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# Final Report on Breeder Spent Fuel Handling (BSFH) Cask Study for FY83

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J. M. Diggs

Prepared by  
Sandia National Laboratories  
Albuquerque, New Mexico 87185 and Livermore, California 94550  
for the United States Department of Energy  
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**FINAL REPORT ON BREEDER SPENT FUEL  
HANDLING (BSFH) CASK STUDY FOR  
FY83**

**J. M. Diggs**  
Sandia National Laboratories  
Transportation Systems Technology and Analysis Division  
Albuquerque, New Mexico 87185

**ABSTRACT**

This report documents a study conducted to investigate the applicability of existing LWR casks to shipment of long-cooled LMFBR fuel from the Clinch River Breeder Reactor Plant (CRBRP) to the Breeder Reprocessing Engineering Test (BRET) Facility. This study considered a base case of physical constraints of plants and casks, handling capabilities of plants, through-put requirements, shielding requirements due to transportation regulation, and heat transfer capabilities of the cask designs. Each cask design was measured relative to the base case.

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## SUMMARY

This report documents work completed in FY83 for the Breeder Spent Fuel Handling program. At that time, the focus was primarily on two facilities: the Clinch River Breeder Reactor (CRBR) and the Breeder Reprocessing Engineering Test (BRET) facility. The emphasis of the study described herein is consistent with that FY83 guidance. The situation changed in FY84 with the termination of funding for the CRBR. There are, however, continued plans for future (and larger) breeder plants as well as for the BRET. Those future LMFBR plants will nevertheless experience problems and seek solutions similar to those of the CRBR in the transportation of spent fuel. This study's results and conclusions should aid in directing those future LMFBR transportation studies.

Specifically, this study was undertaken to reveal the applicability of current cask designs to future LMFBR needs. The transportation of spent fuel from breeder reactors constitutes one of the final steps in closing the fuel cycle. Previous studies have concentrated on shipping short-cooled fuel to enhance economics. The technical difficulties in doing so have directed the program to look at the benefits and penalties associated with transporting long-cooled fuel. As a first step, the inventory of current LWR cask designs was examined for suitability in meeting physical, geometric and shielding requirements. These requirements were developed from plant and transportation requirements.

A detail of the methods and results of a study to determine the application of current LWR casks to the shipment of LMFBR spent fuel is presented in this report. The method involved several steps: 1) base case criteria development, 2) survey of current cask designs, 3) shielding calculations to assess adequacy of current designs, and 4) heat transfer calculations and handling studies. Finally, the existing cask designs were compared to the base case criteria for applicability.

The result is that no one cask, as it is currently licensed, suits the needs of CRBR to ship spent fuel to the BRET. Each of the casks would require some modification to meet either physical or through-put constraints of the plants. Some of these short-comings are obvious, such as a single assembly cask like the T-3 which is too short to hold a CRBR assembly. It was also found that none of the designs meets normal transport shielding requirements. Thus, the structural design changes required (adding wall thickness for shielding) would, in turn, require new analysis in the structural, thermal, and shielding areas. The anticipated modifications then, are not trivial. Although industry has not been solicited directly, the wisdom of opening an existing license by proposing modifications of this type is questioned. The alternative of submitting a new Safety Analysis Report for Packaging (SARP) of a new design appears preferable, although this decision is ultimately one that the licensees must make.

## METHOD OF STUDY

In order to complete this task of investigating current LWR cask designs, a base case was developed against which to measure these designs. This base case consisted of 22 requirements. These requirements arise due to plant restraints (from BRET and CRBR), transportation regulations, and assumptions basic to this study (such as long-cooled fuel).

Next, a survey of available designs was generated. Data included in this were geometric features, shielding materials, allowable heat loads, and weights. This survey allowed initial comparisons to the base case criteria. It also revealed the type and quantity of shielding materials currently used and defined the shielding calculations required to assess these LWR cask designs' adequacy in transporting spent LMFBR fuel.

Concurrent to the shielding calculations, review of a previous CRBR time and motion study [1] was completed. Due to the convoluted cask movement within that plant, it was desirable to investigate how best to meet the through-put defined by the base case. Although this exercise was not performed for the BRET plant, later discussions have concluded that BRET's needs are as severe as CRBR. Indeed, the waste and spent fuel shipping and receiving facilities are one and the same in the BRET. This situation requires coordination of these two streams together with the plant campaign schedules to insure efficient plant use.

As the study progressed to this stage, certain casks were eliminated and others became front-runners. Heat transfer calculations were performed on one front-runner cask (the TN-8) that appeared to meet most of the base case criteria.

As a final step, a matrix of the base case criteria and the cask survey were merged to illuminate the cask possibilities. Actual modifications to casks to meet the base case criteria were not investigated during this study.

## BASE CASE CRITERIA

As a first step, certain base case criteria were developed. These criteria formed the basis for the entire study. The primary assumption of this study which allows current LWR casks to be considered for transport of LMFBR spent fuel, is that of allowing the fuel approximately two years cooling time before shipment. The remaining assumptions used in this study either stem from this one or are plant and transportation constraints placed on any spent fuel transportation system operating between these two plants. These criteria follow.

1. Spent fuel assemblies shall not be cleaned but will be "drip-dried". A residual sodium level of 200 grams per assembly is assumed.
2. Spent fuel assemblies will not be disassembled prior to shipping.

3. Spent fuel assemblies will not be canistered.
4. The decay heat output shall not exceed 1.4 kW per assembly.
5. The dose rates external to the cask shall not exceed 200 mrem/hr at the surface or 10 mrem/hr at 2 meters from the surface.
6. The cask surface temperature during in-plant handling shall not exceed 52 C (125 F).
7. Cask coolant during shipment shall be nitrogen. Cask coolant during loading shall be argon.
8. The fuel pin temperatures shall not exceed 538 C (1000 F) for normal conditions and 816 C (1500 F) for accident (off-normal) conditions.
9. The cask shall have redundant rigging capability for in-plant handling.
10. The loaded cask and associated lifting fixtures shall not exceed 68 tonnes (75 tons) in weight.
11. The cask and associated lifting fixtures shall be designed for a crane hook height of at most 12.8 m (42 feet).
12. The cask shall not be greater than 2.1 m (7 feet) in diameter.
13. The cask shall not be greater than 5.5 m (18 feet) long.
14. The inner lid and/or closure plug must weigh less than 4.1 tonnes (4.5 tons) and have a diameter less than 76 cm (30 in).
15. The loaded cask weight shall be less than 68 tonnes (75 tons) due to BRET transporter limit.
16. The cask must sustain a 2 assembly/day shipping rate (due to BRET through-put requirements).
17. The cask turnaround time in-plant shall average 12 hours per assembly per loading/unloading station.
18. The cask shall be designed such that no "special" maintenance shall be required at loading/unloading stations. Seal replacement shall be possible at stations.
19. The reactor shall receive the cask with a verified seal which is re-seatable after lid removal by the plant.
20. The cask shall be designed to have an availability of 300 days per year.
21. The cask shall be capable of carrying one assembly.
22. The cask and its interfaces with plants shall meet seismic requirements of CRBRP and BRET.

In addition to these base case requirements, several alternatives were considered. These are listed below under their corresponding base case criteria number.

3. The shipment of canistered failed fuel will be considered.
4. Decay heat outputs to 3 kW/assembly shall be considered.
5. A dose rate external to the cask not to exceed 10 mrem/hr at the surface shall be considered.
7. Cask coolant during shipment of helium shall be considered.
10. The loaded cask and lifting fixtures shall not exceed 114 tonnes (125 tons) in weight.
15. The loaded cask shall not exceed 91 tonnes (100 tons).
21. The cask shall be capable of carrying more than one fuel assembly.

#### EXISTING CASK SURVEY

Physical characteristics of a list of currently designed casks was used to compare to the base case criteria. The information needed was obtained from current certificates of compliance [4] as well as the Safety Analysis Reports on Packaging (SARPs) [5-12]. Items of concern included overall diameters, lengths and weights, internal dimensions, shielding materials and thicknesses, and rated allowable heat loads.

The resulting data is presented in Tables I and II. This data is reproduced in English units in Appendix A.

Along with the cask physical applicability, the number available in the U. S. was investigated. The current cask inventory is presented in Table III. It is unlikely that the inventory of any design would be sufficient to ship CRBR spent fuel. A quick study of transportation needs [13] showed that at least seven three-assembly casks would be required to sustain sufficient shipments to meet CRBR requirements. There is no fleet of any one design of that size currently. It is therefore likely that the shipment of fuel from CRBR to BRET will require the manufacture of a new fleet even if an existing design were found suitable.

#### SHIELDING CALCULATIONS

A matrix of desired shielding calculations was drawn up from the cask survey. This matrix endeavored to cover most of the combinations of gamma shielding materials encountered in the survey, including steel, depleted uranium, and lead. The matrix also covered different numbers of assemblies in an effort to encompass all of the designs. An upper limit of 9 assemblies was used for two

Table I. Overall Dimensions of Casks

Cask Type	Overall Length <sup>a</sup> (m)	Overall Dia. (m)	Inner Cavity Dimensions (m)	Rated Load kW	Empty Shipping Wt tonnes	Containment Closure dia (m)	Closure Weight tonnes
NAC-1	5.4	1.3	0.34 x 4.52	2.5	22.0	0.61	---
NLI-1/2	4.96 6.02 (IL)	1.2 1.9 (IL)	0.32 x 4.52	10.6	21.0	0.34	0.34
IF-300	4.68 5.07 (IL)	1.85	0.95 x 4.31	11	54.0	0.762	---
NLI-10/24	5.2 (IL)	2.4 (IL)	1.1 x 4.6	70	72.6	1.1	3.7
TN-8	5.5	1.73	3 cells <sup>b</sup> 0.23x0.23x4.3	35.5	36.0	0.62	0.85
TN-9	5.74	1.7	7 cells <sup>b</sup> 0.15x0.15x4.5	24.4	36.0	0.46	---
T -3	4.5 5.4 (IL)	0.67 1.3 (IL)	0.2 x 3.7	0.6	17.0	---	---
NAC-3K	5.4 7.2 (IL)	1.93	1.2 x 4.95	100	97.5	1.2	2.0
TN-12	5.3 5.9 (IL)	1.85	1.28 x 4.58	120	89.0	1.6	5.2

<sup>a</sup>Dimensions including impact limiters are marked (IL)

<sup>b</sup>Integral basket

Table II. Shielding Designs and Capacities of Casks

Cask Type	Steel (cm)	Lead (cm)	Uranium (cm)	Borated Ethylene Glycol (cm)	Water (cm)	Resin (cm)	# Assy. due to therm. <sup>a</sup>	# Assy. due to geom. <sup>b</sup>	# Canned Assys. <sup>c</sup>
NAC-1	3.96	16.8		11.4			1 (0)	1	1
NLI-1/2	4.13	5.6	7.0		12.7		1 (1)	1	1
IF-300	3.8		10.2		13.0		3 (1)	14	7
NLI-10/14	7.62	15.3			24.8		23 (11)	19	19
TN-8	2.6	13.5				15.0	3 (3)	3	3
TN-9	2.6	12.8				15.0	5 (3)	4	4
T-3	3.8	20.3					0 (0)	1	0
NAC-3K	35.6			5.0			34 (15)	19	19
TN-12	30.5					10.2	40 (19)	19	19

<sup>a</sup>Assumes constraints of: # of assemblies = Rated load/ $Q_{eq}$  (numbers in parenthesis indicate allowable for 3kW assembly where  $Q_{eq} = 0.7(1.4)/(1/3)$  kW  
0.7(1.4) = amount to reject in 1/3 length of cask

<sup>b</sup>Assumes 17.78 cm diameter required

<sup>c</sup>Assumes 20.32 diameter needed per canned assembly where: 17.78 cm - assembly  
1.27 cm - canister & clearance

TABLE III  
CURRENT LWR CASK INVENTORY

MODEL	TYPE	AVAILABLE	COMMENTS
NFS-4 (NAC-1)	LWT	1	1 cask contaminated 6 in service
NLI-1/2	LWT	5	NAC Operates
TN-8	OWT	2	2 casks at Barnwell
TN-9	OWT	2	1 cask at Barnwell 1 cask owned by Commonwealth Ed.
IF300	Rail	4	3 by GE, 1 by Carolina Power and Light (CPL)
NLI-10/24	Rail	0(2)	2 casks available, but baskets not available

reasons: 1) it was initially felt that some levelling off of shielding requirements (with respect to the number of assemblies) would occur, and 2) it was felt that a truck shipment was desirable (from BRET through-put considerations) which limited the load carrying capability of the design to some number under 9.

Source data supplied by CRBR [14] for long-cooled fuel was used for these calculations. Specifically, an assembly with a thermal rating of 1.4 kW was used as the base case. A summary of the source data is included as Table IV. The requirement was to determine, given a specified thickness of steel and water, the thickness of other gamma shielding which resulted in meeting regulatory requirements [3]. The 49 CFR 173 regulations require a maximum dose rate of 200 mrem/hr at the surface or 10 mrem/hr at 2 meters from the surface. From past experience with LMFBR fuel, the determining factor was believed to be a maximum dose rate of 10 mrem/hr at 2 meters from the surface. For completeness, the thickness required to meet the regulatory dose rate of 200 mrem/hr at the surface was also calculated. The results of this study are presented in the matrix of Table V. The steel thickness of 3.8 cm (1.5") was virtually universal across all cask designs while the 12.7 cm (5") water equivalent was used to approximate the different neutron shield material types actually used. Figures 1, 2, 3, and 4 show the dose rate results for the 10 mrem/hr at 2 meter case for the various combinations of gamma shielding.

The results of the comparison of these calculations and the cask survey shows that no one design incorporates adequate shielding to transport spent CRBR fuel. The T-3 cask, with 20.32 cm lead, appears to be adequate to carry one CRBR fuel assembly. However, the T-3 has no neutron shielding where as the calculations assumed 12.7 cm (5 in.) water equivalent. Thus, the T-3 would require either additional gamma or neutron shielding to carry one CRBR spent fuel assembly and meet transportation requirements. A similar argument might be made for the NLI 10/24 where almost twice the assumed neutron shield exists. An analysis specific to this design would be required to ascertain if the excess neutron shielding compensates for the apparent lack of gamma shielding in the present study. Calculations of dose rates for each cask design (including exact neutron shield dimensions and properties) is not warranted at this time.

No specific analysis was completed to investigate the alternate shielding requirement of 10 mrem/hr at the cask surface. This alternate requirement was intended to investigate the cask cost vs. the advantages of reduced in-plant personnel exposure. However, due to the additional shielding required for each cask just to meet transportation regulations, it was assumed that this alternative would best be addressed once a candidate cask design is chosen. At that time, a cost trade-off study would be appropriate to compare the additional cost of transporting a heavier cask (or possibly transporting fewer assemblies in a cask) to the cost of personnel exposure. Of course there may be ways to control in-plant worker exposure which do not involve modifying the shipping cask but involve remote handling techniques or shadow shielding in-plant.

TABLE IV

## CRBR Assembly\* Source Term

Gamma Source Term		Neutron Source Term
Energy MeV	MeV/cc-s	
2.8	$4.43 \times 10^7$	$2.8 \times 10^8$ N/s
2.4	$3.54 \times 10^8$	
2.0	$4.20 \times 10^9$	
1.575	$2.60 \times 10^9$	
1.125	$7.25 \times 10^9$	
0.65	$2.05 \times 10^{11}$	
0.2	$6.15 \times 10^9$	

## \*Assumptions and conditions:

1.4 kw assembly

Maximum fuel assembly power is 1.27 times average assembly power

90% of assembly power is in fuel

160 assemblies per fuel replacement campaign

Decay time of: a) 280-380 days for FFTF grade  
 b) 394-527 days for LWR recycle

Table V

## Matrix for LMFBR Shielding Calculations

2 meters = 10 mrem/hr requirement

Surface = 200 mrem/hr requirement

No. of Assemblies	1	3	9
Regulatory Requirements	2 meters	2 meters	2 meters
Gamma Shield Combinations	Surface	Surface	Surface
3.8 cm (1.5") Steel + 12.7 cm (5") H <sub>2</sub> O + N cm Pb (inches)	19.8 cm (7.8")  18.3 cm (7.2")	20.8 cm (8.2")  19.0 cm (7.5")	22.9 cm (9.0")  20.8 cm (8.2")
3.8 cm (1.5") Steel + 12.7 cm (5") H <sub>2</sub> O + N cm dep. U (inches)	11.7 cm (4.6")  10.7 cm (4.2")	12.2 cm (4.8")  11.18 cm (4.4")	13.5 cm (5.3")  12.1 cm (4.75")
3.8 cm (1.5") Steel + 12.7 cm (5") H <sub>2</sub> O + Additional Steel in cm (inches)	30.0 cm (11.8")  27.4 cm (10.8")	31.75 cm (12.5")  28.7 cm (11.3")	35.0 cm (13.8")  31.5 cm (12.4")

FIGURE 1. LWR CASK PARAMETRIC SHIELDING  
1 CRBR fuel element in cask  
Dose rates at 2 meters  
1.5 in Fe + 5 in H<sub>2</sub>O + shielding

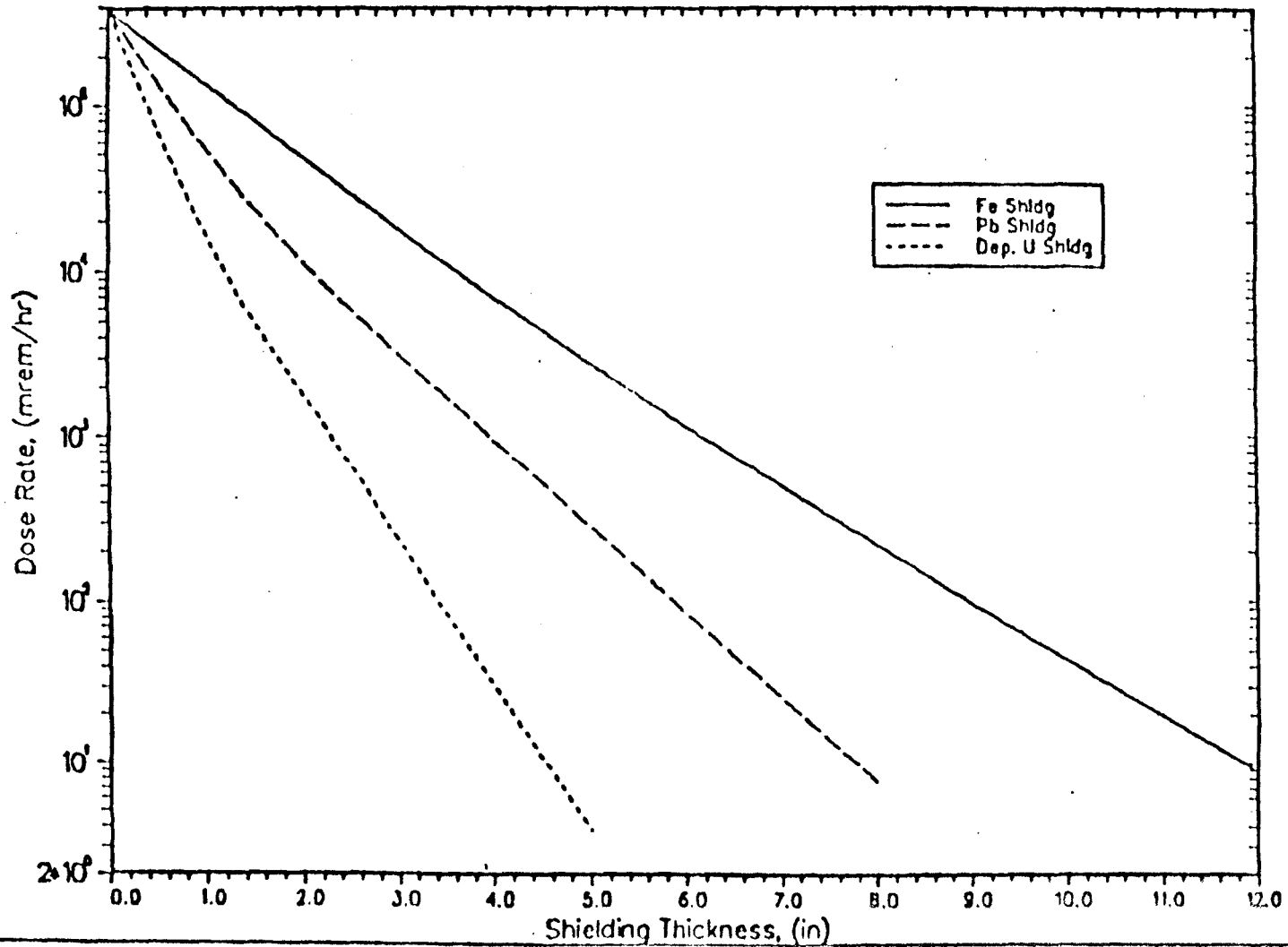


FIGURE 2. DOSE RATES AT 2 METERS  
3 CRBR Fuel Assembly in Cask  
with 1.5 in Fe + 5 in H<sub>2</sub>O + shielding

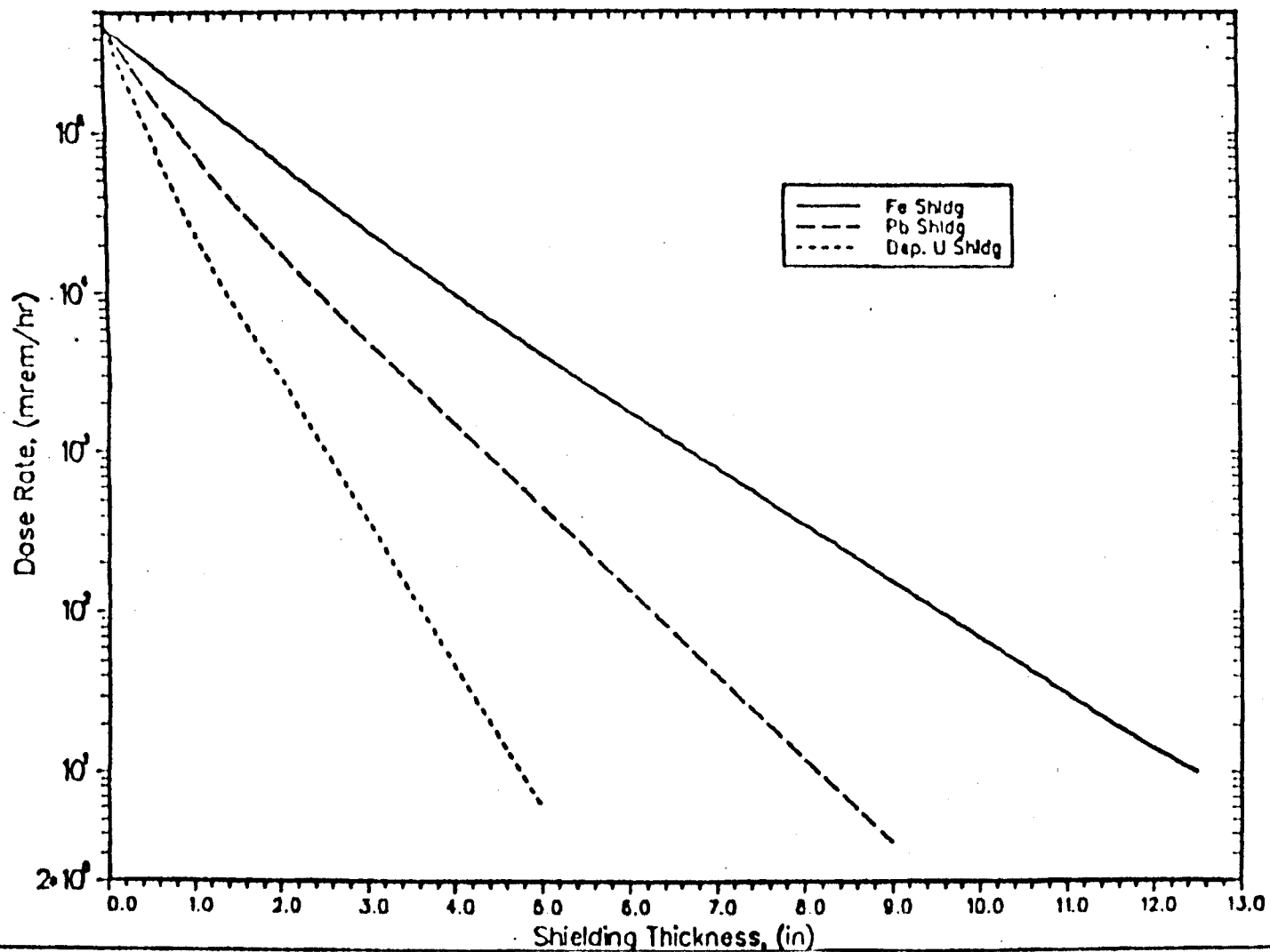


FIGURE 3. DOSE RATES AT 2 METERS  
with 9 CRBR Fuel Assemblies  
in Cask with 1.5 in Fe + 5 in. H<sub>2</sub>O shielding

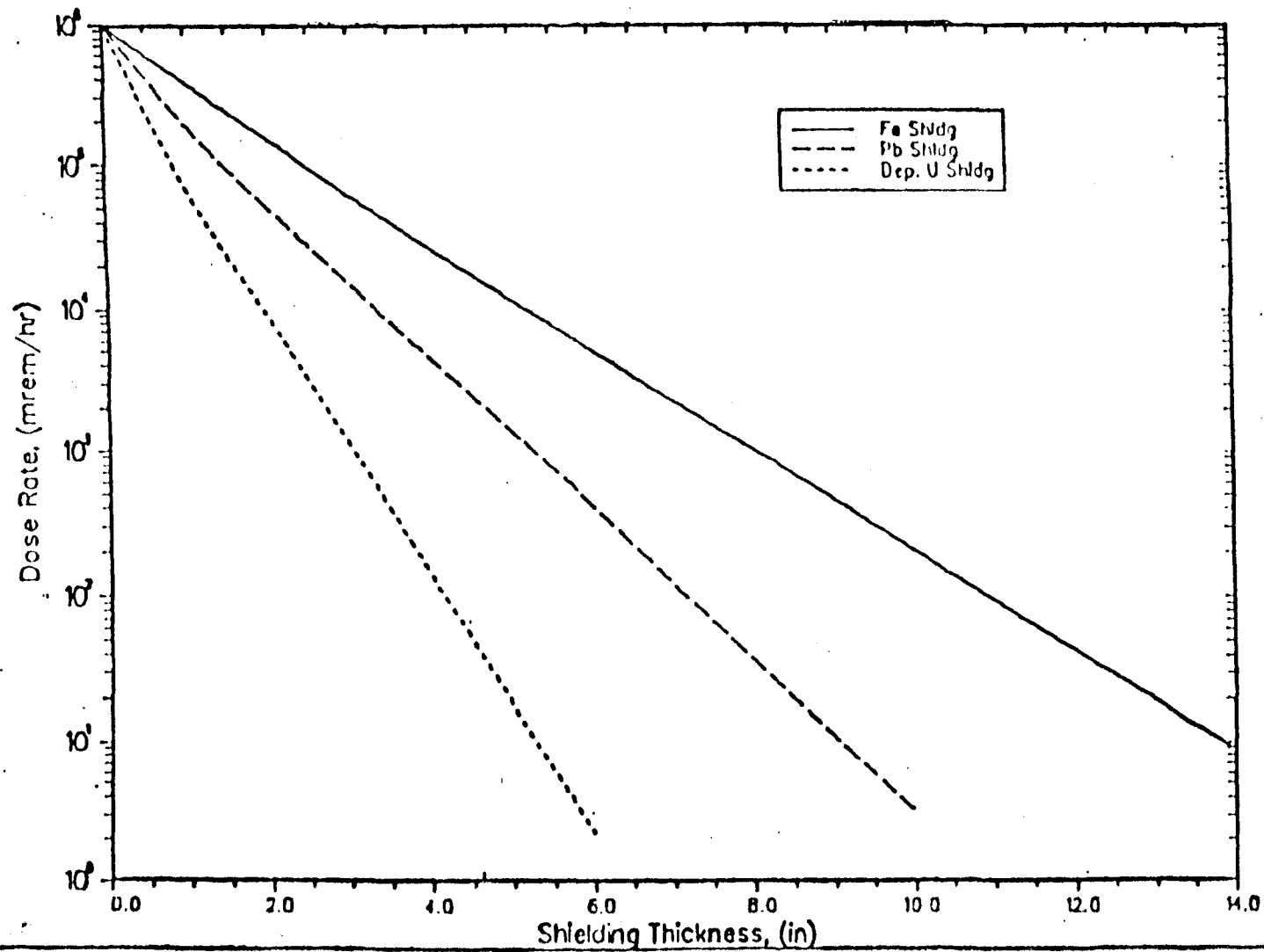
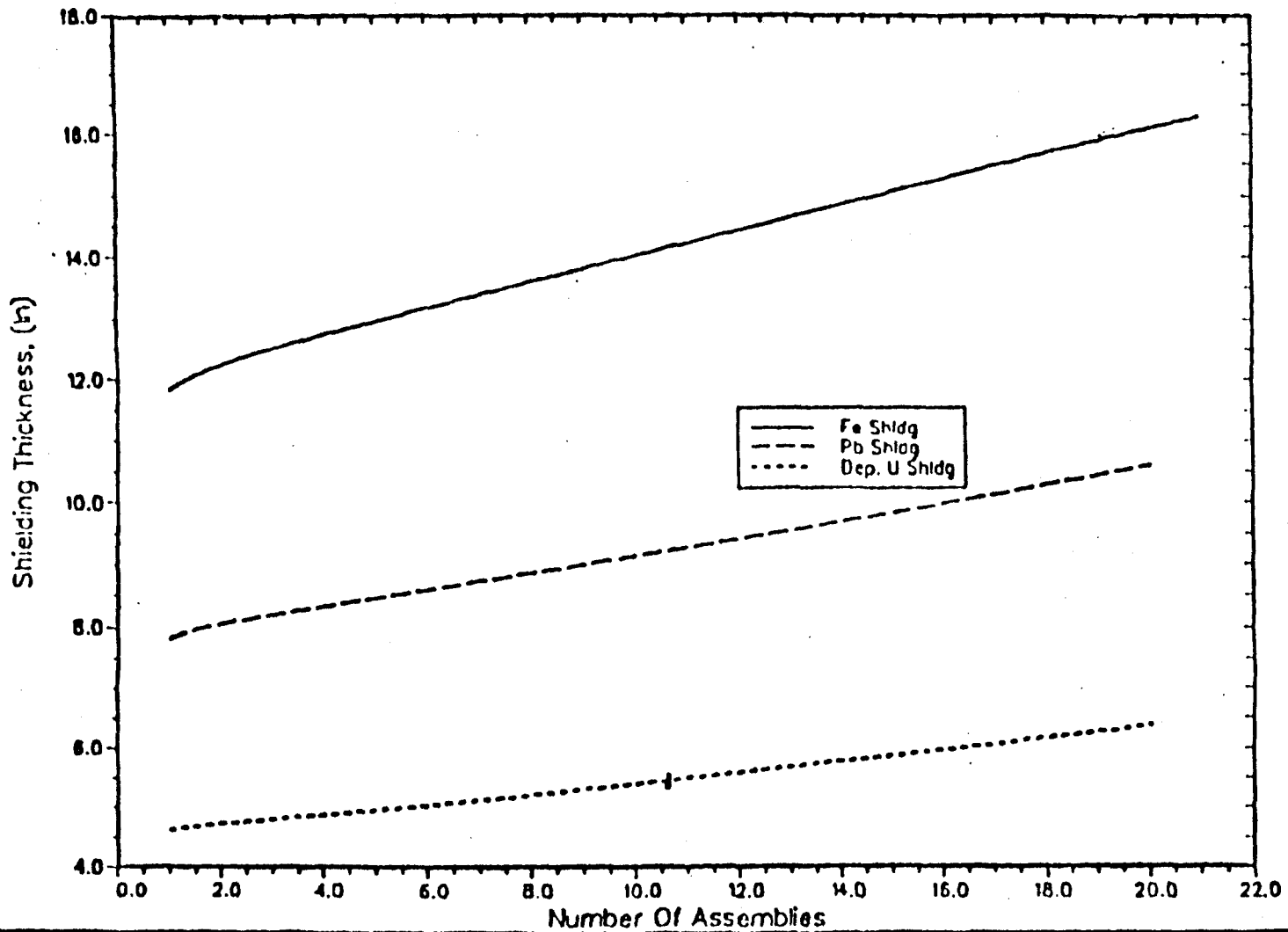


FIGURE 4. SHIELDING THICKNESS REQUIRED  
to meet 10 mrem/hr at 2 meters  
with 1.5 in Fe + 5 in H<sub>2</sub>O + shielding



NOTE: Shielding is linearly extrapolated beyond 9 assemblies.

## TIME AND MOTION STUDY

This portion of the study highlighted the CRBRP's cask handling capability as related to through-put requirements. A study previously completed for the Clinch River Breeder Reactor Plant [1] included a time and motion study. This study traced that conceptual cask design from time of entry (empty) at CRBR, through loading, to leaving the fence of the plant. A total of 127 steps was required for the entire process. For the present task, each step of this study was examined to determine its applicability. The original study involved handling of a 3 level of containment cask with some other exotic features. (This cask had been designed to transport short-cooled fuel.) Because casks under consideration in the current study are generally of a simpler design, some of the steps in the original study have been eliminated. The original study showed a 65 hour 30 minute requirement for moving this complex cask through the plant. Assumption of a single level of containment cask for the present study (vs. triple containment previously) resulted in a 9 hour 15 minute savings. Further, assuming that this cask will handle long-cooled fuel, it will be simpler in design and will not require external in-plant cooling. Validation of the latter assumption requires heat transfer analysis which was not undertaken. It was assumed to give the shortest possible cask handling times. This assumption saved another 5 hours 15 minutes. An additional 2 hours 15 minutes was gained by eliminating all loading time. Of course, some loading time will be required but for a first look, the minimum cask time in-plant was desired. The loading time will be dependent on the number of assemblies the cask carries which is an unknown at this point of the study. Thus, to move a cask in and out of the plant, without loading, would take approximately 48 hours 45 minutes. If we further assume 2 shift days, this time translates to a minimum of just over 3 calendar days per cask.

Thus, CRBR, even with its more relaxed shipping rate requirement of 6 (compared to the BRET) assemblies per week, will need a multi-assembly cask carrying at least 3 assemblies.

The possibility of sending more than one cask through CRBR at one time to enhance through-put was investigated. The impetus was to determine if several one assembly casks could be used in place of one 3 or 4 assembly cask. Of the time spent in CRBRP, 28 hours 30 minutes is spent on the cask corridor transporter where only one cask at a time can be accommodated. This indicates that at CRBR, it will not be possible to handle several casks at one time in the plant any more efficiently than one.

A similar time and motion effort will be required for the BRET facility. A study of waste stream definition and spent fuel through-puts will indicate critical paths and pinch points. It may also disclose additional BRET constraints on the cask design not yet obvious.

## CASK COMPARISON TO BASE CASE CRITERIA

This section details the applicability of each cask to the criteria already described. The form of this section will be to describe the criteria and then list the acceptable casks. It is assumed that new basket configurations would be required in all cases except for the TN8 and TN9 casks which have integral basket designs and cannot be changed out. This and some additional information may be found in matrix form in Table VI.

1. Spent fuel assemblies shall not be cleaned but will be "drip-dried". A residual sodium level of 200 g per assembly is assumed.  
This criteria has not been specifically addressed relative to the LWR cask designs. None of the designs, as currently certificated, can hold this residual sodium. The certificate of the T-3 is expected to be upgraded to handle this amount in FY84.
2. Spent fuel assemblies will not be disassembled prior to shipping.  
This criteria translates to a 4.32 m (14 ft. 2 in.) minimum inside length requirement. Acceptable casks: NAC-1, NLI 1/2, TN-9, IF 300, NLI 10/24, NAC 3K, and the TN-12.
3. Spent fuel assemblies will not be canistered.  
Acceptable casks: All casks with the ability of a basket design change.
4. The decay heat output shall not exceed 1.4 kW per assembly.  
Acceptable casks: All (The T-3 cask has been upgraded as of 7/29/83 to handle 1.4 kW.)
5. The dose rates external to the cask shall not exceed 200 mrem/hr at the surface or 10 mrem/hr at 2 m from the surface.  
Acceptable casks: The T-3 and NLI 10/24 might meet this requirement but detailed analysis is required.
6. The cask surface temperature during in-plant handling shall not exceed 52 C (125F).  
Detailed thermal analysis of each cask relative to handling CRBR spent fuel was not part of this study. This criterion and others like it will be used in later studies.
7. Cask coolant during shipment shall be nitrogen. Cask coolant during loading shall be argon.  
Acceptable casks: None of the casks studied were certified on the basis of nitrogen as the coolant. The T-3 and IF 300 are certified for using air. For heat transfer purposes, the two are similar. For contaminated gas handling in the plants, they may be very different.

Table VI

## SPENT FUEL SHIPPING CASK FEATURES\*

BASE CASE REQUIREMENTS	CASK DESIGNATION									
	T-3	MAC-1/NFS-4	ML-1/2	TN-8, BL	TN-9	1F-300	ML-10/24	MAC-3K	(Model 125) TN-12	
1. The cask shall not be greater than 18 ft. in length. a. Cask b. With limiters c. Shipping fixture	14.0' 17.0'	16.00' 17.83'	16.27' 19.75'	18.00'	18.88'	17.6'	17.04'	17.74' 23.59'	16' 11 1/2" 19' 4.2"	
2. The cask shall not be greater than 7 ft. in diameter (84") a. Cask b. With limiter	26.44" 52"	40" 50"	47 1/8" 75"	68"	68"	64"	96"	75.98"	98.3"	
3. The inner lid, inner shielding closure or other components which must be lifted into the fuel handling cells must not exceed the following maximum horizontal cross-sectional dimension relative to specific cell openings: a. The CRBRP = 63 in. b. The BRET Decon Cell = 30 in.  <i>The maximum dimension of the BRET MPC penetrations (currently 21.6") might be capable of being enlarged to 30 in.</i>  A. Cavity size B. Number and type of assemblies C. Basket required	7.981"x12.25"  NO	13 1/2"x14.83" 1 PWR 2 BWR 4 special YES	13 1/8"x14.83" 1 PWR 2 BWR YES	12 5/8" x 10 x 14.83' long inner container 3 compartments	8.8"x8.8"x14.04' 3 PWR 7 compartments	8.9"x5.9"x14.83' 7 BWR	37 1/2"x15.02' 7 PWR 18 BWR YES	45"x14.95' 10 PWR 24 BWR YES	47.83"x16.24' 12 PWR YES	48" x 15' 12 PWR 32 BWR YES
4. The cask and its interfaces with plants shall meet seismic requirements of CRBRP and BRET.										
5. The decay heat output shall not exceed 1.4 kW/assembly (due to maximum fuel pin temperatures and cover gas assumptions). a. PWR/each b. BWR/each  <i>Decay heat outputs to 8 kW/assembly shall be considered.</i>	0.6 kW (1.4 potential)	2.8 kW  1 2	10.6 kW  1 2	35.5 kW (23.7 kW-TN-BL)	24.4 kW  3 7	61.6 kW (H <sub>2</sub> O)  7 18	70 kW  10 24	100 kW  12	120 kW  12 32	
6. The fuel pin temperatures shall not exceed 1000°F for normal conditions and 1500°F for accident (off-normal) conditions.	801°F									

\*Blanks indicate that information was either unavailable or not computed.

Table VI (con't)

## SPENT FUEL SHIPPING CASK FEATURES\*

BASE CASE REQUIREMENTS	CASK DESIGNATION								
	T-3	MAC-1/NFS-4	ML1-1/2	TN-8, BL	TN-9	1F-300	ML1-10/24	MAC-3K	(Model 125) TH-12
7. The cask surface temperature during in-plant handling shall not exceed 125°F.	140°F					10 ± 210°F during 130°F day with air			
8. Cask coolant during shipment shall be nitrogen (cask coolant during loading shall be argon).  Cask coolant during shipment of helium shall be considered.  D. Designed cooling medium.	Air	Dry	Dry, Helium	Dry	Dry	H <sub>2</sub> O or Air	1 atm He	H <sub>2</sub> O	Air or inert gas
9. The dose rates external to the cask shall not exceed 200 mrem/hr at the surface and 10 mrem/hr at 2 m from the surface.  A dose rate external to the cask not to exceed 10 mrem/hr at the surface shall be considered.  E. Designed shielding materials and thickness 1. gamma 2. neutron	100 mrem at surface 3 mrem at 3 ft.	(27) (neut. dose rate) + (1.4) (gamma dose rate) = 1000 mrem/hr at 3'	gamma dose rate + neutron dose rate = 21 mrem/hr at 3 ft.			(111) (neutron dose rate) + (11.3) (gamma dose rate) = 1000 mrem/hr at 6'			
	8" Pb 3" polyethylene	5" Pb minimum 6 9/16" Pb, 1 5/8" Fe 4 1/2" B <sub>4</sub> H <sub>2</sub> O	2 3/4" depl. U 2 1/8" Pb 5" H <sub>2</sub> O	8.3" Pb 1" steel 8" resin	5.04" Pb 1" steel 6" resin	4" dep. U 2 1/8" SS 4 1/2" H <sub>2</sub> O	6" Pb 9" H <sub>2</sub> O	14" steel 1.96" Resin	12" SS 4" resin
10. The loaded cask and associated lifting fixtures shall not exceed 75 tons in weight. (Notes: Any lift over 55 tons is considered critical).  The loaded cask weight shall not exceed 100 tons (the BART transporter might be capable of being upgraded).  The loaded cask and lifting fixtures shall not exceed 135 tons in weight.  F. Gross weight, empty G. Contents, allowable weight H. Ancillary equipment, weight I. Lifting equipment, weight	37,500 lb 500 lb	80,000 lb	47,500 lb 1600 lb	79,366 lb	79,366 lb	140,000 lb 21,000 lb 35,000 lb	160,000 lb 34,100 lb	198,500 lb 22,000 lb	196,320 lb

\*Blanks indicate that information was either unavailable or not computed.

Table VI (con't)

## SPENT FUEL SHIPPING CASK FEATURES\*

BASE CASE REQUIREMENTS	CASK DESIGNATION								
	T-3	MAC-1/TMS-4	MLI-1/P	TN-8, 8L	TN-9	TF-300	HLI-10/74	MAC-3K	(Model 125) TM-12
11. The inner lid, inner shielding closure or other components which must be lifted into the fuel handling cells must not exceed 4.5 tons.									
12. The cask shall be equipped for redundant lift-path rigging during in-plant handling.	YES				YES	YES		YES	YES
13. The cask and associated lifting fixtures shall be designed for a crane hook height of at least 42 feet. J. Normal mode of transportation K. Attitude during transportation L. Attitude during handling M. Attitude during fuel loading/discharge	Truck Horizontal	Truck, Special Trailer Horizontal	Truck, Special Trailer? Horizontal	Truck	Truck  Vertical Vertical (No Horiz. handling)	Rail** Horizontal with skid  Primary and Secondary lifting Yoke	Special Rail Car** Horizontal?  Special Lift Rig	Special Rail Car Horizontal	*Rail (Road or H <sub>2</sub> O) Horizontal
14. The cask shall be capable of carrying one assembly.  The cask shall be capable of carrying more than one fuel assembly.	1	1, 2, or 4*	1 - 2*	3 PWR*	7 BWR*	7 - 18	10-24	12	12-32
15. Spent fuel assemblies will not be disassembled prior to shipping.									
16. Spent fuel assemblies will not be placed in canisters prior to shipping.  Placement in canisters to enhance heat transfer or to facilitate handling of known failed assemblies will be considered.						Baskets for PWR or BWR	Neutron Po- isoned Baskets	Support Basket	Support Basket
17. Spent fuel assemblies will not be cleaned of sodium. They will only be "drip-dried" prior to shipment. A residual sodium level of 200 g per assembly will be assumed.									

\*Blanks indicate that information was either unavailable or not computed.

Table VI (con't)

## SPENT FUEL SHIPPING CASK FEATURES \*

BASE CASE REQUIREMENTS	CASK DESIGNATION								
	T-3	MAC-1/MFS-4	MLI-1/2	TN-8, BL	TN-9	IF-300	MLI-10/24	MAC-JK	(Model 123) TN-12
18. The cask shall be designed such that, when used in conjunction with the plants, it shall be capable of sustaining a shipping rate of 2 assemblies per day.									
19. The cask turnaround time in-plant shall average 12 hours per assembly per loading/unloading station.									
20. The reactor site shall receive the cask with a verified seal, which is resealable after lid is removed by the reactor.	YES	Pressure test						YES	YES
21. The cask shall be designed such that no "special" maintenance shall be required at loading/unloading stations. Containment boundary seal replacement shall be possible at stations.	YES								
22. The cask shall be designed to have an availability of 300 days per year. (Cask verification testing, maintenance, etc. shall account for no more than 66 days per year).									
FISSILE CLASS	I	III	III	III	III	I	III		Type B, Class I
Miscellaneous	*Neutron shield is removable.	*Fuel rods, irradiated hardware, neutron source components and reconstituted PWR assemblies with less than original number of fuel rods can also be shipped.	*Irradiated uranium and plutonium oxide fuel rods, hardware and neutron source components can be shipped	*Wet Cement layer between Pb and outer layer - TN-8 = 150 rows of fins, TN-8L = 104 rows of fins.	*Wet Cement layer between Pb and outer layer.	*For air coolant 11.7 KW/package 1.7 m <sup>3</sup> /PFR assembly 0.65 KW/BWR assembly Two heads: One = BWR other = PWR Cask and cooling system covered with retractable enclosure **Short distance on highway	*at external radial midplane surface - (625) (neutron dose rate) * (2.5) (dose rate) = <1000 wrem/hr at 3' and at 3 ft from external surface of the bottom - (115)(ndM) * (2)(ydr) = <1000 wrem/hr **special personnel barrier aluminum cage. -Cask was designed to provide double containment for either intact or failed assemblies.	*Personnel barrier required to prevent access to surfaces with temp > 180°F	

\*Blanks indicate that information was either unavailable or not computed.

8. The fuel pin temperatures shall not exceed 538°C (1000°F) for normal conditions and 816°C (1500°F) for accident (off-normal) conditions.  
These data were not computed for each cask carrying CRBR fuel. The maximum pin temperatures cited in the SARPs pertain to LWR fuel only. Due to the differences in heat source geometry, those temperatures are not necessarily applicable to LMFBR fuel, even for comparable heat levels. A TN-8 cask analysis with LMFBR fuel was completed however. The method used followed that in the TN-8 SAR in obtaining temperatures from the external surface to the internal wall. The estimates of the fuel pin temperatures used the method described in [15]. For nitrogen and 1.4 kW/ assembly, there are acceptable pin temperatures. Specifically, the pin temperature with three 1.4 kW assemblies and nitrogen is 438°C (820°F). For the same assemblies and helium, the temperature is 316°C (600°F).
9. The cask shall have redundant rigging capability for in-plant handling.  
Acceptable casks: T-3, TN-8, TN-9, IF 300, NAC 3K, TN-12. A load spreader will probably be required due to the trunnion positions and allowable floor load capacity. Allowable floor loading in CRBR's Reactor Service Building is such that most casks will require the spreader in order to sit the cask on the floor to pick up the opposing trunnions that provide redundant capability.
10. The loaded cask and associated lifting fixtures shall not exceed 68 tonnes (75 tons) in weight (due to BRET crane limit).  
Acceptable casks: T-3, NAC-1, NLI 1/2, TN-8, TN-9
11. The cask and associated lifting fixtures shall be designed for a crane hook height of at most 12.8 m (42 feet).  
Acceptable casks: All
12. The cask shall not be greater than 2.1 m (7 feet) in diameter.  
Acceptable casks: All are acceptable without impact limiters attached. The NLI 10/24 cask impact limiters have a 2.4 m (8 feet) diameter and would therefore need to be removed.
13. The cask shall not be greater than 18 feet long.  
Acceptable casks: T-3, NAC-1, NLI 1/2 ( w/o impact limiters), IF 300, NLI 10/24, NAC 3K (w/o impact limiters) and the TN-12 (w/o impact limiters)
14. The inner lid and/or closure plug must weigh less than 4.1 tonnes (4.5 tons) and have a diameter less than 76 cm (30 in.).  
Acceptable casks: NAC-1, NLI 1/2, TN-8, TN-9, T-3
15. The loaded cask weight shall be less than 68 tonnes (75 tons) (due to BRET transporter limit).  
Acceptable casks: T-3, NAC-1, NLI 1/2, TN-8 and the TN-9

16. The cask must sustain a 2 assembly/day shipping rate.  
As a result of the CRBR time and motion study, the following casks are acceptable: IF 300, NLI 10/24, TN-8, TN-9, NAC 3K, and the TN-12.
17. The cask turnaround time in-plant shall average 12 hours per assembly per loading/unloading station.  
No detailed studies were completed.
18. The cask shall be designed such that no "special" maintenance shall be required at loading/unloading stations. Seal replacement shall be possible at stations.  
No investigations completed on this item.
19. The reactor shall receive the cask with a verified seal which is re-seatable after lid removal by the plant.  
No specific investigations completed on this item.
20. The cask shall be designed to have an availability of 300 days per year.  
No specific investigations completed on this item, though it is a fairly standard assumption in cask design.
21. The cask shall be capable of carrying one assembly.  
Acceptable casks: All but the T-3 which is too short.
22. The cask and its interfaces with plants shall meet seismic requirements of CRBRP and BRET.  
No analysis completed.

By examination of the above, all cask designs are eliminated by virtue of one or more unacceptable characteristics.

The following summarizes the comparison of the alternate criteria to the current cask designs.

3. Shipment of canistered fuel shall be considered.  
Acceptable casks: All designs are acceptable with major modifications.
4. Decay heat outputs to 3 kW/assembly shall be considered.  
This alternative was not researched extensively. However, the TN-8 analysis mentioned previously was completed for this case. For three 3 kW assemblies and nitrogen, the maximum pin temperature is 749°C (1380°F). And for helium as the coolant, that temperature is 516°C (960°F).
5. A dose rate external to the cask not to exceed 10 mrem/hr at the surface shall be considered.  
This alternative was not pursued for reasons already discussed.

7. Cask coolant (during shipment) of helium shall be considered.  
Acceptable casks: NLI 1/2, and NLI 10/24 are certified for shipment in helium.
10. The loaded cask and lifting fixtures shall not exceed 114 tonnes (125 tons) in weight.  
Acceptable casks: All casks
15. The loaded cask shall not exceed 91 tonnes (100 tons).  
Acceptable casks: All but NAC 3K and TN 12.
21. The cask shall be capable of carrying more than one fuel assembly.  
Acceptable casks: IF 300, NLI 10/24, TN-8, TN-9, NAC-3K and TN 12.

#### INSTITUTIONAL CONSIDERATIONS

At this study's beginning, caution was voiced when considering modifications to existing casks. Recent NRC actions had indicated at that time, that some SARP amendment cases were being treated as new applications. This was essentially requiring past designs to meet current concern and regulations. The caution expressed was relative to whether license holders might be willing to risk the possibility of opening past SARPs (and thus endanger the use of casks already on the road) for the benefit of supplying a shipping cask design for LMFBR use. Recent proposed revisions to 10CFR 71 (August 1983) indicate that use of currently licensed casks for transportation will require the fabrication of such casks prior to August 31, 1986. As already mentioned, the type of campaign required to satisfy the breeder cycle will entail fleet fabrication due to limited number of available casks. This additional restriction most certainly will preclude use of old casks. The other option appeared to be a new licensing activity on a new cask design albeit one predicated on the technology of an existing design. At first, this second option appears a longer term and higher cost option. The licensee, however, might consider it the preferable one because of decreased risk. Indeed, it may be the only action available to the licensee when CRBR and BRET come on line.

#### CONCLUSIONS

No present LWR cask design is acceptable in its currently certificated form. Modification to existing designs or a complete new design will be required to ship CRBR spent fuel. Additionally, recent NRC regulations [2] indicate that most requests for modifications to current cask designs will be viewed as new applications for license rather than amendments. Thus, it is unlikely a manufacturer will attempt a modification to an existing design due to the inevitability of bringing into question the original design. Though the change to a design required to meet CRBR shipping needs may be small, it is likely an entire new analysis leading to a new SARP will be required. Finally, the current inventory of casks is limited and inadequate for the campaign considered here. The recent NRC regulations give licensees 3 years to build

new casks under existing certificates. If any cask were to meet all CRBR spent fuel shipping requirements, the new fleet would have to be built now: an unlikely occurrence. Additionally, with regard to the early FY84 development of CRBR cancellation, this point must be stressed in that the date of the first LMFBR shipment from a plant of CRBR size or larger has been postponed well beyond the limit. In fact the design of the plant that might make that shipment will not be advanced enough to hope to take advantage of the 3 year building allowance.

It is apparent from the current study that some of the casks do meet many of the base case criteria. The TN-8 is one example. With additional shielding and shortened overall length, it could suit the CRBR needs. This implies an industry capability (but not necessarily willingness) to design and license a suitable shipping cask for CRBR spent fuel.

Until industry makes that decision, a cask design similar to the TN-8 or TN-9 could be used as a model for BRET and CRBR. Caution should be employed in making too many assumptions based on this. For example, it has not been determined that a cask capable of carrying 3 assemblies can be designed to be a legal weight (or not significantly overweight) truck cask. These are two convenient assumptions which may, in fact, be mutually exclusive but are likely to result from looking at the TN-8 with respect to BRET input and output.

With respect to BRET input (spent fuel) and output (waste logs), one consideration should be the ease of handling of the two types of casks. The spent fuel cask should look as much like the waste log cask as possible. Ultimately, they possibly could be the same design. This would simplify the overall shipping/receiving logistics. Consideration in examining existing designs for shipment of BRET waste logs must include recognition of current regulations and concerns.

#### REFERENCES

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4. Directory of Certificates of Compliance for Radioactive Materials Packages, NUREG-0383, Vol. 2, Rev. 5, published January 1983.
5. Safety Analysis Report for Nuclear Fuel Services, Inc., Spent Fuel Shipping Cask Model No. NFS-4, prepared by Nuclear Fuel Services, Inc., September 1972.
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10. Safety Analysis Report for the FFTF Fuel Pin Shipping Cask Model T-3, prepared by Nuclear Packaging, Inc., Revision 3, January 25, 1980.
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12. TN-12 Safety Analysis Report, prepared by Transnuclear, Inc., Revision 1, April 1979.
13. Personal Correspondance, J. M. Diggs to D. L. Hoof, in June, 1983.
14. Clinch River Breeder Reactor Plant, "Radioactive Source Terms", WARD-D-0193. (Information provided by J. E. Rutenber, CRBRP).
15. R. B. Pope, "Evaluation of Heat Transfer in Conceptual Designs of Spent Fuel Shipping Casks for the United States Breeder Reactor Technology Program", SAND77-1781, May 1978.

Appendix A

Cask Survey Information in English Units

Table A-I. Overall Dimensions of Cask Designs

Cask Type	Overall Length <sup>a</sup> (in)	Overall Dia. (in)	Inner Cavity Dimensions (in)	Rated Load kW	Empty Shipping Wt (lbs)	Containment Closure dia (in.)	Closure Weight (lb)
NAC-1	214	50(IL)	13.5 x 178	2.5	48,500	24	---
NLI-1/2	195.25 237 (IL)	47-1/8 75 (IL)	12.625 x 178	10.6	45,900	13.375	743
IF-300	184.19 199.69(IL)	72.75	37.5 x 169-11/16	11	119,000	30	---
NLI-10/24	204.5 (IL)	96 (IL)	45 x 179.5	70	159,900	45	8122
TN-8	217	68	3 cells <sup>b</sup> 9 x 9 x 168	35.5	79,300	24.4	1872
TN-9	226	67.6	7 cells <sup>b</sup> 5.9 x 5.9 x 178	24.4	79,300	18	---
T-3	177.2 213.2 (IL)	26.44 52 (IL)	7.981 x 147	0.6	37,500	---	---
NAC-3K	213 283 (IL)	75.98	47.83 x 194.88	100	214,800	47.83	4400
TN-12	210.6 232 (IL)	73	50.3 x 180-5/16	120	196,300	64	11400

<sup>a</sup>Dimensions including impact limiters are marked (IL)

<sup>b</sup>Integral basket

Table A-II. Shielding Designs and Capacities of Casks

Cask Type	Steel (in)	Lead (in)	Uranium (in)	Borated Ethylene Glycol (in)	Water (in)	Resin (in)	# Assy. due to therm. <sup>a</sup>	# Assy. due to geom. <sup>b</sup>	# Canned Assys. <sup>c</sup>
NAC-1	1.56	6.63		4.5			1 (0)	1	1
NLI-1/2	1.625	2.215	2.75		5		1 (1)	1	1
IF-300	1.5		4		5.12		3 (1)	14	7
NLI-10/14	3	6			9.75		23 (11)	19	19
TN-8	1.02	5.31				5.9	3 (3)	3	3
TN-9	1.02	5.03				5.9	5 (3)	4	4
T-3	1.5	8					0 (0)	1	0
NAC-3K	14			1.96			34 (15)	19	19
TN-12	12					4	40 (19)	19	19

<sup>a</sup>Assumes constraints of: # of assemblies = Rated load/ $Q_{eg}$  (numbers in parenthesis indicate allowable for 3kW assembly)  
 where  $Q_{eg} = 0.7(1.4)/(1/3)$  kW  
 0.7(1.4) = amount to reject in 1/3 length of cask

<sup>b</sup>Assumes 7" diameter required

<sup>c</sup>Assumes 8" diameter needed per canned assembly where: 7" - assembly  
 1/2" - canister + clearance  
 1/2" - basket wall

Distribution:

DOE/NE R. B. Chitwood  
DOE/NE D. L. Hoof  
HEDL J. D. Berger  
HEDL A. J. Duckett  
3141 C. M. Ostrander (5)  
3151 W. L. Garner (3)  
3154-3 C. H. Dalin (25)  
for DOE/TIC  
6227 J. M. Diggs  
6320 R. W. Lynch, Actg.  
6322 W. E. Wowak  
6322 M. L. Hudson (5)