One Approach to Accepting and Transporting Spent Fuel From Early-Generation Reactors with Short Fuel Assemblies

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ABSTRACT. In the early days of development of commercial nuclear power reactors in the U.S., the overall length and uranium loading of the fuel assemblies were considerably less than those of later generation facilities. In turn, some of these early facilities were designed for handling shorter casks than currently-certified casks. The spent fuel assemblies from these facilities are nearly all standard fuel within the definition in the Standard Contract (10 CFR 961) between the utilities and the U.S. Department of Energy (DOE) (the Big Rock Point fuel cross-section is outside the standard fuel dimension), and the utilities involved hold early delivery rights under DOE's oldest-fuel-first (OFF) allocation scenario. However, development of casks suitable for satisfying the acceptance and transportation requirements of some of these facilities is not currently underway in the DOE Cask System Development Program (CSDP). While the total MTU of these fuels is relatively small compared to the total program, the number of assemblies to be transported is significant, especially in the early years of operation according to the OFF allocation scenario. We therefore perceive a need for DOE to develop an approach and to implement plans to satisfy the unique acceptance and transportation requirements of these facilities. One such approach is outlined below.

REACTOR TRANSPORTATION INTERFACE CONSTRAINTS. The reactor facilities and related spent fuel assemblies which we identified for special consideration in our assessment of Federal Waste Management System (FWMS) interface requirements are listed in **Table 1**. The facility constraints and fuel characteristics fall into two categories: (a) Facility constraints which may limit the size and weight of a cask that can be efficiently handled in the facility, and (b) Fuel assembly characteristics which may require special transport casks in order to optimize payload. The key, generic facility constraints we identified are listed in **Table 2**.

With respect to cask handling constraints, the objective of the special consideration was to eliminate or, at least, to minimize modifications to plant facilities and operating specifications and procedures which would be required to accommodate full-size casks ("full-size" means truck or rail/barge casks with a 180" nominal cavity length as required for all current generation LWR reactor fuel assemblies). This is particularly important because only three of the ten identified reactors are expected to have significant operating life beyond the turn of the century. The other seven reactors have already been retired, or will be in the near future. Accordingly, expenditures for modifications to operating procedures (often requiring NRC approval) and for special equipment appear to be highly undesirable. While the reactor owners may elect to eliminate some of these constraints to reduce cask handling and loading costs and to enable utilization of higher payload casks, this possibility is not

TABLE 1. CHARACTERISTICS OF SHORT FUEL ASSEMBLIES TO BE ACCEPTED INTO THE FEDERAL WASTE MANAGEMENT SYSTEM (1) (2)

REACTOR NAME AND TYPE	ACCEPTANCE PRIORITY RANKING POSITION OF FIRST BATCH (3)	RUN OUT OF STORAGE AND FINAL SHUTDOWN DATES (4)	TOTAL NO. OF ASSY'S ACTUAL OR PROJECTED (4) (5)	FUEL ASSEMBLY CHARACTERISTICS BEFORE IRRADIATION WITHOUT CONTROL ELEMENTS (4)(6)(9)					AS-DISCHARGED CHARACTERISTICS (4)(6)(8)(9)					
				NOMINAL OVERALL LENGTH	SQUARE CROSS-SECTION	NOMINAL ASSEMBLY WEIGHT-LBS	URANIUM LOADING RANGE-KG	ENRICH-MENT W/O U-235	AVERAGE SPECIFIC POWER KW/KG (7)	AVERAGE BURN UP RANGE GWD/MTU	RANGE OF DISCHARGE DATES	OVERALL LENGTH WITH CONTROL ELEMENT	OVERALL LENGTH WITHOUT CONTROL ELEMENT	SQUARE CROSS-SECTION ENVELOPE
BIG ROCK POINT BWR	744	2000 2000	560 P	84.0	6.52	457	112 - 138	2.86 - 3.63	23	1.5 - 25	1974 - TBD	NA	85.0	6.9
HUMBOLDT BAY BWR	126	NA 1984	389 A	95.0	4.67	276	70 - 77	2.11 - 2.43	16	9.0 - 18.2	1971 - 1984	NA	96.0	4.9
LACROSSE BWR	351	NA 1987	333 A	102.5	5.62	377 - 458	108 - 120	3.69 - 3.77	20	14.5 - 14.9	1972 - 1987	NA	103.5	5.9
YANKEE ROWE PWR	173	2002 1992	533 P	111.8	7.62	720 - 800	229 - 273	3.70 - 4.94	32	25.5 - 32	1974 - TBD	NA	112.8	7.9
DRESDEN ONE BWR	5	NA 1978	889 A	134.4	4.28	328	95 - 111	1.47 - 3.5	15	4.5 - 29	1969 - 1978	NA	135.4	4.5
INDIAN PT. ONE PWR	405	NA 1974	160 A	138.8	6.27	900	191	4.11	27	16.7	1972 - 1974	NA	139.8	6.5
HADDAM NECK PWR	32	1995 2007	1450 (10) P	137.1	8.42	1250 - 1420	363 - 422	2.95 - 4.0	30	18.5 - 34	1970 - 2007	139.5	138.0	8.7
SAN ONOFRE ONE PWR	55	2004 1992	665 (11) P	137.0	7.76	1250	366 - 373	3.8	23	29	1970 - TBD	139.5	138.0	8.0
FT. CALHOUN PWR	1045	2002 2008	1086 P	148.8	8.1	1220	353 - 376	2.62 - 3.53	31	27.5 - 36.4	1975 - TBD	161	149.8	8.4
PALISADES PWR	1556	1994 2011	1287 P	149.1	8.2	1360	391 - 413	2.47 - 2.79	31	16 - 28.6	1975 - 2011	NA	150.1	8.5

1. "Short" as used here includes all commercial light water reactor fuel assemblies less than 150 inches long with control elements removed.
2. Data in this table must be confirmed by respective reactor owners before final design and NRC certification of cask designs.
3. Number in this column is the reactor's position in Cumulative MTU Accepted Column in the Annual Capacity Report Table B.1, RW-0331P, 12/91 excluding DOE owned fuel.
4. From EIA SR/CNEAF/92-01, 3/92 and the OCRWM M&O
5. From DOE/RL-90-44, 11/90 and the OCRWM M&O
6. From DOE/RW-0184, 12/87
7. Reactor Thermal Power divided by Total Uranium Loading
8. Dimensions include author's estimate of allowance for irradiation growth and non-fuel hardware.
9. All dimensions in inches.
10. Includes 82 Assys at Morris.
11. Includes 270 Assys at Morris and those in Units 2 and 3 on site.

NA - Not Applicable
TBD - To Be Determined

SOURCE: E. J. Bentz & Associates from the referenced data

Table 2.
KEY GENERIC AT-REACTOR HANDLING AND TRANSPORTATION CONSTRAINTS

- Inadequate or non-existent railroad spur to site or lack of trackage into receiving area
- Inadequate railroad trackage on-site for multiple-cask dedicated train makeup
- Inadequate crane coverage and/or headroom in vehicle receiving bay or fuel handling building
- Inadequate airlock useable dimensions
- Inadequate crane design capacity or operational rating for cask handling
- Mismatch between crane block and standard lifting yoke
- Prohibited crane block immersion
- Inadequate set-down or decon area and/or loading pool lateral dimensions for full-size casks and yokes
- Inadequate floor strength in loading bay and/or cask set-down area for static or dynamic loadings
- Inadequate pool depth or fuel handling crane lift height to accommodate cask length
- Unresolved cask drop accident provisions
- Prohibited cask handling while reactor operating
- Seasonal constraints on cask handling or transportation operations

SOURCE: E.J. Bentz & Associates

considered in this paper.

With respect to fuel assembly length and uranium loading, **Table 1** indicates that the payload in full-size casks will be less than optimum at the facilities considered.

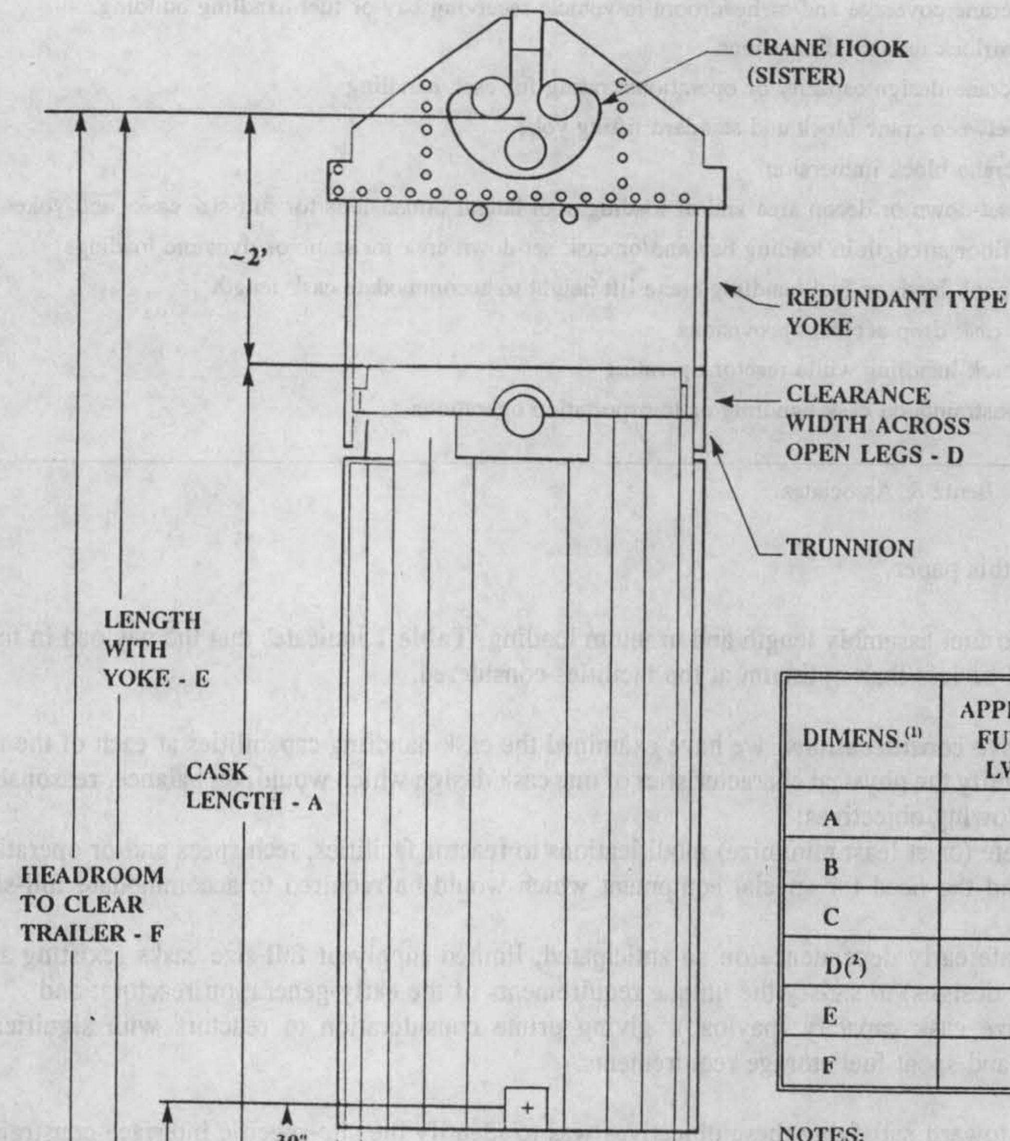
Given the above considerations, we have examined the cask handling capabilities at each of the ten reactors to identify the physical characteristics of one cask design which would, on balance, reasonably satisfy the following objectives:

- To eliminate (or at least minimize) modifications to reactor facilities, tech specs and/or operating procedures, and the need for special equipment which would be required to accommodate full-size casks;
- To eliminate early dependence on an anticipated, limited supply of full-size casks (existing and projected new designs) to satisfy the unique requirements of the early-generation reactors; and
- To optimize cask capacity (payload), giving prime consideration to reactors with significant projected life and spent fuel storage requirements.

The first step toward satisfying these objectives was to identify the site-specific interface constraints at each reactor, and thereby to determine the physical characteristics of a suitable cask. The principal sources of site-specific data were the DOE draft (Rev.0) "Site and Facility Waste Transportation Services Planning Documents" for each of the ten reactors. In some cases the DOE FICA/NSTI data were used to obtain additional detail (NAC: Facility Interface Capability Assessment Project Report and Data Base, ORNL/SUB/86-97393, June 91; Near-Site Transportation Infrastructure Assessment, July 91). In analyzing facility constraints related to full-size casks, the cask dimensions depicted in **Figure 1** were used. The site-specific findings are detailed in the full paper.

Summary of site-specific findings: Indian Point One is the most limited facility, and it appears to be impractical to modify this retired facility to handle a full-size legal weight truck (LWT) cask. While it may be feasible to provide special equipment and to modify procedures for use of a full-size,

FIGURE 1. CASK HANDLING DIMENSIONAL PARAMETERS



DIMENS.(1)	APPROXIMATE FULL-SIZE(3) LWT CASK
A	17
B	3
C	4
D(2)	5
E	19
F	25

NOTES:

1. Dimensions in feet
2. Also, dimension across conventional single yoke
3. Full-size means a cask with a 180" long internal cavity for all current generation LWR fuel assemblies

SOURCE: Adapted from NAC with E.J.Bentz & Associates estimates on full-size LWT casks

LWT cask at Big Rock Point and La Crosse, it is expected that if it were available, those utilities would opt to utilize a "short" cask, thereby eliminating significant interface problems. The "short" cask would also mitigate or eliminate headroom uprighting and/or fuel assembly lift height problems and special equipment needs at Humboldt Bay, Dresden One, Haddam Neck, and San Onofre One. The incentive to utilize the "short" cask at Yankee Rowe would be to increase payload.

CASK DESIGN ALTERNATIVES. The key to optimal acceptance and transport of the assemblies identified in **Table 1** could be in developing one or more "short" casks with cavity lengths designed to accommodate the wide variations in fuel lengths. Given the required cavity lengths, the cavity diameters could be designed to maximize payloads. With respect to accommodating identified, site-specific constraints, it appears that a LWT cask would be most desirable.

Given the apparent requirements for a LWT cask, and the related nominal hook weight and package weight of 25 tons, the next step was to determine feasible cask cavity diameters and, in turn, cask payloads for the various fuel assemblies. Based on the shielding required by the operating PWR's (Haddam Neck, Ft. Calhoun, Palisades), preliminary cask weights were estimated for a cask cavity 161" or 151" long, sized for four PWR assemblies, and using depleted uranium shielding. It was calculated that such a cask would not satisfy LWT weight limits (80,000 lbs Gross Combination Weight (GCW). Rather than sacrifice cask payload to accommodate Ft. Calhoun and Palisades fuel assembly lengths at the expense of the remaining eight reactors, it was judged prudent for this preliminary concept design to reduce maximum cavity length to 140".

Table 3 provides a depiction of two projected, "short" cask designs and the respective reactors that they would serve. Also depicted is a reference comparison of "standard size" cask capacities (both existing and projected, new designs); note the substantial capacity increase enjoyed by the "short" casks.

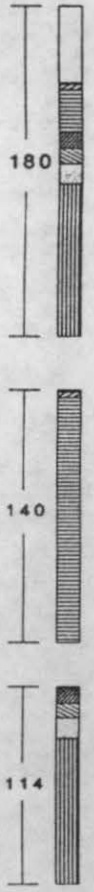
Whereas a two-design approach would necessitate additional development, certification, and fabrication costs (vs. one design), there would be a reduction in the number of trips required and an associated reduction in overall shipping costs. This would be achieved due to the higher capacity payload of the two design approach; **Table** 4 compares the projected number of trips for each of the two alternatives.

Preliminary findings of the authors -- on comparing both the estimated development costs and the shipping costs for each of the design approaches -- indicate that a single, 140" design may offer a comparative cost advantage over the two design approach (140" plus 114") for the eight identified facilities.

SUMMARY: POTENTIAL AVOIDED COSTS AND SYSTEM BENEFITS OF A "SHORT" LWT CASK.

a. Neither currently-certified nor projected, new-design, full-size LWT casks can be handled at the Indian Point One, La Crosse, and Big Rock Point reactors without requiring significant facility modifications and/or resorting to on-site dry transfer from a small transfer cask.

Table 3. ALTERNATIVE CASK DESIGNS TO OPTIMIZE SERVICE TO EIGHT REACTORS.



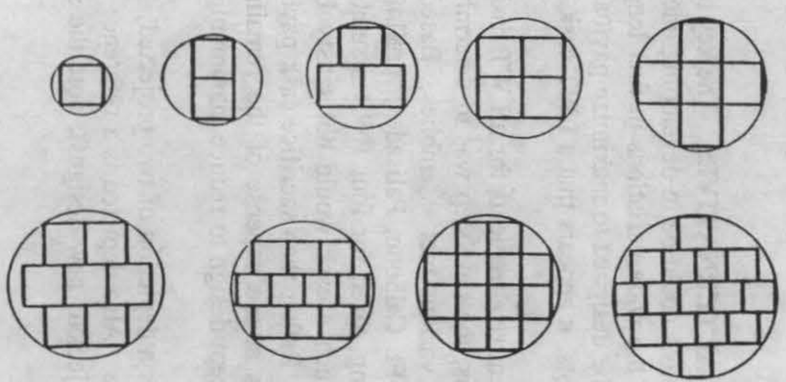
Reactor Facility	Fuel Assembly Nominal Dimensions		No of Fuel Assys	Full-size LWT cask capacities		Aprox. Distance to Generic Eastern MRS (1)	Approx. Distance to Generic Western MRS (1)
	Overall Length	Cross Section		Existing	New		
Indian Point 1	139	6.27	160	1	4	500	2520
Haddam Neck	138	8.42	1450	1	2	560	2600
San Onofre 1	138	7.76	665	1	2	2700	645
Dresden 1	135	4.28	889	2	5	800	1720
Yankee	112	7.62	533	1	2	625	2690
LaCrosse	103	5.62	333	2	5	1100	1820
Humboldt Bay	95	4.67	390	2	5	3300	1050
Big Rock Point	84	6.52	560	1-2	4-8	920	2220
			4984				

26 X 140 "SHORT" LWT cask capacities

Indian Point 1	139	6.27	160	5
Haddam Neck	138	8.42	1450	4
San Onofre 1	138	7.76	665	4
Dresden	135	4.28	889	12
			3164	

31 X 114 "SHORT" LWT cask capacities

Yankee	112	7.62	533	7
LaCrosse	103	5.62	333	10
Humboldt Bay	95	4.67	390	15
Big Rock Point	84	6.52	560	10
			1820	



Typical arrangements of square fuel assemblies in cylindrical cask baskets.

1. Transportation System Data Base, Rev.0 12/89
SOURCE: Table 1 and E.J. Bentz & Associates conceptual estimates

Table 4.
COMPARISON OF NUMBER OF TRIPS FOR ALTERNATIVE CASK DESIGNS

		One Design (140")		Two Designs (140",114")	
Reactor	Number of Assemblies	Cask Capacity	No. of Trips	Cask Capacity	No. of Trips
Big Rock Point	560	5	112	10	56
Humboldt Bay	390	12	33	15	26
La Crosse	333	5	67	10	34
Yankee Rowe	533	4	179	7	102
Dresden 1	889	12	75	12	75
Indian Point 1	160	5	32	5	32
Haddam Neck	1450	4	339	4	339
San Onofre	665	4	140	4	140
TOTAL	4984		977		804

SOURCE: E.J. Bentz & Associates

SUMMARY: (continued)

b. For the eight reactor facilities that have been identified for efficient, "short" LWT use, transport capacities would be more, and required loading times would be less, than those provided by full-size casks:

Reactor	Existing Cask Capacity	Projected Cask Capacity(1)	Short Cask Capacity
Humboldt Bay	2	5	12
Dresden One	2	5	12
Indian Point One	1	4	5
Big Rock Point	1-2	4-8	5
La Crosse	2	5	5
Yankee Rowe	1	2	4
Haddam Neck	1	2	4
San Onofre One	1	2	4

(1) Estimated assuming that projected new cask designs would be modified as required.

SOURCE: E.J. Bentz & Associates

c. Availability of short LWT casks could minimize the impact on the FWMS of a utility's fuel delivery selection, within its OFF allocation, involving long fuels vs. short fuels. We anticipate an approximate five-year schedule for the design, certification, and production of fleet quantities of the short cask, and of new, higher-capacity, full-size LWT casks. If a short cask is not available by 1998, we anticipate a diversion of potentially limited-supply, full-size new or existing casks to inefficient, low-payload use.

d. In the lower-bound acceptance scenario (400 MTU, 1998), 753 BWR and 175 PWR (Haddam Neck and San Onofre) assemblies are to be accepted by DOE from the Morris facility. If the availability of new, higher-capacity casks is not assured, the currently-certified IF-300 Rail and NLI/NAC LWT casks may have to be utilized at this facility. We estimate that this option would require **45** IF-300, and **175** LWT cask loadings, and associated trips; this potentially represents a significant under-utilization of the total transport capacity which we project may be available during the start-up of the FWMS. If the suggested short cask is used, the LWT loadings could be reduced to **44.** Cask handling operations at, and associated trips from, Haddam Neck (76 assemblies, 1998) and Humboldt Bay (95 assemblies, 1998), would also be greatly reduced.

e. We project that a timely FWMS utilization of the short casks could enhance certain utilities' flexibility in providing for necessary, at-reactor storage. Examples are cited in the full paper for Commonwealth Edison, Consolidated Edison, PASNY, Pacific Gas & Electric, Consumers Power, GE, Big Rock Point, and Haddam Neck.

f. Early deployment of short casks at shutdown reactors (eg., Indian Point One, La Crosse, Humboldt Bay, Yankee Rowe, Dresden) could provide the DOE an excellent handling and transportation demonstration and worker training opportunity, without interfering with utility operations at on-line reactors.

g. Given the early availability of the short casks, reactor site and transport operations services related to several of the "short-fuel" reactors could be well enough defined to contract an early, "service job" to the private sector. This could facilitate DOE "privatization" goals.

h. It is quite likely that the short LWT casks could be useful in accepting other fuels/wastes as follows:

- DOE-owned, Big Rock Point fuel from West Valley
- General Atomics Research Reactor fuel
- Non-fuel assembly hardware (NFAH) and other, greater than class C wastes (55 gallon drums could be accommodated)
- Failed fuel assemblies and NFAH from La Crosse, and failed assemblies from Haddan Neck
- DOE, DHLW canisters (from West Valley, Savannah River)

ACKNOWLEDGEMENT. The authors wish to associate with this paper Dr. John W. Bartlett, Director of the DOE Office of Civilian Radioactive Waste Management, and Mr. Ronald A. Milner, Associate Director for Storage and Transportation, who encouraged the performance of the analyses, which were funded in part by DOE Contract No. DE-AC01-87RW00060, under subcontract to Roy F. Weston, Inc.