System Design Specifications for Future Rail Transport of Spent Nuclear Fuel

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INTRODUCTION

Over the past 30 years (1964 - 1994), U.S. commercial spent-fuel shipment volumes have averaged approximately 75 MTU (metric tons of uranium equivalent)/year. This is in stark contrast to the current average annual commercial movement of spent fuel in Europe (approximately 4,500 MTU). Much of Europe (and Japan) has embraced a reprocessing fuel cycle, which has necessitated regular, high volumes of annual shipments of spent fuel to reprocessing centers. Anticipated increases in future demand for spent-fuel shipment in the U.S. under the Nuclear Waste Policy Act (NWPA) and the U.S. Department of Energy (DOE) Programmatic Spent Fuel Management Environmental Impact Statement Record of Decision have raised several emerging concerns regarding future rail transportation system design specifications.

HISTORICAL COMMERCIAL SPENT-FUEL SHIPMENT CHARACTERISTICS

Table 1 provides a summary of the transportation characteristics of recent (1977 - 1994), major U.S. historical commercial and selected DOE spent-fuel shipping campaigns by rail, overweight truck (OWT), and legal-weight truck (LWT). Historical shipments have had an excellent safety record.

Table 1. U.S. Spent-Fuel Shipment Campaign Characteristics

Dates	Shipment Campaign	Mode	Shpmts.	Rt.Mi.	Assmbls. (MTU)	Cask
1977-93 ongoing	Robinson/Brunswick/Harris (CP&L - intrautility)	Rail	128	220.7 longest	528 PWR/753 BWR (376.2)	IF-300
1983-84	West Valley - Point Beach	LWT	114	784	114 PWR (45.5)	NLI-1/2
1983-84	West Valley - Dresden	OWT	30	642	205 BWR (37.5)	TN-9
1984-87	Cooper Station (NPPD) - Morris	Rail	30	612.3	1,056 BWR (193.3)	IF-300
1984-87	Monticello (NSP) - Morris	Rail	30	472.2	1,058 BWR (184.1)	IF-300

1985	West Valley - Oyster Creek	OWT	32	531	224 BWR (42.9)	NLI-1/2
1985-86	West Valley - Ginna	LWT	81	158.5	81 PWR (29.9)	TN-9
1985-86	Surry - INEL	OWT	23	2,506	69 PWR (31.7)	TN-8L
1985-91	Taiwan - Savannah River	LWT	105	439 est.	1,574 FRR (85.2)	NLI-1/2
1986	Nevada Test Site - INEL	OWT	6	527 est.	17 PWR (8.1)	TN-8L
1986-90	TMI - INEL	Rail	20	2,383	PWR core (72.1)	N125B
1989-	Fort St. Vrain - INEL	LWT	124	717 est.	744 HTGR (8.9)	FSV-1
1993-94	Shoreham - Limerick	Bg/Rail	33	350/30	560 BWR (102.5)	IF-300

Legend: CP&L = Carolina Power & Light INEL = Idaho National Engineering Laboratory
NPPD = Nebraska Public Power Distr. TMI = Three Mile Island
NSP = Northern States Power

Source: E.J. Bentz & Associates

HISTORICAL SPENT-FUEL RAIL SHIPMENT CAMPAIGN CHARACTERISTICS

Three hundred and forty-five of the U.S. commercial shipments during the period 1965 - 1994 were made by rail. Most of these shipments were made by or for utilities. Table 1 above provides the general characteristics of the major commercial rail shipment campaigns in the U.S. since 1977. As depicted on the table: 1) most campaigns involved relatively few assemblies and few shipments; 2) most campaigns involved relatively limited route mileage (except for the TMI campaign); and 3) most campaigns were of a limited duration (2 - 5 years). In addition, most campaigns traversed few states (three or fewer states, with the exception of TMI's traverse of nine states), and most experienced limited public involvement.

Since 1956, 599 containers (584 shipments) of naval spent fuel have been shipped by rail to the Naval Reactors Facility (NRF) at INEL for examination, evaluation, and long-term storage, after having been removed from Navy nuclear-powered ships and training prototypes as a routine part of their operational cycle. An additional 16 containers of naval spent fuel (12 from Shippingport; four from NRF) were shipped during this period to DOE's Hanford Site. Shipments to the NRF have originated from two prototype sites (Kesselring Operations Site in West Milton, NY and the Windsor, CT Operations Site), the Shippingport, PA Atomic Power Station, and nine naval shipyard locations (Charleston, SC; Electric Boat Division (Groton), CT; Ingalls Shipbuilding (Pascagoula), MS; Mare Island (Vallejo), CA; Newport News Shipbuilding (Newport News), VA; Norfolk, VA; Pearl Harbor, HI; Portsmouth (Kittery), ME; and Puget Sound (Bremerton), WA. Although transport has originated from all 12 locations, nearly 78% of the shipments have originated from five sites. Two of these sites, Puget Sound and Mare Island, service the Pacific Fleet, while three sites, Portsmouth, Newport News, and Charleston, service the Atlantic Fleet. Both Mare Island and Charleston are scheduled for closure in the near future under Federal Base Closing Commission findings. The naval spent fuel has been shipped using the M-130, M-140, M-160 and S2W/S2Wa (since withdrawn from service) shipping containers.

All recent commercial spent-fuel rail shipments were operated under dedicated special service, and all package weights shipped were under free interchange weight limits (not heavy, restricted loads). Dedicated service is a term that has been used to describe special service conditions, whereby the only ("dedicated") cargo on the train is spent fuel. Other special service conditions that have historically characterized dedicated service for commercial spent-fuel campaigns are provision of expedited schedules with minimum in-transit delays; provision of specialized equipment; and a single bill-of-lading for origin-to-destination. Table 2 summarizes the key operational service specifications for the recent commercial spent-fuel rail shipments. As depicted on the table, the dedicated special service conditions chosen by the

Table 2. Key Historical Rail Operational Service Specifications

Description	CP&L	NPPD/NSP	TMI	Shoreham
Service Level	Dedicated: Loaded General: Empty	Dedicated: Loaded General: Empty	Dedicated: Loaded General: Empty	Dedicated: Loaded Dedicated: Empty
Speed Restriction	N/A	35 mph	30 mph (Conrail portion only)	30 mph
Shipment Size	Single cask	Multiple cask	Multiple cask	Single cask
Surveillance/Escort Requirement	NRC	NRC State	NRC State	NRC State

Source: E.J. Bentz & Associates

shippers for commercial campaigns have varied. All commercial shipments, including TMI (DOE shipment), moved loaded casks in dedicated trains; in all moves but the recent Shoreham campaign, all empty casks moved in non-dedicated, general service.

Most commercial spent-fuel campaigns had operating speed restrictions, although speed restrictions varied among campaigns, and even within specific campaign route segments. For example, in the TMI campaign a special speed restriction of 30 mph was maintained for the Conrail segment of the route (889 miles), whereas no speed restriction (other than the normal speed restrictions applying to all trains) was placed by the Union Pacific on its route segment (1,479 miles). Campaign shipment sizes varied from single cask to multiple cask shipments. The recent Shoreham campaign utilized single cask shipments reflecting logistical and at-reactor handling schedule needs (coupled with short turnaround availability).

Rail Equipment Provisions. Special service conditions regarding provision of rail equipment have varied for the different commercial spent fuel shipping campaigns. In all campaigns, the shipper has provided the cask and the rail car. Idler cars, used to interspace cask cars, have been provided by both shippers and carriers. The caboose, used to house escort personnel, has also been provided by both shippers and carriers. In all campaigns, the locomotive power has been provided by the carriers.

Escort Requirements. All campaigns were subject to NRC licensee security escort requirements. In addition, many of the campaigns were subject to additional State escort requirements, and additional shipper-imposed escort requirements. The composition of escort personnel (crew, State officials, shipper personnel) has varied. For example, in the recent DOE TMI campaign (1986 - 1990), Conrail insisted on meeting the NRC in-transit security surveillance requirements by using a road foreman and a Conrail security officer as well as train crews. In contrast, on the same shipment on the UP (Union Pacific) portion of the move, UP utilized the train crew only to provide security surveillance.

The location of escort personnel has varied. NRC regulations require "line-of-sight" surveillance. For previous defense shipments, this was provided by special rail agents in a caboose; for more recent commercial and DOE shipments, contractor personnel traveled in a caboose, and State employees followed in a highway chase vehicle. Carriers have interpreted NRC escort surveillance requirements differently. For the relatively recent TMI campaigns from Pennsylvania to Idaho (1986 - 1990), Conrail on their portion of the move (889 miles) required immediate inspection by train crews of the train upon stopping. In addition, Conrail required a passing rule whereby the radwaste train would stop when being met or passed enroute by another train. The combination of these two rules led to the train stopping 39 times for 46 trains to pass on a typical trip from Middleton, PA to East St. Louis, IL (889 miles). In contrast, on the UP portion of the same trip, there was a no-passing rule but no mandatory inspection upon stopping.

Liability. Rail carriers have become increasingly concerned about liability (i.e., liability associated with a radioactive material release [covered under Price Anderson], as well as liability associated with non-release incidents). Even non-release incidents may tie up a revenue-producing mainline and result in significant rail carrier economic losses. Significant liability-insurance indemnification provisions were required by the rail carriers for two of the recent campaigns: the commercial CP&L campaign and the DOE TMI campaign. In addition, for the TMI campaign, contract requirements called for DOE coverage of related costs, such as inspection costs and increased crew costs. This may have set a precedent for future DOE campaigns.

Special Service Rates. Associated with the special service conditions described above are additional, special service rate charges. Table 3 describes these charges for the recent commercial spent-fuel campaigns. All of the campaigns negotiated a service contract. All of the negotiated service contracts had a three-part charge structure: loaded and empty cask charges, the dedicated train charge, and extra equipment provision charges. For campaigns involving multiple carriers, the principal carrier negotiating party was the destination carrier (UP for the TMI campaign), or the mainline carrier (BN for both the NSP and NPPD campaigns). The DOE TMI campaign involved extensive negotiations over two years. The shipment moved under a negotiated contract rate, although the first Conrail shipment was under a negotiated government tender rate. The overall negotiated contract was later amended during the campaign to reflect actual cask weights versus estimated weight charges; this reduced the overall shipping charges. The total shipping charges for the TMI Campaign (22 rail shipments; 49 cask loads) was $3,354,381. Of this total, the expedited service portion (dedicated service plus accessorial service charges) was $1,188,500. For a typical, triple-cask-car movement, the total round-trip cost was $199,092, and the expedited service portion represented 38% of the total loaded portion ($161,031) (empty cars did not return in special expedited service). For a typical, triple-cask movement with expedited service on one leg of the route (not on the return trip), the expedited service charge was $41.40/mile.

Domestic naval spent-fuel shipments have historically utilized "special train" service approximately 42% of the time. The rail carriers have arranged for most of the special train service to suit rail scheduling needs. On occasion, the Navy has requested special train service for high-priority shipments, where spent fuel was needed for critical examination or testing. Naval spent-fuel shipments are required under DOE-DOD government tender to be transported at speeds that do not exceed 35 mph. However, government escort logs from historical shipments indicate the actual average trip speed has been approximately 15 mph. Operating

Table 3. Key Historical Rail Shipment Rate Characteristics

Description	CP&L	NPPD/NSP	TMI	Shoreham
Contract Vehicle	Negotiated Service Contract (CSX)	Negotiated Service Contract (BN)	Negotiated Service Contract (UP, Conrail)	Negotiated Service Contract (Conrail)
Loaded & Empty Cask Charges	N/A	Class 22 tariff rates $3.68/cwt loaded/unloaded	Conrail: $5.50/cwt loaded; $2.48/cwt empty UP: $9.78/cwt loaded; $4.41/cwt empty	$5,000/one-way cask trip flat rate
Dedicated Train Charge	N/A	$57/mile (est.)	Conrail: $17,500 1st cask; $5,000 each additional cask UP: $29,500 flat train rate	Included above
Extra Equipment Provision	Shipper provided buffer cars/ caboose	Does not include buffer cars or guard service	Includes accessorial requirements (e.g. surveillance)	Included above

Source: E. J. Bentz & Associates

service requirements for DOE-DOD spent-fuel rail shipments (from Government instructions on the Bill of Lading) also prohibit switching with locomotives attached and humping, and require 1) that cask car(s) be placed on the rear of the train next to the caboose, 2) that cask car(s) be placed clear of rail switch points when on a yard or siding, and 3) that protection be provided after classification.

When special trains have been used, the trains have been configured to place the cask car one car back from the locomotive. All naval spent-fuel shipments are accompanied by Government escorts. Specific routes have been selected by the rail or shipping companies. All rail carriers, with the exception of Burlington Northern (BN), have used two-man crews located in the locomotive for naval spent-fuel shipments to the NRF. BN adds a third crew member in a caboose immediately behind the Government escort caboose.

ANTICIPATED FUTURE SPENT-FUEL SHIPMENT CHARACTERISTICS

NWPA Commercial Spent-Fuel Shipments. From 1968 through December 1993, more than 98,400 spent-fuel assemblies have been discharged from 117 commercial LWRs (light water reactors); of these, 94,952 have been stored at reactor sites and 3,448 have been stored at away-from-reactor-sites (1,717 commercial spent-fuel assemblies were reprocessed at the West Valley, NY facility). Through the 40-year anticipated period each current commercial reactor is licensed to operate, a total of 297,000 assemblies are expected to be discharged. Current Congressional bills call for annual acceptance rates of 3,000 MTU, which, if transported by high-capacity rail packages, would in one year be approximately equal to the sum of all commercial spent-fuel rail movements in the U.S. over the last 30 years (i.e., 345 rail shipments). Transport will be from 119 facilities at 74 locations in 34 states. This includes 109 operating commercial reactors, one start-up reactor, eight shut-down reactors, and one independent storage facility (Morris, IL).

With a projected, high-capacity (approximately 400,000 lbs. versus the historical free interchange limit of 263,0000 lbs.) multi-purpose canister (MPC), there would be a need for at least 10,000 rail shipments (excluding truck shipments at truck-only reactors) over a 40-year period. *This averages annually to approximately the total number of commercial rail shipments over the last 30 years*. By way of contrast, if a high-capacity MPC is not available, and transport is mainly dependent on a new generation of high-capacity, not-yet-certified truck casks (the GA 4/9) and limited certified rail package capacity, the anticipated number of shipments increases to over 40,000 truck shipments during the same 40-year period. Hence, in the best case scenario (fewest number of shipments), the annual anticipated rail throughput is equivalent to the total of the last 30 years combined.

In addition to transporting significantly more spent-fuel assemblies, in heavier packages, over longer-duration campaigns, the average trip length is expected to increase considerably. Although a destination for a proposed near-term interim storage facility is not yet known, a western destination -- such as the Nevada Test Site -- would involve a 10+ state traverse from most of the reactor points of origin.

DOE Spent-Fuel Shipments. During the last 40 years, DOE and its predecessor agencies have generated, transported, received, stored, and reprocessed large amounts of research and defense-related spent fuels (more than 100,000 MTHM [metric tons of heavy metal equivalent]) at facilities in DOE's nationwide defense complex. In April 1992, DOE began to phase out reprocessing of spent nuclear fuel for recovery and recycling of highly enriched uranium and plutonium. A total of 2,646 MTU of DOE spent fuel (at 56 domestic locations and 8 ports of entry) remain that have not been reprocessed. An additional, approximate 100 MTU of DOE-owned spent fuel is expected to be generated in the next 40 years. On May 30, 1995, DOE published a Record of Decision (ROD) regarding the conduct of its Spent Fuel Management Program through the year 2035. Under the ROD, 1) all Hanford Production Reactor fuels will remain at the Hanford Site; 2) all aluminum clad spent fuels will be consolidated by shipment to the Savannah River Site (SRS); and 3) all non-aluminum-clad fuels (including naval spent fuel) will be transferred to INEL.

It is anticipated that under the ROD, approximately 575 shipments of naval spent fuel will be made by rail to INEL from six sites (Kesselring, Norfolk, Newport News, Pearl Harbor, Portsmouth, and Puget Sound). At the current time, there is inadequate data regarding specific transport variables (i.e., applicable infrastructure, cask availability, etc.) to provide an accurate assessment of the total number and modal mix of the other shipments necessary to implement the ROD. However, the ROD has estimated that the total number (including naval spent fuels) of shipments (to INEL and SRS combined) will be a maximum of 3,655 (assuming all DOE spent-fuel shipments are by truck, with the exception of naval spent-fuel shipments made by rail), including approximately 546 shipments of special case commercial spent fuels from 11 non-DOE commercial source origins; 1,008 shipments of foreign research reactor spent fuel through eight potential ports of entry; 519 shipments of domestic University research reactor spent fuels from 35 university reactors; and 1,007 intrafacility shipments of DOE-owned spent fuels from eight DOE weapons complex facilities. A significant portion of these shipments are expected to be made by rail.

EMERGING CONCERNS REGARDING ANTICIPATED SPENT-FUEL SHIPMENTS

Several emerging concerns will require resolution in advance of this increased volume of spent fuel traffic in the U.S. The anticipated future high volume of spent-fuel transport will have to share an increasingly traffic-dense rail system. The last 15 years have seen an increasing consolidation of rail carriers and of rail networks, with the emergence of high-traffic mainline corridors moving significant volumes of goods (bulk such as coal and finished products such as automobiles) to meet shipper schedules dictated by global competition. Union Pacific projects significant increases in rail car density over its East-West mainlines over the next 20 years. For some lines, it projects carload increases from 640,000 today to over 8,000,000 in 2010; this represents up to 200 trains/day. A premium is accordingly placed on efficient dispatch of trains and highly efficient track utilization to meet the demands of a consolidated, highly-utilized system. Maintenance and repair will be increasingly performed "on the fly" using automated equipment versus historical closing and rerouting of lines. Spent-fuel trains sharing the well-maintained, high-density corridors will have to meet the dispatch requirements of the system. It will be difficult to run spent-fuel trains at operating speeds significantly below other traffic sharing the line without causing expensive interruption of scheduled service (average speed for heavy-load intermodal traffic is 70 mph; average speed for heavy-load bulk trains is 60 mph). A rail incident involving no release of radioactive materials but tieing up a mainline for hours or days for inspections and recovery could be economically disastrous for a carrier.

Not all commercial reactors are equally served by all transportation modes. Although all reactors are accessible by highway (mostly local/State roads), only 48 reactors are accessible directly by rail to the fuel-handling building. For those not accessible by rail, but desiring to use a higher-capacity rail transportation package, shipments might be heavy-hauled by truck to the nearest suitable rail transfer location. However, not all local rail lines or highway access roads have been built or maintained to carry the heavy loads characteristic of larger rail packages such as the proposed DOE MPC. These would have to be upgraded at additional cost. Similarly, in the absence of historical traffic, many of the originating rail lines have deteriorated (have been maintained only for lower density traffic) or have been abandoned (or are subject to abandonment proceedings). These would need to be rehabilitated and upgraded to carry the required package loads. For the public infrastructure portion (e.g. highways, highway bridges), the upgrading and potentially increased maintenance cost would put increased budgetary pressure on a diminishing pool of available public sector transportation infrastructure funds. For the private rail infrastructure, upgrades can be accommodated by increased rates.

As indicated above, recent operating service conditions for rail shipment campaigns have included numerous operating restrictions, and these restrictions have varied by carrier over their portion of the movement to reflect their unique operating rules, track condition and capability, physical terrain, and traffic conditions (e.g. TMI campaign). The trend over time has been for increasing operating restrictions as rail carriers have become increasingly concerned about potential liabilities and have taken protective measures accordingly. With the anticipated spent-fuel shipments, it is expected that rail carriers will take increasingly restrictive positions in general, and concerning heavy-load spent-fuel shipments in particular.

Transporting longer route distances, over longer campaign time periods, from many more originations, and through more States will also involve more interested parties. To date, the number of "stakeholders" that have had "affected" standing (either by statute such as NWPA, or through administrative or judicial proceedings) represent over 682 organizations (authors' research). These include 199 state transportation agencies, 140 state emergency response agencies, 33 state utility commissions, and 28 public interest groups. Most of the issues raised by stakeholders have focused on accident prevention and mitigation measures such as routing and emergency response procedures and capabilities.

CHECKLIST OF RAIL TRANSPORTATION SYSTEM DESIGN SPECIFICATIONS

There will be a number of significant impacts on future spent-fuel rail transportation systems arising from the emerging issues cited above and their resolution. Based on historical spent-fuel rail shipment experience, the anticipated volume of future spent-fuel rail shipments, and the nature of the emerging issues, the authors have developed the following checklist (abbreviated listing, Table 4) of system specification guidelines and criteria for identification and resolution of issues and the specification of future spent-fuel rail transport systems.

Table 4. Checklist of Rail Transportation System Design Specifications

Physical Capabilities • Fixed Assets - Track; Structures (e.g. bridges, tunnels) - Equipment (e.g. communications, switching) • Rolling Stock (locomotives, cars) • Classification Yards and Interchange Points	Testing • Acceptance testing of equipment • "Cold test" runs • Quality assurance surveys • Emergency response tests • FRA inspections
Non-Physical Capabilities • Carrier-Specific - Financial stability - Equipment/track maintenance records - Interchange flexibility • Route-Specific - Accident statistics - Traffic - Non-track route characteristics	Special Requirements/Services • Regulatory compliance • Emer. response procedures and equipt. • Shipment security • Shipment escort/surveillance • Personnel selection • Security-planning assistance • Public awareness/education assistance • Railroad employee training • State/local interactions
Service Operations • Regular or dedicated trains • Linehaul • Shipment frequency/schedule • Special handling • Speed limits • Classification/interchange operation parameters • Holding facility specifications • Turnaround time • Train priority • Shipment handling - interrupted/prevented service	Financial • Rates - Loaded cask car; empty cask car - Buffer car; escort personnel and/or car - Switching terminal; holding facilities - Interrupted movement handling - Emer. services; other provided services • Rate increases • Billing • Payment procedures • Liability • Indemnification

Source: E. J. Bentz & Associates