.21	0.29	0.24
Light Rail	0.58	0.69	0.62

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[a] Spent fuel inventories in 1998 at the reactors considered total approximately 38,900 MTU. Of this amount, 24,400 MTU will be PWR spent fuel and 14,500 MTU will be from BWRs.

REFERENCES

1. C. M. HEEB, R. A. LIBBY, AND G. M. HOLTER, "Reactor-specific Spent Fuel Discharge Projections," PNL-5396, Pacific Northwest Laboratory, Richland, Washington (1985).

2. P. M. DALING, G. J. KONZEK, A. J. LEZBERG, E. F. VOTAW, AND M. I. COLLINGHAM, "Spent Nuclear Fuel Shipping Cask Handling Capabilities of Commercial Light Water Reactors," PNL-5384, Pacific Northwest Laboratory, Richland, Washington (1985).