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MARTIN MARIETTA

**Acceptance of Spent Nuclear Fuel in
Multiple Element Sealed Canisters by
the Federal Waste Management System**

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ACCEPTANCE OF SPENT NUCLEAR FUEL IN MULTIPLE
ELEMENT SEALED CANISTERS BY THE FEDERAL
WASTE MANAGEMENT SYSTEM

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Prepared by
E. R. Johnson Associates, Inc.
10461 White Granite Drive
Suite 204
Oakton, Virginia 22124
under
Purchase Order No. 41X-SA094V

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OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
operated by
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FOREWORD

This report is one of a series of eight prepared by E. R. Johnson Associates, Inc. (JAI) under ORNL's contract with DOE's OCRWM Systems Integration Program and in support of the Annual Capacity Report (ACR) Issue Resolution Process. The report topics relate specifically to the list of high priority technical waste acceptance issues developed jointly by DOE and a utility-working group. JAI performed various analyses and studies on each topic to serve as starting points for further discussion and analysis leading eventually to finalizing the process by which DOE will accept spent fuel and waste into its waste management system. The eight reports are concerned with the conditions under which spent fuel and high level waste will be accepted in the following categories:

1. Failed Fuel
2. Consolidated Fuel and Associated Structural Parts
3. Non-Fuel-Assembly Hardware
4. Fuel in Metal Storage Casks
5. Fuel in Multi-Element Sealed Canisters
6. Inspection and Testing Requirements for Wastes
7. Canister Criteria
8. Spent Fuel Selection for Delivery
9. Defense and Commercial High-Level Waste Packages

As a part of the report preparation, each was subjected to a rigorous peer review by a group of knowledgeable and independent experts. These reports have not yet been formally reviewed by DOE and, therefore, do not represent DOE policy.

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ACCEPTANCE OF SPENT NUCLEAR FUEL IN
MULTIPLE ELEMENT SEALED CANISTERS BY THE
FEDERAL WASTE MANAGEMENT SYSTEM

1.0 INTRODUCTION AND BACKGROUND

The Standard Contract (1) between utilities and the Department of Energy (DOE) for the disposal of spent nuclear fuel (SNF) provides for the disposal of several categories of standard fuel, non-standard fuel, and failed fuel. Standard fuel is described in Appendix E of the Contract as being intact and non-defective PWR and BWR fuel assemblies that have had a minimum cooling time and which fall within an envelope of fixed maximum nominal dimensions. Included in the non-standard fuel category are fuel assemblies that exceed the fixed maximum dimensions, non-fuel components, fuel cooled less than 5 years, non-LWR fuel, and consolidated fuel rods. Included in the failed fuel category are fuel assemblies that exhibit visual failure or damage, radioactive leakage, and those that have been encapsulated previously. Basically all of the foregoing categories of SNF will be accepted by DOE for disposal purposes, however, all forms other than standard fuel may be subjected to delayed acceptance because of any special handling that might be involved therewith.

Separate from the Contract, the utilities have been considering alternative methods of storage of SNF at reactor sites. One of the alternative methods consists of storage of the spent fuel in a horizontal concrete module in which the fuel is contained within a special multiple-element sealed canister (MESC). The canister is placed in a transfer cask, filled with water, and lowered into the cask loading pool where the canister is loaded with fuel assemblies. After loading, a shielded end plug is placed on the canister, the transfer cask is lifted out of the pool, the water inside the cask and MESC is lowered from the MESC shielded end plug, and the plug is welded to the MESC. After all water has been removed from the MESC and it is backfilled with helium, a cover plate is placed on the MESC and welded in place. The transfer cask cover is bolted in place and the cask is placed on a trailer. The cask and contained MESC are then transferred to the horizontal concrete module where the MESC is pulled (or pushed) into the module.

Subsequent to the execution of the Contracts, the question has been raised regarding whether or not a MESC containing spent fuel constitutes a fuel form that should be accepted by DOE. From a strict interpretation of the Contract provisions, DOE is only required to accept SNF which meets the general requirements set forth in Appendix E thereto -- and this does not appear to include SNF contained in MESCs inasmuch as no mention of acceptance of aggregate units of fundamental fuel forms* is included therein. This would appear to be reasonable inasmuch as theoretically a virtually endless number of aggregate configurations of the basic fuel forms might exist in at-reactor storage and it may be impractical to design to accommodate each of these configurations. It is to be expected that some configurations would not be able to be handled by the FWMS, while others could be handled at added cost and/or reduced throughput, and still others could be handled with little or no impact.

This question has been exacerbated somewhat as a result of the Nuclear Regulatory Commission (NRC) consideration of the prospective licensing of dry storage facilities at reactor locations, and NRC's apparent desire to achieve compatibility and standardization between the utility spent fuel management systems and the FWMS (2).

Basically two different capacity MESCs have been selected for use by utilities in connection with the dry storage of spent fuel at reactor locations; one involves a 7 PWR assembly canister and the other involves a 24 PWR assembly canister. While many other capacities are possible, only these two have been proposed to date. Moreover, the 24 PWR assembly canister is probably the largest one that could be practically transported.

Since the Standard Contracts were executed, a number of issues have been identified regarding the waste acceptance criteria and scheduling of receipts of SNF by the FWMS that require clarification. The clarification of these issues may result in modifications to the Standard Contract or in establishing agreed-upon procedures for equitably dealing with them. In

*Fundamental fuel forms refers to intact spent fuel assemblies, canisters of failed fuel, and canisters of consolidated fuel and non-fuel components having cross-sectional dimensions about the same as that of the intact fuel assemblies.

order to support DOE's consideration of the possibility of acceptance of SNF from the utilities in MESCs, a study was conducted to estimate the cost and operational impacts on the FWMS as a result of receiving SNF assemblies in MESCs. It was recognized that DOE's acceptance of MESCs would result in benefits to the utilities using them for at-reactor storage including reduced fuel handling, reduced impact on reactor operations, reduced radiation exposure at reactor sites, and reduced utility costs. However, the study dealt only with impacts on the FWMS and did not attempt to estimate utility impacts. Moreover, the study:

- (1) assumed that SNF would be consolidated in the FWMS, which was the basic DOE plan at the time the study was conducted,
- (2) assumed that SNF contained in MESCs would be in the form of intact, non-defective fuel assemblies,
- (3) assumed that only PWR fuel would be contained in MESCs inasmuch as current utility plans therefor only involve storage of PWR fuel,
- (4) assumed that only 7 PWR assembly and 24 PWR assembly MESCS would be available for delivery to DOE,
- (5) did not consider a contract category designation for SNF contained in MESCs,
- (6) developed information that could be used to judge whether or not (and under what conditions) SNF delivered to DOE in MESCs could be accepted by DOE, and whether or not it could be accepted on the same scheduling basis as "standard fuel" as defined in the Standard Contract, and
- (7) developed estimates of costs to the FWMS of receiving SNF in MESCs, and the number of significant figures used in the cost estimates are not intended to imply an accuracy greater than that normally associated with estimates.

This report describes the work performed during the study and the results obtained therefrom. Section 2.0 of this report presents a summary of the results of the work and the resulting conclusions. Section 3.0 describes the use of MESCs for at-reactor storage of SNF and current utility plans for use of MESCs for such storage. Section 4.0 presents an analysis of the impacts on the FWMS, including estimated costs, as a result of receipt of SNF in MESCs, and Section 5.0 presents a summary of these cost impacts. Estimates of life cycle costs for the FWMS that are associated with the receipt of SNF

in MESCs are included in Appendices A through E. Section 6.0 describes the policy alternatives available to DOE regarding the acceptance of SNF in MESCs.

Since the various cases analyzed regarding costs to the FWMS involved both different schedules and different amounts of SNF being handled by the systems, it was necessary to determine the unit costs for storage, transport and disposal so that a proper comparison could be made of the costs associated with the receipt of SNF in MESCs. The methodology used to calculate the unit cost is described in Appendix F. This unit cost (in 1988 dollars) is that which must be escalated at the inflation rate to the time of performance in order to effect full recovery of all costs involved in the operation.

2.0

SUMMARY

A study was made of the impacts on the Federal Waste Management System (FWMS) that would be caused by DOE acceptance of spent nuclear fuel (SNF) assemblies in multiple element sealed canisters (MESCs). Two different MESCs were considered -- a 24 PWR assembly MESC and a 7 PWR assembly MESC. The design modifications required and related operational and cost impacts of acceptance of PWR assemblies in MESCs were developed and compared to those involved in the receipt of individual PWR assemblies in a reference FWMS composed of shipping casks typical of those that have been ordered by DOE, and surface facilities at a MRS facility or repository that are represented by existing designs of such facilities. All of the impacts of receiving MESCs into the FWMS were assumed to be mitigated by the inclusion of additional facilities and equipment that would permit the FWMS to accept and handle MESCs therein without an adverse impact on its acceptance and handling of SNF assemblies. The costs for these additional facilities and operations were estimated and the added costs or savings resulting from the receipt of MESCs were determined. The following sections describe the impacts of receiving PWR assemblies in MESCs on the FWMS and summarize the incremental costs or savings associated therewith.

2.1

IMPACTS ON FROM-REACTOR TRANSPORTATION

With respect to impacts of acceptance of MESCs on from-reactor transportation activities, it was found that specially designed shipping casks would be necessary for the transport of MESCs inasmuch as:

- o both types of MESCs were longer than the cavity length of the reference shipping casks
- o the 24 PWR assemblies MESCs were larger in diameter than the cavity diameter of the reference shipping casks, and the 7 PWR assembly MESCs were much smaller in diameter.

Costs were estimated for shipping various quantities of SNF contained in MESCs, over distances of 500 miles and 2,800 miles, (nominally representing shipments to a MRS facility and a repository), under conditions where only MESCs were shipped and where individual fuel assemblies were

shipped in MESC casks to the extent no MESCs were available for shipment (to maximize the utilization of the cask). It was found that PWR assemblies contained in MESCs were generally more expensive to ship than individual PWR assemblies in the reference shipping cask. In the case of the 24 PWR assembly MESCs this increased cost varied from \$2.40 to \$24/kgU depending on the distance, the total amount shipped (500-2,000 MTU), and whether maximum use was made of the cask. In the case of the 7 PWR assembly MESCs, this increased cost varied from \$30 to \$450/kgU depending on the distance, the total amount shipped (50 - 250 MTU), and whether maximum use was made of the cask. These cost increases are primarily due to the need to procure a special cask for the MESCs and to charge the full cost thereof to the quantity of fuel shipped in MESCs. The much higher costs involved in shipping the 7 PWR assembly MESCs was due to both the small amount of SNF expected to be in this form and the higher freight costs associated with the use of the smaller cask having a higher shipping cask weight per contained MTU.

It was concluded that the minimum operational impact on the FWMS would result if the MESC casks were used solely for MESC shipment.

2.2 IMPACTS ON FWMS FACILITIES

With respect to the impacts of acceptance of MESCs on the fixed-base facilities of the FWMS (MRS facility or repository), it was determined that the MESCs will have to be opened, and the empty MESCs disposed of, and that both these operations would be incremental to those associated with the receipt of individual PWR assemblies in a reference shipping cask. If the weld on the lid of the MESC is cut open while the MESC is in the shipping cask (or a transfer cask), the addition of hot cell space for MESC handling may be avoided. If a MRS facility is included in the FWMS, and the MESCs are received in time to be committed to interim storage there, the MESCs can be readily stored in vertical concrete casks with little modification to the existing designs of such casks. MESCs can also be stored in HSMs, in which case the MESCs can be transferred directly from the shipping cask to the HSM, however, special equipment will be required for such transfer and a transfer cask will be required later to retrieve the MESC.

The costs and operational impacts of a number of handling and processing scenarios were considered -- twenty-four different such scenarios

were considered for the 24 PWR assembly MESCs, and eighteen scenarios were considered for the 7 PWR assembly MESCs. These scenarios included all reasonable combinations of the following:

- o Total quantity of SNF received in MESCs -- ranging from 500 - 2,000 MTU for the 24 PWR assembly MESCs, and 50 - 250 MTU for the 7 PWR assembly MESCs
- o No MRS facility in the FWMS, and a FWMS which included a MRS facility
- o Cutting the welds on the MESC lid outside of the hot cell facilities followed by unloading the contained assemblies into the hot cell, or, alternatively, unloading the MESC into the hot cell and cutting the welds and unloading the assemblies therein, and
- o Storage of MESCs in concrete casks and horizontal storage modules (HSM) at the MRS facility, or immediately opening and unloading the MESCs.

All of the scenarios assumed that the MESC would be acceptable to NRC for shipment after the at-reactor storage period.

Incremental life cycle costs were calculated for each of the scenarios considered and the incremental unit costs resulting from the acceptance of MESCs by FWMS facilities were determined. As a result of the foregoing, it was found that the receipt of PWR assemblies in MESCs is more expensive to the FWMS facilities than the receipt of individual PWR assemblies, but that this cost can be minimized by cutting the weld on the MESC lid while it is in the shipping cask (or a transfer cask), thus avoiding the high additional cost of adding hot cell facility space for this operation and the attendant operating costs. However, in cases where the 24 PWR assembly MESCs are received in time to be stored at MRS facilities, the savings associated with storage in HSMs more than offsets the added costs involved in opening the MESCs and disposing of them once they have been unloaded.

2.3 SUMMARY OF ESTIMATED INCREMENTAL UNIT COSTS OR SAVINGS

The estimated incremental unit costs or savings associated with the receipt of PWR assemblies in MESCs by the FWMS are shown in Tables 2-1 and 2-2.

TABLE 2-1
ESTIMATED INCREMENTAL UNIT COSTS (OR SAVINGS) TO THE FWMS RESULTING
FROM RECEIPT OF SNF IN MESC'S AT A MRS FACILITY^a
(1988 Dollars)

Type of MESC	Quantity of SNF Received in MESC's (MTU) ^c	FWMS Facilities	Incremental Unit Costs or Savings(\$/kgU) ^b			
			From Reactor Transport In		Total W/DOE Cask	Total W/Utility Cask
			DOE- Furnished Cask	Utility- Furnished Cask		
2-4 24 PWR Assembly (Received in time for storage at MRS facility)	564	\$(9.46)	\$16.69	-	\$ 7.23	-
	940	(10.96)	10.18	-	(0.78)	-
	1,504	(11.86)	6.54	-	(5.32)	-
	1,880	(12.18)	5.32	-	(6.86)	-
24 PWR Assembly (Not received in time for storage at MRS facility)	564	3.73	16.69	-	20.42	-
	940	3.42	10.18	-	13.60	-
	1,504	3.25	6.54	-	9.80	-
	1,880	3.20	5.32	-	8.52	-
7 PWR Assembly (Received any time)	58	6.31	93.26	\$3.63	99.57	\$9.94
	116	5.37	51.72	3.63	57.09	9.00
	232	4.92	30.96	3.63	35.88	8.55

^a Assumes a 500-mile one-way shipment.

^b Savings are shown in parentheses.

^c Assumes each PWR fuel assembly contains 461 kgU prior to irradiation.

TABLE 2-2
ESTIMATED INCREMENTAL UNIT COSTS (OR SAVINGS) TO THE FWMS RESULTING
FROM RECEIPT OF SNF IN MESCS AT A REPOSITORY^a
(1988 Dollars)

	Type of MESC	Quantity of SNF Received in MESCs (MTU) ^c	Incremental Unit Costs or Savings (\$/kgU) ^b			
			FWMS Facilities	From Reactor Transport In		Total W/DOE Cask
				DOE- Furnished Cask	Utility- Furnished Cask	
2-5	24 PWR Assembly	534	\$ 3.77	\$ 24.04	-	\$ 27.81
		890	3.45	14.46	-	17.91
		1,424	3.28	9.08	-	12.36
		1,780	3.22	7.30	-	10.52
	7 PWR Assembly	52	6.51	118.90	\$13.17	125.41
		104	5.46	72.58	13.17	78.04
		208	4.95	49.47	13.17	54.42
						\$19.68
						18.63
						18.12

^a Assumes a 2,800-mile one-way shipment.

^b Savings are in parentheses.

^c Assumes each PWR assembly contains 461 kgU prior to irradiation.

These incremental unit costs are those resulting from the use of special MESC shipping casks that are incremental to the presently planned DOE fleet and are used exclusively for shipment of MESC's -- and the use of the most economical scenarios considered during the course of the study for handling of MESC's in the FWMS facilities. From the cost data shown in the tables it can be seen that receipt of SNF in MESC's into the FWMS results in cost increases over those which would have been otherwise incurred had the SNF been received in the form of individual PWR assemblies --except where 900 MTU or more of SNF was received in 24 PWR assembly MESC's in time to store it in MRS facilities (2005 or thereabouts). In all cases, the cost of from-reactor transport is higher as a result of the need to add special-purpose cask(s) to the DOE fleet. However, in the limited instances cited above (where 900 MTU or more of SNF was received in 24 PWR assembly MESC's early enough to commit it to storage in the MRS facility), the cost savings resulting from the use of low cost HSMs more than offset the added cost of shipment.

Extrapolating the incremental unit costs (or savings) shown in the tables for the 24 PWR assembly MESC's to those applicable to 10,000 MTU, indicate that

- savings for MESC's received in time to be stored at the MRS facility would increase to about \$13/kgU
- added costs for MESC's otherwise received at the MRS facility would decrease to \$5-6/kgU
- added costs for MESC's received at the repository would decrease to about \$6/kgU.

2.4 THE ISSUE OF MESC ACCEPTANCE

There are several policy alternatives that might be followed by DOE in dealing with the prospective acceptance of SNF in MESC's for transport and disposal. The DOE could either decline to accept SNF in such a form (package) or it could agree to accept it. If it agreed to accept MESC's, it could either do so without charge or it could charge for the added costs (or credit for avoided costs) to the FWMS resulting from such acceptance. The basic issues that must be addressed arise because the acceptance of MESC's may directly increase FWMS costs, and hence the collective costs shared by all utilities.

Further, such cost increases are at the discretion of the individual utility delivering the MESCs, which has the viable alternative of delivering fuel assemblies. The discretionary nature of this cost increase directly raises the issue of inter-utility equity, and the three alternatives deal with this issue in the following ways:

- (1) DOE declines to accept MESCs. This approach avoids the issue of inter-utility equity by foreclosing the possibility of incurring MESC-related cost increases in the FWMS.
- (2) DOE accepts MESCs without charge for added costs or credits for avoided costs. This approach implicitly accepts and tolerates any inter-utility inequity that may be incurred.
- (3) DOE accepts MESCs with payment for added costs (or provides credits for avoided costs). This approach avoids inter-utility inequities by charging or crediting the full amount of the increases or decreases in costs that are incurred thereby.

Section 6.0 of this report lists the technical conditions under which MESCs could be accepted by the FWMS and provides a mechanism for charging (or crediting) utilities for the incremental costs or savings to the FWMS resulting from acceptance of MESCs.

3.0 USE OF MESCs FOR AT-REACTOR STORAGE OF SPENT FUEL

This section describes the use of MESCs for at-reactor storage of SNF and the current utility plans for such use.

3.1 DESCRIPTION OF THE USE OF MESCs FOR AT-REACTOR STORAGE

MESCs are cylindrical stainless steel canisters, which are shielded at both the top and bottom with lead. SNF assemblies are loaded into guide sleeves that are positioned in the cavity of the MESC, and which form a part of its internal basket structure. Once the MESC has been loaded with SNF assemblies, the internal cavity is drained, dried, and purged with helium -- after which the top shield plug and top cover plate are seal welded. A diagram of the loaded MESC is shown in Figure 3-1.

HSMs are concrete structures into which loaded MESCs are inserted for storage in a horizontal configuration. The HSMs provide cooling of the MESC by natural air convection, and radiological shielding. The MESCs are loaded into openings in the front of the HSM, and the opening is closed with a shielded door. A diagram of the loaded HSM is shown in Figure 3-2.

Loaded MESCs are moved from the reactor pool to the HSM using a metal transfer cask, such as that shown in Figure 3-3.

The following summarizes the basic operations involved with the use of MESCs and HSMs for at-reactor storage:

- (1) The empty MESC is loaded into the transfer cask and the latter is lowered into the cask loading pool.
- (2) SNF assemblies are loaded into the MESC while it is positioned under water in the transfer cask, and the top shield plug is inserted into the MESC.
- (3) The transfer cask is removed from the pool and placed in the cask decontamination pit where it and the loaded MESC is drained, dried, inerted, and the top shield plug of the MESC is seal welded. The top cover plate is then seal welded over the shield plug. A diagram of the seal welding operation is shown in Figure 3-4.
- (4) The transfer cask is loaded onto a trailer and moved to the HSM location where the MESC is inserted into the HSM using either a ram to push it from the cask into the HSM or one that pulls it in from the cask, depending on the design of the individual installation.

The foregoing operations are shown in Figure 3-5.

FIGURE 3-1
DIAGRAM OF MULTIPLE ELEMENT SEALED CANISTER* (MESC)

-Courtesy NUTECH, Inc.

*Multiple-element sealed canisters (MESCs) and dry storage canisters (DSCs) are synonymous.

FIGURE 3-2
DIAGRAM OF HORIZONTAL STORAGE MODULE

-Courtesy NUTECH, Inc.

FIGURE 3-3
DIAGRAM OF MESC TRANSFER CASK

-Courtesy NUTECH, Inc.

SECTION A-A

FIGURE 3-4
DIAGRAM OF MESC SEAL WELDING SYSTEM

-Courtesy NUTECH, Inc.

FIGURE 3-5
LOADING AND TRANSFER OF MESC TO HORIZONTAL STORAGE MODULE

Removal of the MESC from storage, and removal of the SNF assemblies from the MESC, is accomplished by reversing the above-described procedure -- only in this instance, a cutting tool is used on the apparatus shown in Figure 3-4 instead of a welding device. It is also possible that a DOE-supplied shipping cask could be loaded with a MESC directly from the HSM, should DOE agree to accept SNF in MESCs, thus eliminating the need to open the MESC at the reactor and transfer the SNF to a shipping cask.

To date, only two principal types of MESCs are planned for use by utilities; a 24-PWR assembly MESC and a 7-PWR assembly MESC, although other types are possible. However, the 7-PWR assembly MESC is being used principally to demonstrate the technology and is not expected to be used elsewhere. The 24-PWR assembly MESC is probably the design that is most likely to be used for any widespread at-reactor storage application.

3.2 PLANS FOR USE OF MESCs BY UTILITIES

As of the Spring of 1989, three utilities have announced plans to use horizontal concrete modules and their associated MESCs for supplemental at reactor storage.

- (1) Carolina Power & Light Co. (CP&L) is involved in a demonstration program with DOE and others at its H. B. Robinson reactor site in which MESCs having a capacity for 7 PWR assemblies will be used. This demonstration commenced in the Spring of 1989, and will involve the storage of 21 PWR assemblies (3,4). The MESC design to be used in the CP&L facilities is 37 inches in diameter, 179 inches long, and weighs 22,000 lb loaded (about 12,000 lb empty). CP&L is licensed to store up to 56 PWR assemblies at H. B. Robinson and may add more such storage modules there and at its Brunswick plant if the need therefor arises (2,8).
- (2) Duke Power Company (Duke) plans to use this method of dry storage at its Oconee Station using MESCs having a capacity for 24 PWR assemblies. This storage activity is scheduled to commence in 1990, and Duke has requested NRC authorization to store up to 2112 PWR assemblies in this fashion (5,6,7). Duke plans to store 168 PWR assemblies in 1990, 144 PWR assemblies in 1991, and 96-120 PWR assemblies every year thereafter until the authorized capacity of 2112 PWR assemblies has been reached (8). This means that additions to storage will be made at least through the year 2008. The MESC design to be used in the Duke facilities is nominally 66.5 inches in diameter, 186 inches long and weighs 80,000 lb loaded (about 45,000 lb empty).

- (3) Baltimore Gas & Electric (BG&E) plans to use this method of dry storage at its Calvert Cliffs Station (9) using a MESC essentially identical to the one to be used by Duke (2), except it is 173 inches long. BG&E plans to store 576 PWR assemblies commencing in 1991 and 192 PWR assemblies every other year thereafter until DOE accepts spent fuel (8). This means that the total amount committed to such storage could be as much as that planned for storage by Duke.

In addition, other utilities have indicated an interest in this method of storage although no known commitments therefor have been made as of mid-1989. However, based on existing plans it can be expected that as much as 2000 MTU as SNF will be stored in 24 PWR assembly MESC's and as little as 25 MTU as SNF will be stored in 7 PWR assembly MESC's.

No particular interest has been evidenced to date regarding the storage of consolidated SNF in MESC's. This is probably due to the fact that the cost of consolidation may well exceed the savings that result from storing consolidated SNF in MESC's/HSM's.

4.0 IMPACTS OF ACCEPTANCE OF SNF IN MESCs ON THE FWMS

A review was conducted of each operation in which a MESC would likely be involved in the FWMS and the impact that it would have on each portion of the system. The results of this review are described in the following sections.

4.1 IMPACTS ON FROM-REACTOR SHIPPING

This section reports the results of the study of the impacts and costs associated with the acceptance of MESCs on the transport of spent fuel from reactors to DOE facilities.

4.1.1 Analysis of Impacts on Shipments

The DOE has contracted with three organizations for the development of rail-type shipping casks for SNF. The preliminary capacities, cavity dimensions and weights of these casks are described in Table 4-1.

TABLE 4-1
FROM-REACTOR SNF SHIPPING CASK CAPACITIES, DIMENSIONS & WEIGHTS

<u>Contractor</u>	<u>Cask Capacity (Assys)</u>		<u>Cavity Dimensions (in)</u>		<u>Cask Weights (tons)^a</u>	
	<u>PWR</u>	<u>BWR</u>	<u>Diameter</u>	<u>Length</u>	<u>Empty</u>	<u>Loaded</u>
Nuclear Assurance Corp. (NAC)	26	52	66	178	78	100
Nuclear Packaging (NUPAC)	21	48	55	178	80.5	97
Babcock & Wilcox (B&W)	16	40	64	180	73	98.5

^aWithout impact limiter

From the data shown in the table it can be seen that none of the casks has a cavity that is sufficiently large to accommodate a 24 PWR assembly MESC (see MESC dimensions in Section 3.2). This means that a larger cask would be needed to transport the 24 PWR assembly MESC. On the other hand, the data shows that these casks have a considerably larger diameter than the 7 PWR

assembly MESC, and, in the case of two of the casks, the cavities thereof are slightly shorter than the length of the 7 PWR assembly MESC. This means that a smaller diameter cask having a slightly longer cavity length would be needed to transport a single 7 PWR assembly MESC efficiently, or that a larger diameter cask having a slightly longer cavity length would be required to transport two 7 PWR assembly MSCs.

All three such MESC cask designs were considered in this study and conceptual designs were developed for each. It was recognized that in order to obtain efficient utilization of the MESC casks it might be necessary to be able to ship spent fuel assemblies in the cask as well as MSCs. Therefore, the design of the MESC casks included the alternative of having a removable assembly basket. The basic characteristics of these casks are described in Table 4-2.

TABLE 4-2
CONCEPTUAL CHARACTERISTICS OF MESC SHIPPING CASKS^a

	<u>24 PWR Assembly MESC Cask</u>	<u>7 PWR Assembly MESC Cask</u>	<u>2/7 PWR Assembly MESC Cask^b</u>
<u>Payload Capacity</u>			
No. Assemblies	24	7	14 (26)
MTU	11.06	3.23	6.45 (11.99)
<u>Overall Dimensions</u>			
Diameter (in.)	92	63	101
Length (in)	208	200	200
<u>Cavity Dimensions</u>			
Diameter (in.)	67	38	76
Length (in)	187	180	180
<u>Weight On Transport Vehicle (tons)</u>			
Loaded with Assemblies	131	70	143
Loaded with MESC	145	72	142
Empty with Assembly Basket	113	65	125
Empty w/o Basket	105	61	120
<u>Weight on Reactor Crane Hook (tons)</u>			
Loaded with Assemblies	113	57	123
Loaded with MESC	127	60	121
Empty with Assembly Basket	95	40	104
Empty w/o Basket	87	49	99

^aCask design does not take shielding credit for MESC.

^bFigures in parentheses apply to shipments of uncanistered SNF assemblies.

It is apparent from the weights shown in the above table that a reactor site which intends to handle a 24 PWR assembly MESC and shipping cask in the reactor pool will have to have a lifting capability of about 130 tons. Alternatively, the cask might be loaded directly from the HSM used for storage.

4.1.2 Estimates of Transportation-Related Cost Impacts

The cost impacts of incorporating MESC shipping casks into the DOE cask fleet were estimated and are described in this section. This includes a review of the costs associated with the cask fleet planned for use in transporting spent fuel assemblies, estimates of costs of MESC casks and those costs associated with the use of the MESC casks, and a comparison of the life cycle costs and unit costs for transportation of spent fuel in a "standard" or reference assembly shipping cask and in MESC casks. For the purposes of this study the NUPAC rail cask was selected as the reference shipping cask inasmuch as both its capacity and cost were in the mid-range of all of the prototype rail casks contracted for by DOE.

4.1.2.1 Estimated Cost of the Reference Shipping Cask

The contract for the two shipping casks entered into between DOE and NUPAC amounted to \$13.591-million, broken down as follows:

TABLE 4-3
COST OF REFERENCE SHIPPING CASK

<u>Description</u>	<u>Cost (\$000)</u>	
	<u>1987 Dollars</u>	<u>1988 Dollars^a</u>
Design & Development	\$ 3,770	\$ 3,906
Model Fabrication	837	861
Model - Engineering, Design Verification Testing, Management and Admin, and QA	1,184	1,227
Prototype Fabrication (2 casks)	6,421	6,602
Prototype - Acceptance Testing, Performance Evaluation, Support to DOE, Management and Admin, and QA	1,379	1,429
Total	<u>\$ 13,591</u>	<u>\$ 14,025</u>

^a Fabrication costs escalated by 3.6% (based on changes to the Machinery and Equipment Index). Other costs, essentially all labor related, escalated by 2.82% (based on changes to labor rates for Production Workers on Non-Agricultural Payrolls).

The foregoing costs were estimates used in developing a cost-plus-fixed-fee contract for the casks and did not include the cost of NRC certification fees.

4.1.2.2 Estimated Cost of MESC Shipping Casks

The cavity size of the NUPAC rail cask was about 178 inches long by about 55 inches in diameter. This is a little short to be able to accommodate the MESC's (the H. B. Robinson MESC is 179 inches long and the Oconee MESC is 186 inches long). Also, the diameter for the NUPAC cask is clearly too small to accommodate the Oconee MESC (67 inches in diameter), while it is much too large to efficiently accommodate the 37-inch diameter H. B. Robinson MESC and too small to accommodate two such MESC's (requiring a 75-inch cavity diameter).

Therefore, the costs of three different sized MESC shipping casks were estimated, including casks capable of transporting (i) one 24 PWR assembly MESC, (ii) one 7 PWR assembly MESC, and (iii) two 7 PWR assembly MESC's. These costs included the cost of:

- o shop fabrication
- o administrative and support costs associated with shop fabrication
- o design and development
- o model fabrication and associated costs
- o auxiliary equipment
- o NRC certification fees, and
- o allocation of certain costs of reference casks resulting from the use of MESC casks.

A summary of these costs is set forth in Table 4-4; the derivation of the costs contained in the table is described in the remainder of this section.

In the cases involving casks for shipping single MESC's, it was assumed that the MESC would serve as the cask basket. In the case of the 2/7 PWR assembly MESC cask, it was assumed that a MESC basket would be required. Furthermore, it was assumed that an assembly basket might be required for the MESC casks for instances in which there was an insufficient number of MESC's available for efficient cask utilization.

TABLE 4-4
SUMMARY BREAKDOWN OF TOTAL PER CASK COST OF REFERENCE SHIPPING CASKS AND MESC SHIPPING CASKS
(000, 1988)

Description	Reference NUPAC Shipping Cask		24 PWR Assembly MESC Shipping Cask						7 PWR Assembly MESC Shipping Cask				2/7 PWR Assembly MESC Shipping Cask					
			Without Basket			With Basket			Without Basket		With Basket		Without Basket			With Both Baskets		
	2 Casks	10 Casks	1 Cask	2 Casks	3 Casks	1 Cask	2 Casks	3 Casks	1 Cask	2 Casks	1 Cask	2 Casks	1 Cask	2 Casks	3 Casks	1 Cask	2 Casks	3 Casks
Design & Development	\$1,953	\$ 390	\$ 547	\$ 274	\$ 182	\$ 781	\$ 391	\$ 260	\$ 547	\$ 274	\$ 781	\$ 391	\$ 781	\$ 391	\$ 260	\$ 1,016	\$ 508	\$ 339
Model Fabrication, Engineering, Design Verification Testing, Management & Admin, and QA	1,044	209	2,559	1,280	853	2,559	1,280	853	a	a	a	a	b	b	b	b	b	b
Cask Fabrication	3,301	2,790	3,741	3,030	2,794	4,819	3,999	3,726	2,686	2,046	3,231	2,482	4,383	3,565	3,292	5,900	4,972	4,663
Acceptance Testing, Performance Eval., Support to DOE, Management & Admin, and QA	715	554	812	634	575	970	758	688	671	525	829	648	883	690	626	1,095	857	777
Auxiliary Equipment	664	664	664	664	664	664	664	664	664	664	664	664	664	664	664	664	664	664
NRC Certification Fee	83	16	165	83	55	165	83	55	a	a	a	a	b	b	b	b	b	b
Allocation of Added Cost of Reference Casks ^c	N/A	N/A	896	896	896	896	896	896	261	261	261	261	971	971	971	971	971	971
Total Cost of Cask	<u>\$7,760</u>	<u>\$4,623</u>	<u>\$9,384</u>	<u>\$6,861</u>	<u>\$6,019</u>	<u>\$10,854</u>	<u>\$8,071</u>	<u>\$7,142</u>	<u>\$4,829</u>	<u>\$3,770</u>	<u>\$5,766</u>	<u>\$4,446</u>	<u>\$7,682</u>	<u>\$6,281</u>	<u>\$5,813</u>	<u>\$ 9,646</u>	<u>\$7,972</u>	<u>\$7,414</u>

^a Covered by the costs for the reference shipping cask.

^b Covered by the costs for the 24 PWR assembly MESC cask.

^c Allocation to MESC casks of added costs for reference casks resulting from fewer reference casks being procured.

The method of estimating the cost of the MESC casks as shown in Table 4-4 is described by the following:

(1) Fabrication of the Casks

Since no detailed breakdown of the costs for the NUPAC rail cask were publicly available, independent estimates of these costs were made during the course of this study. The difference between the costs estimated in this study and those in Section 4.1.2.1 was taken as a contingency associated with the cask fabrication cost estimate. Using this information as a base, the cost of NUPAC-type casks having different diameters and lengths from that of the reference cask were estimated. A summary of the estimated costs developed in this study for fabrication of the reference NUPAC cask, and NUPAC casks modified for shipment of MESCs, is set forth in Table 4-5.

The labor, materials and utilities costs were those estimated during the course of this study; labor costs included a 35 percent labor burden and an allowance for 50 percent efficiency due to scheduling; materials costs included allowances for fabrication losses. Overhead and G&A (general and administrative) were taken as being 100 percent of labor costs and 10 percent of the cost of materials and special equipment. The cost of fabrication facilities was estimated during the study as was the utilization efficiency thereof; depreciation was calculated on a 10-year straight-line basis assuming a 50 percent utilization efficiency. Property taxes and insurance were calculated on the basis of \$1/\$100 valuation assuming a 50 percent utilization efficiency. Pre-tax profit was calculated on the basis that the fabricator would require a 17 percent discounted cash flow after-tax return on its investment in the fabrication facilities used, and assumed a 46 percent Federal Tax rate, a 6 percent State tax rate, and a 50 percent facility utilization efficiency. The cost of special equipment was estimated during the study.

Using the foregoing methodology, it was determined that the fabrication costs so calculated for the two prototype NUPAC rail casks were about 29 percent less than the estimated costs under the contract between DOE and NUPAC. This was assumed to be the contingency associated with cask fabrication, and this same contingency percentage was used for the MESC casks as well. The total costs were then increased by 2.82 percent to escalate them to 1988 dollars.

The estimated cost of fabricating multiple numbers of casks was calculated by spreading the cost of special equipment over the numbers of casks involved. This produced multiple cask fabrication costs as shown in Table 4-6.

TABLE 4-5
ESTIMATED FABRICATION COST OF FROM-REACTOR SNF SHIPPING CASKS
(\$000)

	Two NUPAC Rail Casks	Single NUPAC Rail Cask	Single 24 PWR Assy MESC Cask		Single 7 PWR Assy MESC Cask		Single 2/7 PWR Assy MESC Cask	
			W/O Basket	With Basket	W/O Basket	With Basket	With MESC Basket	With Both Baskets
Labor	\$ 528	\$ 264	\$ 108	\$ 281	\$ 84	\$ 151	\$ 136	\$ 376
Materials	1,064	532	455	638	278	348	526	815
Utilities	50	25	31	31	21	21	32	32
Overhead and G&A	722	361	251	457	200	288	301	585
Depreciation	520	260	298	328	168	179	354	408
Property Taxes & Insurance	52	26	30	33	17	18	35	41
Pre-Tax Profit on Fabrication Facilities	<u>1,174</u>	<u>587</u>	<u>673</u>	<u>741</u>	<u>380</u>	<u>404</u>	<u>800</u>	<u>920</u>
	4,110	2,055	1,846	2,509	1,148	1,409	2,184	3,177
Special Equipment	<u>875</u>	<u>875</u>	<u>974</u>	<u>1,124</u>	<u>877</u>	<u>1,027</u>	<u>1,121</u>	<u>1,271</u>
	4,985	2,930	2,820	3,633	2,025	2,436	3,305	4,448
Contingency (29%)	<u>1,436</u>	<u>850</u>	<u>818</u>	<u>1,054</u>	<u>587</u>	<u>706</u>	<u>958</u>	<u>1,290</u>
 Total Fabrication Cost (1987 Dollars)	<u>\$6,421</u>	<u>\$3,780</u>	<u>\$3,638</u>	<u>\$4,687</u>	<u>\$2,612</u>	<u>\$3,142</u>	<u>\$4,263</u>	<u>\$5,738</u>
 Escalated Fabrication Cost (1988 Dollars) ^a	<u>\$6,602</u>	<u>\$3,887</u>	<u>\$3,741</u>	<u>\$4,819</u>	<u>\$2,686</u>	<u>\$3,231</u>	<u>\$4,383</u>	<u>\$5,900</u>

^aEscalated from 1987 to 1988 dollars using Machinery and Equipment Index (1.0282)

TABLE 4-6
ESTIMATED FABRICATION COST OF SNF SHIPPING CASKS
AS A FUNCTION OF THE NUMBER OF CASKS BUILT
(\$000, 1988)

<u>Cask Type</u>	<u>Cost Per Cask For Indicated Number of Casks Built</u>			
	<u>1 Cask</u>	<u>2 Casks</u>	<u>3 Casks</u>	<u>10 Casks</u>
Reference NUPAC Shipping Cask	\$3,887	\$3,301	-	\$2,790
24 PWR Assembly MESC Cask				
W/O Basket	3,741	3,030	\$2,794	-
With Basket	4,819	3,999	3,726	-
7 PWR Assembly MESC Cask				
W/O Basket	2,686	2,046	1,833	-
With Basket	3,231	2,482	2,232	-
2/7 PWR Assembly MESC Cask				
W/MESC Basket	4,383	3,565	3,292	-
W/Both Baskets	5,900	4,972	4,663	-

The 10 cask case for the reference shipping cask was calculated inasmuch as it was assumed that at least 10 casks of the reference design would be procured for the DOE cask fleet.

(2) Other Costs Associated With Fabrication

Other costs associated with fabrication include acceptance testing, performance evaluation, support to DOE, management and administration, and quality assurance. Here again, since no detailed breakdown of these costs was publicly available for the NUPAC rail cask, independent estimates of the costs were made during the course of this study. The difference between the costs estimated in this study and those set forth in Section 4.1.2.1 was taken as a contingency that was applicable to the other costs associated with cask fabrication. A summary of the estimated additional costs associated with cask fabrication for the reference NUPAC cask and the MESC casks is set forth in Table 4-7.

The professional fees and expenses shown in Table 4-7 were developed from estimates of the professional time required for the activities as estimated during the study, and using a \$75/hour professional fee rate. All other costs were estimated during the course of the study.

Using the foregoing methodology, it was determined that the costs so calculated for the two prototype NUPAC rail casks were about 17 percent less than the estimated costs under the contract

TABLE 4-7
ESTIMATED ADDITIONAL COSTS ASSOCIATED WITH THE FABRICATION OF FROM-REACTOR SNF SHIPPING CASKS^a
(\$000)

	Two NUPAC Rail Casks	Single NUPAC Rail Cask	Single 24 PWR Assy MESC Cask		Single 7 PWR Assy MESC Cask		Single 2/7 PWR Assy MESC Cask	
			W/O Basket	With Basket	W/O Basket	With Basket	With MESC Basket	With Both Baskets
Professional Fees & Expenses	\$ 950	\$ 620	\$ 522	\$ 652	\$ 437	\$ 567	\$ 580	\$ 755
Travel Expenses	123	78	81	81	69	69	81	81
Rental Equipment	82	41	48	48	36	36	48	48
Miscellaneous Supplies	23	15	19	19	12	12	19	19
	1,178	754	670	800	554	684	728	903
Contingency (@ 17%)	201	128	114	136	94	116	124	154
 Total (1987 Dollars)	 <u>\$1,379</u>	 <u>\$ 882</u>	 <u>\$ 784</u>	 <u>\$ 936</u>	 <u>\$ 648</u>	 <u>\$ 800</u>	 <u>\$ 852</u>	 <u>\$1,057</u>
 Escalated Total (1988 Dollars) ^b	 <u>\$1,429</u>	 <u>\$ 914</u>	 <u>\$ 812</u>	 <u>\$ 970</u>	 <u>\$ 671</u>	 <u>\$ 829</u>	 <u>\$ 883</u>	 <u>\$1,095</u>

^a Acceptance testing, performance evaluation, support to DOE, management and administration, and quality assurance

^b Escalated from 1987 dollars to 1988 dollars using the Labor Index on Non-Agricultural Production Workers (1.036)

between DOE and NUPAC. This was assumed to be the contingency associated with the costs involved, and the same contingency percentage was used for the MESC casks as well. The total costs were then increased by 3.6 percent to escalate them to 1988 dollars.

The estimated amounts of such other costs associated with fabrication of multiple numbers of casks was calculated using the linear relationship that was found to exist between the first and second reference NUPAC rail cask that was fabricated. This relationship can be expressed by the following algorithm:

$$C_n = \frac{a(1+1.29n)}{n}$$

where C_n = the other cost associated with the nth cask built in a single procurement

n = the number of casks procured in a given procurement

a = a constant which is equal to 43.7 percent of the other fabrication costs associated with the procurement of a single cask

This produced the other fabrication costs associated with multiple cask procurements as shown in Table 4-8.

TABLE 4-8
ESTIMATED OTHER COSTS ASSOCIATED WITH FABRICATION OF SNF SHIPPING CASKS
AS A FUNCTION OF THE NUMBERS OF CASKS BUILT IN A SINGLE PROCUREMENT^a
(\$000, 1988)

<u>Cask Type</u>	<u>Cost Per Cask For Indicated Number of Casks Built</u>			
	<u>1 Cask</u>	<u>2 Casks</u>	<u>3 Casks</u>	<u>10 Casks</u>
Reference NUPAC Shipping Cask	\$ 914	\$ 715	-	\$ 554
24 PWR Assembly MESC Cask				
W/O Basket	812	634	\$ 575	-
With Basket	970	758	688	-
7 PWR Assembly MESC Cask				
W/O Basket	671	525	476	-
With Basket	829	648	587	-
2/7 PWR Assembly MESC Cask				
W/MESC Basket	883	690	626	-
W/Both Baskets	1,095	857	777	-

^a Acceptance testing, performance evaluation, support to DOE, management and administration, and quality assurance

(3) Design and Development

It was assumed that the \$3.9-million cost for design and development of the reference NUPAC rail cask would also constitute the basic cost for the development of a family of casks of similar design though of difference size. For the purposes of this study, it was assumed that 30 percent of the design and development cost was associated with the cask basket (\$1.17-million) and 70 percent was associated with the cask body (\$2.73-million).

However, it was also assumed that there would be additional design and development costs associated with the MESC casks, and that these additional costs would amount to 20 percent of the cost of design and development of the cask body and of the cask basket for assemblies (where such was applicable). Moreover, it was assumed that the cost of design and development of the MESC basket would involve an additional cost of 30 percent of the cost of design and development of the reference cask basket. This resulted in added costs for cask design and development of MESC casks, as follows:

TABLE 4-9
ESTIMATED ADDED COSTS FOR DESIGN AND DEVELOPMENT OF MESC SHIPPING CASKS
(\$000, 1988)

<u>Cask Type</u>	<u>Added Costs for Single Cask</u>
7 & 24 PWR Assembly MESC Casks	
W/O Basket	\$ 547
With Basket	781
2/7 PWR Assembly MESC Casks	
W/MESC Basket	781
W/Both Baskets	1,016

For multiple units of the MESC casks, the above design and development costs would be divided by the number of casks involved.

(4) Model Fabrication and Associated Costs

For the purposes of this study it was assumed that the development, fabrication and testing of the model for the reference NUPAC shipping cask would suffice as well for the licensing of a 7 PWR assembly MESC cask. However, it was assumed that the 24 PWR assembly MESC cask would require the development, fabrication, and testing of a completely new model -- but that such model would also suffice for the licensing of the 2/7 PWR assembly MESC cask.

The fabrication cost of the new model was developed by multiplying the costs of fabrication of the reference model cask by the ratio of the cost of fabrication of a single full-sized 24 PWR assembly MESC shipping cask to that for fabrication of a single full-sized reference cask (both with baskets). The other costs associated with the development of the new model were determined by multiplying the other such costs involved for the reference model cask by the ratio of such other costs for a single full-sized 24 PWR assembly MESC cask to that for a single full-sized reference cask (both with baskets).

The estimated cost of the models for multiple numbers of casks represented thereby was calculated by spreading the cost of model development over the numbers of casks involved.

(5) Auxiliary Equipment

The estimated cost of auxiliary transport equipment was taken as \$0.664-million (1988 dollars). This consisted of \$0.553-million for a rail car, personnel barrier and tie downs, plus \$0.111-million for a lift beam, special tools and miscellaneous equipment. This estimate is the same as that reported in Reference 10, with escalation added. It was assumed that every cask would require a set of this auxiliary equipment and that the cost thereof would be the same for both the reference shipping cask and the MESC casks.

(6) NRC Certification Fees

The NRC Certification Fees that are applicable as of January 1989 amount to about \$0.165-million. There is a proposed change in 10CFR170 and 171 that, if approved, would allow NRC to collect a certification fee that represented the full recovery of all of the costs it incurs in connection with a given certification. Notwithstanding the foregoing, a \$0.165-million certification fee was used for the design of both the reference shipping cask and the 24 PWR assembly MESC cask. No certification fee was assumed for the 7 PWR assembly MESC cask or the 2/7 PWR assembly MESC cask since it was assumed that these would be certified along with the reference and 24 PWR assembly MESC casks.

The estimated cost of certification of a given cask type was spread over the numbers of casks built.

(7) Allocation of Added Cost of Reference Casks

For the purpose of this study, it was assumed that at least 10 reference shipping casks of a given design would be procured by DOE for its cask fleet. If MESC casks were substituted for one or more of the reference shipping casks, the total cost of the latter would be expected to rise inasmuch as there would be fewer numbers of casks over which to spread the cost of design and development, models, special fabrication equipment, fixed acceptance testing costs and certification fees. These added costs are as follows:

TABLE 4-10
ADDED COST OF REFERENCE SHIPPING CASK AS A RESULT OF
PROCUREMENT OF FEWER NUMBERS OF A GIVEN DESIGN
(\$000, 1988)

<u>Description</u>	<u>Added Cost (Per Cask)</u>
Development Costs	\$390
Models	209
Fabrication	116
Acceptance Testing	52
Certification	<u>17</u>
Total	<u><u>\$784</u></u>

The added costs attributable to the MESC casks were calculated by adjusting the above costs to account for the differences between the capacities of the MESC casks and the reference FWMS shipping cask, on a linear basis. This gave the following additional costs of the reference casks that resulted from the use of the various MESC casks.

TABLE 4-11
ADDED COSTS ATTRIBUTABLE TO MESC CASKS AS A RESULT
OF PROCUREMENT OF FEWER NUMBERS OF REFERENCE SHIPPING CASKS
(\$000, 1988)

<u>Description</u>	<u>Added Cost (Per Cask)</u>
24 PWR Assembly MESC Cask ^a	\$896
7 PWR Assembly MESC Cask ^b	\$261
2/7 PWR Assembly MESC Cask ^c	\$971

^a 24/21 times total from Table 4-10

^b 7/21 times total from Table 4-10

^c 26/21 times total from Table 4-10

4.1.2.3 Estimate of Freight and Other Costs Associated With Cask Use

Estimates of costs were developed for operating expenses associated with the use of the reference shipping cask and MESC shipping casks, as well as freight charges, security escort costs, and decommissioning costs. These costs were developed for two different shipping distances -- 500 miles and 2800 miles, which are those assumed to be applicable for shipments from reactor sites using MESC's for storage and the MRS and repository facilities, respectively. In the event other reactor sites commit to the use of MESC's, additional distance cases would have to be estimated.

The number of cask shipments that could be achieved in a single year for each of the above distances was calculated to be 18 for the 500-mile shipments (17 where MESC's were opened and unloaded while still in the cask) and 8 for the 2800-mile shipments (for all cases). This was based on rail speeds of 88 miles/day for a 500-mile (one-way) shipment and 182 miles/day for a 2800-mile (one-way) shipment. The turnaround time of the cask was taken at 4.5 days/shipment (per the 1988 TSLCC assumptions); an additional 8 hours/shipment was allowed for opening of the MESC while they were still in the cask and 10 hours/shipment less time was allowed where the loaded MESC was removed from the cask and unloaded in the hot cell.

The cost of freight and other transport-related costs were calculated as described in the following:

(1) Operating Costs

Operating costs include cask maintenance and the cost of inspectors dispatched to reactor locations to observe the loading of shipping casks there.

A cost for cask maintenance of \$125-thousand/year was used in this study; this was the figure obtained from the assumptions used in the 1988 Total-System Life Cycle Cost (TSLCC). In addition, this document included an assumption that two inspectors would be provided for one shift a day while the shipment is at the reactor. The cost of these inspectors, including their associated travel costs was estimated to be \$4,700/cask trip (1988 dollars). This results in operating costs of \$210-thousand/year for 500-mile shipments (\$205-thousand/year where the MESC was opened and unloaded while still in the cask), and \$163-thousand/year for 2800-mile shipments.

(2) Freight Charges

The freight rates were determined using the algorithms developed in Reference 10 for shipments of both loaded and empty casks, as follows:

$$R_l = 0.1678D^{0.5815}$$

$$R_e = 0.1600D^{0.5790}$$

where R_l = the freight rate for the loaded cask (CWT)

R_e = the freight rate for the empty cask (CWT)

D = the one-way shipment distance

The freight rates so determined amounted to \$6.23/CWT loaded and \$5.85/CWT empty for 500-mile shipments, and \$16.96/CWT loaded and \$15.85/CWT empty for 2800-mile shipments. These were then escalated to 1988 dollars from 1986 dollars (the basis for the algorithms in Reference 10) and multiplied by the weight of the shipping casks on the transport vehicle as described in Table 4-2. A minimum of 250,000 lb for loaded casks and 225,000 lb for empty casks was assumed to be applicable for these freight rates*. This produced the total freight costs for a single round-trip shipment of both MESC shipping casks and the reference cask shown in Table 4-12.

TABLE 4-12
FREIGHT COSTS FOR A SINGLE ROUND TRIP SHIPMENT OF MESC SHIPPING CASKS
AND THE REFERENCE SHIPPING CASK^a

<u>Cask Type</u>	<u>Form of Fuel Shipped</u>	<u>Cost of a Single Round-Trip Shipment (1988 Dollars)</u>	
		<u>500 Miles</u>	<u>2800 Miles</u>
Reference Rail Cask	Assemblies	\$29,888	\$81,186
24 PWR Assembly MESC Cask	MESCs	32,479	88,241
24 PWR Assembly MESC Cask	Assemblies	30,726	83,466
7 PWR Assembly MESC Cask	MESCs	29,888	81,186
7 PWR Assembly MESC Cask	Assemblies	29,888	81,186
2/7 PWR Assembly MESC Cask	MESCs	32,878	89,314
2/7 PWR Assembly MESC Cask	Assemblies	33,745	91,668

^aAll casks are rail casks.

*No allowance was made for any premium rates that might apply to extra-heavy shipments (i.e., those over 263,000 lb).

(3) Security Escort Charges

The 1988 TSLCC assumptions included provisions for two armed escorts to accompany rail shipments of spent fuel. The cost for these escorts was developed using the following assumptions:

- (a) Two men (a guard sergeant and a security officer) would be located in the caboose during the entire loaded portion of the shipment. The sergeant would carry a rate of \$13.01/hr and the officer a rate of \$11.83/hr. Each would receive 16 hours of pay for each 24 hours involved in the shipment. The guards' pay would carry a 35 percent burden; a 13 percent general administrative cost would be applied to the salary rate plus burden; and a 5 percent profit would be applied to the sum of the foregoing. This produces a total of \$637/day for the escorts. This cost was applied to the total elapsed time of the shipment plus a 16 hour layover, air travel at 500 mph, and 4 hours for ground travel time.
- (b) Each of the guards would each receive a \$26/day subsistence allowance.
- (c) In addition to (b), above, the guards would receive \$73/day for hotel and taxi expenses on the return trip.
- (d) A rail fare of \$.089/mile per guard was assumed to be applicable to the shipment. Air fare was estimated at \$0.30/mile per guard for the return trip.
- (e) A security equipment charge of \$12/day (total) was assumed to be applicable.

These costs were developed by escalating similar costs used to develop estimated transportation costs in Reference 10 using applicable indexes. Using the above costs, the security costs associated with a single 500-mile shipment would amount to \$5,131, and for a 2800-mile shipment would amount to \$13,855.

(4) Decommissioning Costs

The cost of disposal of shipping casks at the end of their useful life was estimated using the following assumptions:

- (a) The freight rate for the shipment of the cask to a low-level waste burial site was estimated as being that of a 1500-mile shipment of an empty cask calculated as described in (2), above, (\$11.43/CWT).
- (b) The cost of disposal was determined by multiplying the volume of the shipping cask, excluding impact limiters by the applicable 1988 Chem-Nuclear low level waste burial charges plus a weight surcharge and a local tax of 2.4

percent on the total. The base disposal charges, taxes, fees and funds amounted to \$44.78/cu. ft. The weight surcharges amounted to \$2,520 for the first 50,000 lb plus \$605/10,000 lb thereafter (11). The weight of the empty cask without impact limiters was used as the basis for calculating the weight surcharge.

- (c) For the case where both a MESC basket and an assembly basket was used in connection with a MESC shipping cask, the cost of disposal of the MESC basket was estimated on the basis that the basket would be compacted to 33 percent of theoretical density, using the \$44.78/cu. ft. disposal charge. It was assumed that it could be disposed of under the weight surcharge paid for the cask, and that it could be shipped with the cask, with no additional charges being applicable thereto. Volume reduction of the MESC cask was estimated to require 160 person hours of effort at \$65/hour fully burdened and with overhead and G&A, and materials costs associated therewith were estimated at \$600.

- (d) A 15 percent contingency was added to the above costs.

A summary of the estimated total costs for disposal of the reference shipping casks and each type of MESC cask considered in this study is set forth in Table 4-13.

The above charges were developed on the assumption that disposal may take place at any one of several low level waste burial sites. The Chem-Nuclear charges have been used in developing the estimated costs described in Table 4-13 inasmuch as it was believed that these would be representative of costs that might be incurred during disposal at any low level waste burial site, including any special site developed by DOE for this purpose.

Moreover, it is possible that the foregoing costs might be reduced considerably if the casks could be sufficiently decontaminated for the contained metal to be sold for salvage. However, this would require careful testing and certification prior to release to unrestricted use.

TABLE 4-13
SUMMARY OF ESTIMATED SHIPPING CASK DISPOSAL COSTS
 (1988 Dollars)

4-18

<u>Description</u>	<u>Reference Shipping Cask</u>	<u>24 PWR Assembly MESC Cask</u>		<u>7 PWR Assembly MESC Cask</u>		<u>2/7 PWR Assembly MESC Cask</u>	
		<u>W/O Basket</u>	<u>With Basket</u>	<u>W/O Basket</u>	<u>With Basket</u>	<u>W/MESC Basket</u>	<u>W/Both Baskets</u>
Volume Reduction of MESC Basket	-	-	-	-	-	-	\$ 11,000
Transport	\$25,830	\$25,830	\$25,830	\$25,830	\$25,830	\$25,830	25,830
Disposal	<u>35,265</u>	<u>46,885</u>	<u>47,938</u>	<u>22,199</u>	<u>22,633</u>	<u>54,548</u>	<u>58,188</u>
	61,095	72,715	73,768	48,029	48,463	80,378	95,018
Contingency (15%)	<u>9,164</u>	<u>10,907</u>	<u>11,065</u>	<u>7,204</u>	<u>7,269</u>	<u>12,057</u>	<u>14,253</u>
Total	<u>\$70,259</u>	<u>\$83,622</u>	<u>\$84,833</u>	<u>\$55,233</u>	<u>\$55,732</u>	<u>\$92,435</u>	<u>\$109,271</u>

4.1.2.4 Life Cycle Transport Costs and Unit Costs

The total life cycle costs associated with the use of a single reference shipping cask and MESC shipping casks for shipments from reactors to DOE facilities were developed assuming the casks would be utilized to their full capacity over their assumed 20-year lifetime -- to ship either individual PWR assemblies or MESCs containing PWR assemblies, exclusively. These cost calculations and the assumptions associated therewith have been included in Appendix A and are summarized in Table 4-14.

TABLE 4-14
COMPARISON OF UNIT COSTS FOR TRANSPORT OF SNF IN
REFERENCE SHIPPING CASK AND MESC SHIPPING CASKS^a
(\$/kgU, 1988)

<u>Cask Type</u>	<u>Unit Costs for Indicated One-Way Shipping Distances</u>			
	<u>500 miles</u>		<u>2800 miles</u>	
Reference Shipping Cask	\$ 6.68		\$16.17	
Single 24 PWR Assembly MESC Cask in DOE Fleet				
MESCs	8.07	(1.39)	18.57	(2.40)
Assemblies	8.20	(1.52)	19.30	(3.13)
Two 24 PWR Assembly MESC Casks in DOE Fleet				
MESCs	7.09	(0.41)	16.50	(0.33)
Assemblies	7.18	(0.50)	17.01	(0.84)
Single 7 PWR Assembly MESC Cask in DOE Fleet				
MESCs	20.68	(14.00)	48.47	(32.30)
Assemblies	21.44	(14.76)	51.01	(34.84)
Single 2/7 PWR Assembly MESC Cask in DOE Fleet				
MESCs	12.65	(5.97)	29.41	(13.24)
Assemblies	7.34	(0.06)	17.55	(1.38)

^a Numbers in parentheses represent an increase in unit cost over that for shipping individual fuel assemblies in the reference shipping cask.

It should be pointed out that the costs shown in the foregoing table represent the lowest unit costs possible under the estimated cost of casks, freight, etc., inasmuch as the casks were assumed to be fully utilized during their lifetime. From the information set forth in the table, it can be seen that the unit costs for shipment of either individual fuel assemblies or MESC's in MESC shipping casks were invariably higher than the unit cost for shipment of individual fuel assemblies in the reference shipping cask.

It was recognized that there is no current reason to expect that shipment of MESC's would commence as early as 2003, and that current plans of utilities only provided for up to 1900-2000 MTU (4224 PWR assemblies) to be stored in 24 PWR assembly MESC's and up to 26 MTU (56 PWR assemblies) to be stored in 7 PWR assembly MESC's -- although there is a distinct possibility that utilities will commit to store additional quantities of SNF in such a fashion (particularly in the higher capacity MESC's). Considering the existing known plans of utilities in this regard, it was determined that a single 24 PWR assembly MESC shipping cask and a single 7 PWR MESC shipping cask would have sufficient capacity for transport of the MESC's, except in the case of long distance shipments where two 24 PWR assembly MESC casks might be needed. Therefore, additional total life cycle costs associated with the use of the casks were developed for a range of quantities so that the sensitivity of unit costs to the quantities of PWR assemblies shipped in MESC's could be determined. This was done in two different ways; (i) assuming the cask would be used to ship individual PWR assemblies to the extent there were insufficient MESC's available to fully utilize the cask capacity over its assumed 20-year lifetime, and (ii) assuming the cask would be used to ship only MESC's and that the cask would be utilized only to the extent that MESC's were available for shipment. These cost calculations and the assumptions associated therewith have been included in Appendix B for the 24 PWR assembly MESC cask, Appendix C for the 7 PWR assembly MESC cask, Appendix D for the 2/7 PWR assembly MESC cask, and a summary of the increases in unit costs over those involved with transport of individual PWR assemblies in the reference shipping cask is set forth in Table 4-15.

TABLE 4-15
INCREASE IN UNIT COSTS FOR THE TRANSPORT OF PWR ASSEMBLIES IN MESCs
OVER TRANSPORT IN UNCANISTERED CONDITION IN A REFERENCE SHIPPING CASK
(1988 Dollars)

Cask Type	Distance Shipped (miles)	Total Quantity Shipped in MESCs (MTU) ^a	Increase in Unit Cost (\$/kgU) Resulting From	
			Mixed Use of Cask ^b	Use Dedicated to MESCs
24 PWR Assembly MESC Shipping Cask	500	564	\$ 14.34	\$ 16.69
		940	8.49	10.18
		1,504	5.21	6.54
		1,880	4.09	5.32
	2,800	534	7.63	24.04
		890	4.65	14.46
		1,424	2.97	9.08
		1,780	2.40	7.30
<hr/>				
7 PWR Assembly MESC Shipping Cask	500	58	409.60	93.26
		116	199.39	51.72
		232	95.89	30.96
	2,800	52	445.95	118.90
		104	222.98	72.58
		208	104.93	49.47
<hr/>				
2/7 PWR Assembly MESC Shipping Cask	500	55	75.78	133.79
		110	41.20	68.33
		220	23.24	36.09
	2,800	52	81.57	145.44
		104	46.30	77.23
		208	29.49	43.13

^a Assumes each PWR fuel assembly contains 461 kgU prior to irradiation.

^b Used to ship both individual assemblies as well as MESCs as available.

The increases in unit cost were calculated by taking the increase in the cost of shipping spent fuel in MESC shipping casks and attributing it solely to the cost of MESC shipments. In cases where a cask was used solely for shipments of MESC's when they were available, an addition to the unit cost was made amounting to \$1.85/kgU for the 500-mile shipment cases and \$4.18/kgU for the 2800-mile shipment cases to effect a prorata charge for a lower utilization of the reference cask as a result of having the MESC cask in the DOE fleet.

From the information contained in the foregoing table, the following can be concluded:

- (1) The shipment of PWR assemblies in MESC's is generally more expensive than the shipment of individual PWR assemblies in the reference shipping cask.
- (2) The use of the 24 PWR assembly and 2/7 PWR assembly MESC casks are generally more expensive when used solely for shipment of MESC's (dedicated use) than when they are fully utilized by shipping both individual PWR assemblies and MESC's to the extent the latter are available (mixed use), within the quantity range studied.
- (3) The use of a 7 PWR assembly MESC cask is less expensive when used solely for shipment of MESC's (dedicated use) than when they are fully utilized by shipping both individual PWR assemblies and MESC's to the extent the latter are available (mixed use), within the quantity range studied. This is due to the high cost of shipping individual PWR assemblies in the 7 PWR assembly MESC cask over that of shipment in the reference cask, and the fact that this much higher cost has to be allocated to the relatively small amount of SNF contained in the 7 PWR assembly MESC's.

Considering the fact that the weight of the 24 PWR assembly MESC cask and the 2/7 PWR assembly MESC cask loaded with individual PWR assemblies (127 tons and 121 tons, respectively) may be too high for all reactors having rail access to use, the most conservative approach would be to assume that the MESC casks would only be used for the shipment of MESC's. Also, under these circumstances it would appear that the use of a 7 PWR assembly MESC shipping cask would be preferable to the use of a 2/7 PWR assembly MESC shipping cask.

The high cost of shipping the 7 PWR assembly MESC casks might be avoided if the utility had a shipping cask (e.g., the IF-300 cask) that could be used for the shipment and would provide it at no cost to DOE. In such an

instance, only the freight and escort charges shown on Tables C-7 through C-12 of Appendix C would be incurred by the FWMS. These amount to \$10.26/kgU for a 500-mile shipment and \$29.23/kgU for a 2800-mile shipment, or an increase of \$3.63/kgU and \$13.17/kgU, respectively, over the cost of use of the reference cask for shipping individual fuel assemblies.

The increases in unit costs set forth in Table 4-15 were based on the assumption that loaded casks (both the reference cask and MESC casks) would be shipped by regular train. In the event the loaded reference casks were shipped by special train, with 3 casks being involved in a single shipment, the cost per cask shipment could be reduced by as much as 28 percent for a 500-mile shipment and by as much as 12 percent for a 2,800-mile shipment. This reduction amounts to about \$2.00/kgU and \$2.50/kgU, respectively, for shipments of 500 and 2,800 miles. The reduction in costs associated by the shipment of MESC shipping casks by special train could be expected to be slightly higher because of the shorter overall time required for the shipment by special train and the higher cost of MESC shipping casks. Thus, the impact on the increases in unit costs shown in Table 4-15 that is occasioned by the use of special trains instead of regular trains can be expected to be small.

4.2 MESC PROCESSING IN FWMS FACILITIES

This section reports the results of the study of the impacts and costs associated with the acceptance of MESC's at MRS or repository facilities.

4.2.1 Processing Alternatives for MESC's

There are three basic alternatives for handling MESC's in the FWMS facilities regardless of whether or not a MRS facility is included therein. These alternatives are shown in the block diagram set forth in Figure 4-1 and are summarized in the following:

Alternative #1 -- The weld on the MESC lid and shield plug could be cut open while the MESC still is in either the shipping cask or a transfer cask and the assemblies unloaded into the hot cell facilities, in the same way they would otherwise be unloaded (and subsequently handled and processed) from a reference shipping cask (one that was designed for shipping individual SNF assemblies). Subsequently, the MESC could be decontaminated using the equipment normally used for decontamination of cask internals, unloaded from the shipping or transfer cask, and packaged for disposal.

Alternative #2 -- The MESC's could be unloaded into the hot cell facilities and the weld on the MESC lid and shield plug could be cut open inside the hot cell, the contained assemblies unloaded, and the MESC decontaminated and packaged for disposal. Some lag storage space for the MESC's would be required in the hot cell whether they were subsequently stored in separate interim storage facilities (MRS) or processed directly. Once the assemblies were removed from the MESC in the hot cell they would be subsequently handled and processed in the same way they would have otherwise been had they not been received in MESC's.

Alternative #3 -- There has been a suggestion that MESC's might be used as a repository package and might not have to be unloaded in the FWMS facilities (2). However, the design of the repository package represents a vital part of the waste isolation system and is not expected to be finalized for a number of years in the future. Therefore, it does not appear to be possible presently to specify the characteristics of a MESC that would meet the requirements of a repository package, nor reasonable to force the designers of the repository package to design the package around the characteristics of a MESC. Moreover, MESC's will probably be needed to meet at-reactor storage requirements (to the extent they are so used) prior to finalization of the design of the repository package, and the SNF assemblies contained therein will represent only a fraction of the total number of assemblies expected to be received by the FWMS. Therefore, the possible use of a MESC as a repository package was not considered in this study.

If there is a MRS facility in the FWMS, the MESC's could be stored therein in either vertically-loaded concrete casks or in horizontal concrete modules (HSM). MESC's could be directly loaded into HSMs from the shipping cask by pulling them in to the module, but would have to be unloaded from the shipping cask and subsequently loaded into the vertically-loaded concrete casks. MESC's could also be loaded into a transfer cask from the hot cell facilities and the transfer cask used to load the HSMs.

All of the processing alternatives described in Figure 4-1, and outlined above, were considered in the course of this study, except the alternative where the MESC was used as a repository package, to identify:

- (1) The most economical (and operationally efficient) combination of handling alternatives available for the SNF contained in MESC.
- (2) The added cost or savings to the FWMS facilities resulting from the receipt of SNF in MESC's compared with the receipt of individual PWR assemblies in a reference shipping cask.

4.2.2 Reference Facility Design

The design of the Integral Monitored Retrievable Storage (MRS) Facility, developed by The Ralph M. Parsons Co. (12), was used as the reference processing facility for evaluating acceptance of MESC's into FWMS facilities. This advanced conceptual design (ACD) has a capacity for receiving, handling and processing of 3,600 MTU/year of spent fuel in assembly form and has a capability for storing consolidated SNF in concrete storage casks. This particular facility design was selected because it represents a major design effort and the documentation available includes detailed drawings, equipment specifications and cost estimating data.

The design of processing facilities associated with the Nevada Nuclear Waste Storage Investigation Project (13), located at a proposed tuff repository site, was also evaluated with respect to MESC acceptance. Although the design of the Nevada spent fuel processing facilities is only preliminary, it was determined that any changes in the Parsons ACD would be representative of those changes and additions required at the Nevada facility as well.

The following provides a brief description of the facilities involved in the Parsons ACD:

(1) Receiving and Handling Facility

For illustrative purposes a simplified plan of ACD facility hot cells is shown in Figure 4-2. The four process hot cells are functionally identical except that one pair of hot cells would be dedicated to PWR fuel disassembly and rod consolidation and the other pair of hot cells would process BWR fuel. The ACD concept also uses 55-gallon drums as containers for shredded non-fuel bearing components from the fuel assemblies. The two large "canyon cells" are intended to be kept clean, or at a very low contamination level, as no bare fuel or fuel components are handled in these areas.

The ACD facility consolidates the spent fuel rods into 12-3/4 inch diameter canisters (schedule 20 stainless steel pipe). Each canister holds the consolidated rods from 3 PWR or 7 BWR fuel assemblies. Consolidation takes place in the four process hot cells. The canisters are loaded horizontally through a port in the wall separating the process and canyon hot cells. The two canyon cells contain the canister sealing and testing equipment. The canyon cells also contain the equipment for placing the spent fuel canisters in repository overpacks and sealing the overpacks. The two canyon cells also contain forced air-cooled storage vaults with a combined capacity of approximately 1000 MTU of fuel in canisters. The design drawings and text do not indicate whether or not the

FIGURE 4-2
ACD FACILITY HOT CELL AREA

vaults are arranged to hold loaded overpacks and NFBC drums, although it would be advantageous to do so. The process cells and canyon cells have small lag storage racks near the cask loading/unloading ports. The process cell lag storage racks can each hold about 80 MTU in the form of intact fuel assemblies which are held in removable, interchangeable support baskets while the canyon cell lag storage racks are designed to hold either canisters or repository overpacks.

(2) MRS Area

The ACD includes the design and layout of a 133 acre storage area for MRS with space for 1760 casks of consolidated and unconsolidated fuel (in canisters), non-fuel components, various types of radioactive waste, and a number of dual-purpose metal casks. The casks sit on long, 18 inch thick concrete pads.

(3) MRS Casks

The ACD includes the designs of concrete storage casks for holding canisters of spent fuel and other materials to be kept in the MRS area. Figure 4-3 illustrates the Parsons spent fuel storage cask which was designed to contain 12 canisters of consolidated fuel rods. The casks are moved to and from the storage area by a crawler type transporter and lifted and placed by a 600-ton mobile crane.

It was determined that the ACD facility's concrete MRS casks could be easily adapted for storing MESCs with no impact on the cask handling or transport system or the total area required for storage. However, if MESCs were stored in the MRS area, it was evident that the total number of casks would be affected and it might be necessary to add additional support pads in the storage area.

Details of the modifications and additions to the ACD facility materials handling systems, hot cells, storage casks and MRS area required for the facility to be able to accept SNF in MESCs are discussed in detail, along with associated costs, in Section 4.2.3.

4.2.3 Estimates of Cost Impacts at FWMS Facilities

In order to estimate the costs of changes in the ACD facilities and equipment required to accept MESCs, the Parsons detailed cost estimates (in 1985 dollars) were used to determine appropriate unit costs for materials, construction labor, work-hours per task, overhead and burdens, and add-ons for engineering and construction management. The cost estimates thus

FIGURE 4-3
ACD FACILITY SPENT FUEL STORAGE CASK

developed for required changes in facility and equipment design occasioned by the acceptance of SNF in MESCs were determined on the same basis as was used by Parsons in its original cost estimates. These estimates were escalated with appropriate indices to 1988 dollars. In cases where the ACD facility cost estimating information was inadequate or missing, current labor, equipment and materials costs were obtained from industry vendors, services and cost estimating sources.

Estimates of additions (or savings) to the capital and operating costs of the reference ACD facility were developed for each of the MESC processing alternatives described in Section 4.2.1 as being considered in this study. In the following Sections 4.2.3.1 through 4.2.3.9, the additional costs involved for each additional operation involved in the handling of MESCs in FWMS facilities are developed. Section 4.2.3.10 develops the incremental life cycle costs and associated unit costs for each of the alternatives considered for handling MESCs in FWMS facilities, and identifies those alternatives that are the most cost effective.

4.2.3.1 Cost of Equipment for Cutting Open MESCs Outside of Hot Cell Facilities

If MESCs are to be cut open outside of hot cell facilities the shipping casks (or transfer cask) would be received in the normal fashion, and after removal of the cask closure in the Cask Receiving Bay, a cutting machine would be fitted on the top of the cask and the outer cover seal weld removed. After removal of the outer cover, the shield plug seal weld would be removed. Removal of the cutting machine would then permit the cask to be positioned under the unloading port of the Process Cell and the fuel assemblies would be removed in the normal manner for processing. The cask, with the empty MESC would be removed to the decontamination station where the MESC internals and cask outside would be decontaminated. Following replacement of the shield plug and tack welding, the MESC would be removed and the outside decontaminated preparatory to disposal.

The cost of the additional facilities was estimated at \$499-thousand, as described in Table 4-16.

TABLE 4-16
ESTIMATED COST OF EQUIPMENT FOR OPENING AND HANDLING OF MESCs
(\$000, 1988)

<u>Description</u>	<u>Amount</u>
Weld Cutting Machine	\$ 150
Vacuum Follower	60
Stand & Frame	50
Remote Operation Controls & Console	35
	<u>295</u>
Construction Management (10%)	30
System Design & Engineering (25%)	74
	<u>399</u>
Contingency (25%)	100
Total	<u>\$ 499</u>

The foregoing costs are fixed costs and would have to be distributed over the total amount of SNF received in MESCs.

4.2.3.2 Operating Costs for Cutting Open MESCs Outside of Hot Cell Facilities

In addition to the required equipment described in Section 4.2.3.1, some additional operating costs would be involved in cutting open the MESCs outside the hot cell, as follows:

(1) Labor and Materials

The labor effort involved in setting up the cutting operation, performing the cutting work, installation of the lid lifting fixture, decontamination of the MESC after the assemblies have been removed, replacement of the shield plug and tack welding thereof, and removal of the MESC from the cask into the disposal container -- was estimated to amount to 52 person-hours for a 24 PWR assembly MESC and 40 person-hours for a 7 PWR assembly MESC. A labor hour cost of \$65.34 was used which included wages, labor burden, supervision, support, overhead, general and administrative expenses, and operating supplies. This would produce an incremental unit cost of \$0.31/kgU for 24 PWR assembly MESCs and \$0.81/kgU for 7 PWR assembly MESCs based on an assumed initial uranium content of 461 kg/assembly.

(2) Utilities; Maintenance Parts and Supplies

An allowance was made for the cost of utilities and maintenance parts and supplies amounting to \$200 for the opening and handling of a 24 PWR assembly MESC and \$150 for a 7 PWR assembly MESC, such would amount to \$0.02/kgU and \$0.05/kgU, respectively.

Thus, the total incremental unit costs for cutting open the MESC's outside the hot cell facilities and the handling thereof amounts to \$0.33/kgU for a 24 PWR assembly MESC and \$0.86/kgU for a 7 PWR assembly MESC.

4.2.3.3 Cost of MESC Disposal

The cost of MESC disposal will be the same for both alternatives examined (either cutting open the MESC in the cask outside the hot cell facilities, or in the hot cell after removal from the cask). The cost of MESC disposal includes the labor associated with the packaging of the MESC and its preparation for shipment, package costs, shipping costs, and burial ground fees. Volume reduction, by cutting up or melting down the MESC, was not considered inasmuch as it would require additional processing areas, equipment and operating labor -- and was expected to be more expensive than disposal of the intact MESC. A summary of these estimated costs (all incremental) is set forth in Table 4-17.

TABLE 4-17
ESTIMATED MESC DISPOSAL COSTS
(1988 Dollars)

	24 PWR Assembly MESC	7 PWR Assembly MESC
Labor (disposal preparation)	\$ 1,094	\$ 1,094
Disposal Container	4,050	2,151 ^b
Shipping Cost ^a	1,650	825 ^b
Burial Ground Fees ^c	<u>22,111</u>	<u>7,182</u>
Total Disposal Cost	<u>\$28,905</u>	<u>\$11,252</u>
Total Unit Cost	\$ 2.61/KgU	\$ 3.49/KgU

^a Based on an assumed \$1.65/mile for a 1000-mile shipment

^b Assumed two 7 PWR assemblies MESC's can be shipped in a single shipment

^c Based on Chem Nuclear rates for Barnwell disposal site effective January 15, 1988

4.2.3.4 Cost of Additions to ACD Facility Receiving and Hot Cell Facilities

If MESCs are to be opened ultimately in the hot cell facilities of the FWMS, some modification and/or additions will be required to the shipping cask receiving facilities, the process hot cells, and lag storage facilities. These modifications and/or additions are described in the following:

(1) Receiving, Inspection and Shipping Area

Both of the transport cask receiving bays in the ACD facility have 150-ton bridge cranes for shipping cask handling and they are entirely adequate for handling the MESC shipping casks. MESC transport cask handling and preparation for top closure removal or replacement is not seen as being different from any other spent fuel shipping cask that would be used in the FWMS. However, each type, style or size of cask used in the FWMS requires a unique set of handling fixtures; i.e., cask lifting yoke adaptor, cask transfer cart adaptor and unloading cell contamination control barrier. These items would normally be considered a part of the facility tool and equipment complement. Thus, it is to be expected that each MESC rail shipping cask design would have different dimensions than other casks in the FWMS fleet and that each would require a special set of cask handling tools.

The ACD facility cask unloading/loading cells appear to be adequately sized to permit the receipt and unloading of SNF assemblies from MESC shipping casks without modification, except that the unloading port would have to be sized to allow the accommodation of a wide range of cask cavity diameters. Since the internal cavities of the shipping casks currently being procured by DOE range from less than 20 inches square to 66 inches in diameter, the unloading ports already have a wide range of capability to accept casks of varying internal dimensions and thus should be able to handle the MESC casks with no additional cost being associated with any minor design changes that might be required.

(2) Process Hot Cell

As noted earlier, the ACD facility hot cells were designed for the handling and processing of individual fuel assemblies and both hot cell space and equipment would have to be added to open the MESCs, remove the fuel assemblies therefrom, and decontaminate the empty MESCs. It was determined that the following additions, modifications, and associated systems would be needed in the process hot cell:

- (a) Hot Cell Service Crane; upgrade from 20 tons capacity to 50 tons, to lift the loaded MESCs.
- (b) MESC Lifting Grapple(s); unique to MESCs.

- (c) Hot Cell Floor Space; one process hot cell would require widening by approximately 8 feet to accommodate the MESC processing equipment. The ACD did not include a contingency or special purpose hot cell for any sort of non-routine processing operations.
- (d) Intercell Transfer Door; required to move MESCs from the canyon cell directly into the process hot cell. The ACD did not anticipate transferring material directly from the canyon cell into the process hot cell and MESCs would otherwise have to be transferred between the two cells in a shielded cask via the cask receiving bay outside. The transfer door is for operational convenience.
- (e) Modify Lag Storage; the ACD lag storage holds approximately 80 MTU of individual PWR or BWR fuel assemblies in removable, interchangeable baskets. The pit requires widening by several inches and rearrangement of the basket support structure to hold the large size MESC. Savings in concrete would probably offset any increase in costs, resulting in little or no incremental cost adjustment for this item, except for some additional design work.
- (f) MESC Open/Weld Station; required to support, cut and remove closures and seals. The station might also be needed to replace the closures.
- (g) Decontamination Station; to clean empty MESCs prior to removal from the hot cell. This function can be combined with item (f) in a machine similar to the R.O. weld/decon station specified in the canyon cell which is used for opening or closing the repository overpacks.
- (h) M/S Manipulator; a dedicated master/slave manipulator will be needed adjacent to the work station in items (f) and (g).
- (i) Shielding Windows; for viewing of MESC operations in the hot cell.
- (j) CCTV Viewing Equipment; for viewing of MESC operations.

(3) Lag Storage Vault Cell

The storage vault cell would be used primarily as a storage facility for MESCs that were not to be immediately opened or to be transferred to a storage cask for MRS. Required revisions to the lag storage vault cell would include the following items:

- (a) Service Cranes; upgrade from 35 tons to 50 tons lift capacity.

- (b) MESC Lifting Grapple(s).
- (c) Revise Lag Storage; similar to the lag storage pit in the process hot cell, with no incremental cost incurred.
- (d) Revise Vault; to accommodate MESC(s). Like the lag storage pits, there would probably be little, if any, costs incurred since the MESC support baskets would be installed in place of canister baskets during initial construction of the vault.
- (e) Lag Storage Vault Decontamination Station: enlarge the size of the existing ACD facility cell decontamination station to accommodate MESC's along with spent fuel canisters or waste packages.

The estimated cost for modifications and additional equipment in the hot cell facilities for MESC transfer and storage are shown in Table 4-18.

TABLE 4-18
SUMMARY OF INCREMENTAL RECEIVING AND HANDLING FACILITY COSTS
FOR HOT CELL OPENING AND UNLOADING OF MESC's
(\$000, 1988)

	<u>Labor</u>	<u>Materials</u>	<u>Total</u>
Receiving Bay Equipment	\$ 3	\$ 84	\$ 87
Process Hot Cell			
Structure	97	175	272
Equipment	83	2,655	2,738
Electrical/Instrumentation	14	102	116
Lag Storage Vault Cell	<u>3</u>	<u>174</u>	<u>177</u>
Total Direct Costs	\$ 200	\$3,190	\$3,390
Construction Management (10%)			339
Engineering (25%)			<u>847</u>
Subtotal			4,576
Contingency (25%)			<u>1,144</u>
Total Estimated Cost			<u><u>\$5,720</u></u>

The foregoing costs are fixed costs and would have to be distributed over the total amount of SNF received in MESC's.

4.2.3.5 Additional Costs of Operations at ACD Facility Receiving and Hot Cell Facilities

In addition to the required capital additions and modifications described in Section 4.2.3.4, some additional operating costs for these facilities will also be incurred as the result of acceptance of spent fuel in MESCs. The principal operating costs associated with handling MESCs in the ACD facility receiving and handling building (hot cells) were identified as those involving opening the MESCs and removing the fuel, and the disposal of the empty MESCs.

(1) Labor

The labor effort for a 2 person hot cell crew to open and remove the fuel from the 24 PWR assembly and 7 PWR assembly MESCs was estimated to be 35.7 and 33.2 person-hours, respectively. This effort includes bringing the MESC into the process hot cell, cutting and removing the closures, decontamination of the empty MESC and removing it from the hot cell. Using a labor cost of \$65.34/hr. the unit cost for labor would amount to \$0.21/kgU for a 24 PWR assembly MESC and \$0.67/kgU for a 7 PWR assembly MESC.

(2) Utilities

The operating expense for utilities would primarily be the electricity cost in the process hot cell for lights and the ventilation system, which operate continuously, with only a small incremental demand for process equipment. This utility cost is incurred regardless of the number of MESCs received and opened. The utilities cost for the additions to the facility for MESC processing was estimated at \$22-thousand per year, and is applicable from the time the hot cell is placed in service until it is decommissioned.

(3) Maintenance Parts and Supplies

The cost of maintenance parts and supplies was estimated at \$172-thousand per year, or approximately 3% of the capital cost of the additional facilities, and was assumed to be incurred regardless of the number of MESCs received and processed -- and is applicable from the time the hot cell is placed in service until it is decommissioned.

Thus, the total additional operating costs that would be incurred in connection with processing MESCs in hot cell facilities would involve a variable cost of \$0.21/kgU contained in 24 PWR assembly MESCs and \$0.67/kgU contained in 7 PWR assembly MESCs -- plus a fixed annual charge of \$194-

thousand that would have to be distributed over the total amount of SNF received in MESCs.

4.2.3.6 Cost of MRS Casks and Storage Modules

Figure 4-1 showed two different ways of storage of MESCs in monitored retrievable storage; a vertical MRS concrete storage cask similar to that used in the Parsons ACD of the MRS facility, and a horizontal concrete storage module. The estimated cost of these casks and modules were developed and the change in unit cost for storage modules as a result of storing MESCs was calculated by the difference between the unit costs associated with each of the MESC storage casks and modules, and the unit costs of the casks for storage of consolidated rods and non-fuel components as developed from the Parsons estimates thereof. These are described in the following:

(1) Parsons Cask Costs (14)

Parsons estimated that the cost of a vertical concrete storage cask for canned fuel rods would be \$220-thousand (1985 dollars) and would be capable of storing the rods from 36 PWR assemblies. Escalating this cost to 1988 dollars produced a cask cost of \$242-thousand, or about \$14.58/kgU assuming 461 kgU/PWR assembly.

Parsons also estimated that the cost of a vertical concrete storage cask for non-fuel components would be \$120-thousand (1985 dollars) and would be capable of storing the components from about 150 PWR assemblies. Escalating this cost to 1988 dollars produced a cask cost of \$132-thousand, or about \$1.91/kgU.

In addition, Parsons allocated a cost of \$12-thousand/cask for amortization of the capital cost of a cask manufacturing facility based on the cost of the latter being \$15.36-million plus 25 percent for overhead and 10 percent for fee -- spread over 1,768 casks. Escalating this cost of 1988 dollars produced a cask manufacturing facility cost of about \$23.3-million, or about \$13-thousand/cask. This produced a unit cost of \$0.78/kgU for casks designed for storing fuel rods, and \$0.45/kgU for casks designed for storing non-fuel components.

Parsons estimated that the cost of cans for consolidated rods would be about \$4,700 (1985 dollars) and that the cost of drums for non-fuel components would be about \$520 (1985 dollars). Escalating this cost to 1988 dollars produced a can cost of \$5,180 and a drum cost of \$573 -- amounting to \$3.75/kgU and \$0.12/kgU, respectively, for cans and drums.

The foregoing costs for vertical concrete storage casks and associated cans and drums are summarized in Table 4-19.

TABLE 4-19
COST OF MRS CASKS FOR ACD FACILITY
(1988 Dollars)

<u>Description</u>	<u>Cost (\$/kgU)</u>
Casks for Fuel Rods	\$14.58
Cans for Fuel Rods	3.75
Casks for Non-Fuel Components	1.91
Drums for Non-Fuel Components	0.12
Allocation for Cask Manufacturing Facility Capital Cost	1.23
Total	<u>\$21.59</u>

(2) Cost of MESC Storage Casks

Using the same basic costing approach as Parsons used in developing the costs described above, JAI developed estimates of costs for concrete storage casks that were capable of storing one 24 PWR assembly MESC and one, two, and three 7 PWR assembly MESC's. These are summarized in Table 4-20.

TABLE 4-20
ESTIMATED COSTS OF CONCRETE STORAGE CASKS FOR MESCs
(1988 Dollars)

4-39	<u>Description</u>	<u>Capacity (MTU)</u>	<u>Cask Cost (\$000)</u>	<u>Allocation Of Cost Of Cask Manufacturing Fac. (\$000)</u>	<u>Total Cost (\$000)</u>	<u>Unit Cost (\$/kgU)</u>	<u>Increase (Decrease) in Unit Cost Over ACD Casks (\$/kgU)</u>
	Cask for 24 PWR Assembly MESC	11.06	\$207	\$13	\$220	\$19.89	\$(1.70)
	Cask for 7 PWR Assembly MESC	3.23	120	13	133	41.18	19.59
	Cask for 2/7 PWR Assembly MESCs	6.45	230	13	243	37.67	16.08
	Cask for 3/7 PWR Assembly MESCs	9.68	265	13	278	28.72	7.13

(3) Cost of Horizontal Storage Modules

The cost of horizontal storage modules (excluding the MESC), similar to those used by utilities for the storage of MESC's, was estimated at \$106-thousand for a 24 PWR assembly MESC module and \$65-thousand for a 7 PWR assembly MESC module -- or \$9.58/kgU and \$20.14/kgU, respectively. This represented a decrease in unit cost from the ACD concrete cask of \$14.90/kgU for the 24 PWR assembly MESC module and \$4.34/kgU for the 7 PWR assembly MESC module.

In addition to the foregoing variable costs, the use of a horizontal storage module would require some capital equipment for unloading the MESC's directly into the module, as described by the following:

- (a) It was assumed that the shipping cask would be placed onto a skid and transporter and unloaded directly into the module by pulling the MESC into it. The capital costs estimated for the required equipment are summarized in Table 4-21.

TABLE 4-21
ESTIMATED COST OF EQUIPMENT REQUIRED FOR LOADING MESC'S FROM SHIPPING
CASKS INTO STORAGE MODULES AT THE MRS FACILITY
(\$000, 1988)

<u>Description</u>	<u>Cost</u>
Skid	\$ 100
Transporter/Trailer	250
Ram and Accessories	<u>100</u>
	450
Construction Management (10%)	45
Engineering (25%)	<u>113</u>
	608
Contingency (25%)	<u>152</u>
Total	<u><u>\$ 760</u></u>

This cost would be incurred immediately prior to receipt of the first MESC's and would have to be distributed over the total amount of SNF received in MESC's.

- (b) It was also assumed that whenever the MESC's were removed from storage a transfer cask would be required to move the MESC's to the unloading hot cell. This cask was assumed to cost about \$1-million (1988 dollars). Separate casks would be required for the transfer of 24 PWR assembly and 7 PWR assembly MESC's.

The cost of each of these casks would be incurred immediately prior to receipt of the first MESC of a particular type (24 PWR assembly or 7 PWR assembly MESC), or to the first transfer thereof, and would have to be distributed over the total amount of SNF received in the particular MESC type.

From the foregoing it can be seen that the most cost effective of the vertical MESC concrete storage casks are the 24 PWR assembly MESC cask and the 3/7 PWR assembly MESC cask. The use of horizontal concrete storage modules would be more economical in cases where large quantities of SNF are received in MESC's. Therefore, only these concrete storage casks and modules have been considered further in this study.

4.3.2.7 Cost of Additions to Storage Areas

The reference ACD concrete storage cask has a capacity for storing the fuel rods from 36 PWR assemblies and the non-fuel components cask has a capacity for storing the components from 150 PWR assemblies. This means that an average of 1.24 casks is required to store both the fuel rods and non-fuel components of 36 PWR assemblies. Comparing this with the MESC casks, it would require 1.5 24 PWR assembly MESC casks or 1.71 3/7 PWR assembly MESC casks to store 36 PWR assemblies.

The number of additional casks required to store MESC's will depend on the amount of SNF received in MESC's, and can be determined by the following equations:

$$N_{24} = \frac{Q_{24}}{(24)(.461)} - \left[\frac{Q_{24}}{(36)(.461)} + \frac{Q_{24}}{(150)(.461)} \right]$$

$$N_{21} = \frac{Q_{21}}{(21)(.461)} - \left[\frac{Q_{21}}{(36)(.461)} + \frac{Q_{21}}{(150)(.461)} \right]$$

where N_{24} = the number of additional 24 PWR assembly MESC casks required to store Q_{24} MTU of SNF contained in 24 PWR assembly MESCs,

N_{21} = the number of additional 3/7 PWR assembly MESC casks required to store Q_{21} MTU of SNF contained in 7 PWR assembly MESCs.

The ACD storage facility occupies approximately 133 acres with pad space for 1760 concrete casks. If the total number of casks placed in the storage area exceeds 1760, additional space for the pads will have to be provided. The design of the ACD storage area was very conservative in some aspects and there is space available for pads to hold an additional 542 casks without enlarging the area of the site.

The cost of the additional pads can be estimated by the following expression that was developed during the study:

$$\text{Pad Cost} = \$9,982(N) + \$15,854$$

where N is the number of additional casks required. (The last term of the expression is the cost of the ends of the pad which is shared by all of the casks on the pad.)

By combining the formulas described above, the pad cost as a function of quantity of SNF stored in MESCs can be obtained as follows:

$$\text{Pad Cost} = \$9,982(.0157Q_{24} + .0286Q_{21}) + \$15,854$$

where Q_{24} = MTU of SNF contained in 24 PWR assembly MESC casks

Q_{21} = MTU of spent fuel contained in 3/7 PWR assembly MESC casks.

No additional pad costs would be incurred as a result of the use of horizontal storage modules inasmuch as such costs have been included in the construction cost of the modules as set forth in Section 4.2.3.6.

4.2.3.8 Additional Cost of Operations in Storage Areas

Inasmuch as the storage areas would not have to be expanded to accommodate any credible number of MESCs, it is not expected that the cost of lighting, physical security, radiological surveillance and general

maintenance would change as a result of receipt of SNF in MESCs. However, there is an incremental cost in transferring casks from the receiving and handling facility to the storage area (and retrieving them at the end of their storage period) since more MESC casks are required than reference consolidated fuel casks to store a given amount of SNF. It was determined that the labor involved in moving casks to and from storage was the major variable storage area operating expense and that it was proportional to the number of casks (and MTU of fuel) stored.

It was estimated that about 12 hours of elapsed time and 37 person-hours would be required to emplace an ACD consolidated spent fuel cask including a pro-rata share of the time and labor to emplace the cask of associated non-fuel components. This effort includes all activities from moving the empty cask from the cask manufacturing facility into the loading hot cell to placing the cask on a pad in the storage area. For the same activities, the time and labor to load and emplace (or retrieve) several types of MESC storage casks were also determined.

A comparison of the labor required to emplace the consolidated spent fuel cask and the MESC casks, and the added labor cost associated with emplacement of the MESC cask, is shown in Table 4-22.

TABLE 4-22
CASK EMPLACEMENT EFFORT COMPARISON AND ADDITIONAL LABOR COSTS
FOR EMPLACEMENT OF A MESC CASK IN STORAGE

<u>Cask Type</u>	<u>No. Assemblies</u>	<u>Labor Person-Hours/ Cask</u>	<u>Incremental^a Labor Costs (\$/kgU, 1988)</u>
ACD Casks (Reference)	36	37	-
24 Assembly MESC Cask	24	27	\$0.01
3/7 Assembly MESC Cask	21	28	0.04
1/7 Assembly MESC Cask	7	27	0.40

^a Incremental labor cost is the difference between the ACD consolidated spent fuel cask emplacement labor and the MESC cask emplacement labor determined as follows:

$$\frac{(27 \text{ hr})(\$65.34/\text{hr})}{(24 \text{ Ass'y})(461 \text{ kgU/Ass'y})} - \frac{(37 \text{ hr})(\$65.34/\text{hr})}{(36 \text{ Ass'y})(461 \text{ kgU/Ass'y})}$$

$$= \$0.01/\text{kgU to emplace a 24 assembly MESC}$$

These same incremental costs would also apply to retrieval of the casks from storage and the unloading thereof into the hot cell facilities.

In the case of the use of horizontal storage modules it was assumed that the retrieval cost for a 24 PWR assembly MESC and a 7 PWR assembly MESC would be the same as the retrieval cost for a concrete cask capable of storing these MESCs. However, no incremental emplacement cost would be incurred inasmuch as the direct introduction of the MESC from the shipping cask into the horizontal storage module would, in effect, eliminate the need for first unloading the shipping cask into a hot cell.

4.2.3.9 Decommissioning Costs

It was assumed that the cost of decommissioning hot cell facilities would be 20 percent of the capital cost of the facilities. It was also assumed that the cost of disposal of MESC opening equipment used outside of the hot cell facilities, the concrete storage pads, the MRS concrete casks and horizontal storage modules, and transfer casks would only be about 5 percent of the capital cost thereof inasmuch as none of these items should be seriously contaminated.

4.2.3.10 Incremental Life Cycle and Unit Costs for Handling MESCs in FWMS Facilities

The total incremental life cycle costs, and incremental unit costs, associated with the receipt of SNF in MESCs was developed for a variety of cases involving (i) varying quantities of SNF received in MESCs, (ii) two different MESC types, (iii) both the existence and absence of a MRS facility in the FWMS, and (iv) both opening of the MESCs outside the hot cell facilities and within them. These cost calculations and the assumptions associated therewith have been included in Appendix E and are summarized in Table 4-23.

TABLE 4-23
SUMMARY OF INCREMENTAL UNIT COSTS AT FWMS FACILITIES RESULTING
FROM ACCEPTANCE OF SNF IN MESC^a

(1)	Type of MESC Received	MRS Status	MESC Opening Operation		Total Quantity SNF Received in MESC ^s (MTU)	Incremental Costs (\$/kgU)
			Location	Time		
(1)	24 PWR Assy	With MRS	Outside of Hot Cell	Upon Receipt	564	\$ 3.73
					940	3.42
					1,504	3.26
					1,880	3.20
(2)	24 PWR Assy	No MRS	Outside of Hot Cell	Upon Receipt	534	3.77
					890	3.45
					1,424	3.28
					1,780	3.22
(3)	7 PWR Assy	With MRS	Outside of Hot Cell	Upon Receipt	58	6.31
					116	5.37
					232	4.92
(4)	7 PWR Assy	No MRS	Outside of Hot Cell	Upon Receipt	52	6.51
					104	5.46
					208	4.95
(5)	24 PWR Assy	With MRS (Vertical Concrete Cask)	In Hot Cell	After Storage	564	29.74
					940	17.57
					1,504	10.68
					1,880	8.35
(6)	24 PWR Assy	No MRS	In Hot Cell	After Storage	534	33.38
					890	20.61
					1,424	13.44
					1,780	11.06
(7)	7 PWR Assy	With MRS (Vertical Concrete Cask)	In Hot Cell	After Storage	58	43.52
					116	27.18
					232	18.91
(8)	7 PWR Assy	No MRS	In Hot Cell	After Storage	52	39.17
					104	21.14
					208	12.15
(9)	24 PWR Assy	With MRS (HSM)	In Hot Cell	After Storage	564	18.74
					940	5.42
					1,504	(2.11)
					1,880	(4.64)
(10)	7 PWR Assy	With MRS (HSM)	In Hot Cell	After Storage	58	48.48
					116	23.42
					232	10.83
(11)	24 PWR Assy	With MRS (HSM)	Outside of Hot Cell	After Storage	564	(9.46)
					940	(10.96)
					1,504	(11.86)
					1,880	(12.18)
(12)	7 PWR Assy	With MRS (HSM)	Outside of Hot Cell	After Storage	58	18.38
					116	8.68
					232	3.75

^a Unit costs are based on the assumption that a PWR assembly contains 461 kgU. To obtain the unit cost per assembly regardless of the uranium content thereof, the unit costs in the right hand column must be first multiplied by 461 kgU, and then divided by the weight of initial uranium contained in the assembly.

It should be pointed out that the incremental unit costs shown in the table are based on an allocation of the cost of hot cell facilities, the fixed operating costs associated therewith, the cost of equipment to open the MESC's outside of the hot cell facilities and the cost of HSM loading equipment to the 24 PWR assembly and 7 PWR assembly MESC's. The costs have been based principally on the assumption that about 90 percent of the SNF received in MESC's would be in 24 PWR assembly MESC's and the remainder in 7 PWR assembly MESC's. If no SNF were delivered in 7 PWR assembly MESC's, the incremental unit costs associated with the receipt of 24 PWR assembly MESC's would increase from \$0.85-\$3.20/kgU for cases involving handling of MESC's inside of the hot cell, \$0.05-\$0.15/kgU for HSM loading equipment for cases where MESC's are stored in HSM's, and \$0.05-\$0.20/kgU for MESC opening equipment for cases where MESC's are opened outside of the hot cell, over the quantity ranges considered. Moreover, for every 10% reduction in the amount of SNF received in 24 PWR assembly MESC's, the incremental unit costs associated with the receipt of 7 PWR assembly MESC's would increase from \$7.60-\$32.30/kgU for hot cell activities, \$0.40-\$1.50/kgU for HSM loading equipment, and \$0.55-\$2.00/kgU for MESC opening equipment (outside of hot cell), over the quantity ranges considered.

From the information contained in the foregoing table, the following can be concluded (within the limitations of the assumptions used to develop the contained costs):

- (1) The receipt of PWR assemblies in MESC's is more expensive to the FWMS facilities than the receipt of individual PWR assemblies when there is no MRS facility in the system. This is because the MESC has to be cut open prior to removal of the assemblies therefrom and the MESC disposed of.
- (2) The cutting of the welds on the lid and shield plug of the MESC while it is in either the shipping cask or an on-site transfer cask is significantly less expensive than opening of the MESC inside a processing hot cell. The former avoids the installation of costly additional hot cell space prior to the initiation of operations at either the MRS facility or repository, and incurring the fixed annual operating costs associated therewith throughout the entire period of operation of the facilities. Instead a much smaller equipment cost is incurred immediately prior to the cutting of the MESC welds.
- (3) Regardless of whether there is a MRS facility in the FWMS or otherwise, the 7 PWR assembly MESC's are more expensive to

handle in FWMS facilities than are individual PWR assemblies, within the range of quantities considered. While the HSMs used for storage of 7 PWR assembly MESC's in the MRS case are less expensive than the vertical concrete storage casks for storage of consolidated SNF, the resultant savings are never large enough to offset the added costs of handling these MESC's at the MRS facility.

- (4) Acceptance of 24 PWR assembly MESC's result in lower costs to FWMS facilities than for individual fuel assemblies provided that (i) there is a MRS facility in the system, (ii) they are received from the utility early enough to be stored at the MRS, (iii) HSMs are used for storage, and (iv) the cutting of the welds on the shielded lid of the MESC is performed outside the hot cell while it is in either the shipping cask or an on-site transfer cask. This is due to the large savings resulting from the use of HSMs for storage of 24 PWR assembly MESC's that more than offset the other added costs of handling these MESC's at the MRS facility.
- (5) Acceptance of 24 PWR assembly MESC's result in lower costs to FWMS facilities than for individual fuel assemblies under the conditions described in (4)(i), (ii), and (iii), above, even when the MESC is opened inside the process hot cell facilities provided that the total quantities of SNF received in these MESC's is greater than 1300 MTU. This is due to the savings resulting from the use of HSMs for storage of 24 PWR assembly MESC's offsetting the other costs of handling these MESC's at the MRS facility for the larger quantities.

As a result of the foregoing it is clear that the most economical way to handle MESC's at repository facilities would be to cut the weld on the shield plug and lid of the MESC while it is outside the hot cell and in the shipping cask, and to unload the assemblies from the MESC into the hot cell facilities. The incremental unit costs for this as a function of quantity is shown in Items (2) and (4) of Table 4-23.

The most economical way to handle the 7 PWR assembly MESC's at MRS facilities would be the same as described above for receipt of such MESC's at the repository. The incremental unit costs for this as a function of quantity is shown in Item (3) of Table 4-23.

The most economical way to handle the 24 PWR assembly MESC's at MRS facilities would be to transfer them directly from a shipping cask to HSMs and, after the storage period, to cut the welds on the shielded lid of the MESC while it is in the transfer cask outside the hot cell facilities, and unload the assemblies from the MESC into the hot cell facilities. However,

this can only be done if the MESCs are received in time to be stored at the MRS facilities. The incremental unit costs for this as a function of quantity is shown in Item (11) of Table 4-23.

If the 24 PWR assembly MESCs are not received in time to be included as part of the SNF in interim storage at the MRS facility, they would have to be handled the same as described above for receipt of MESCs at the repository. The incremental unit costs for this as a function of quantity is shown in Item (1) of Table 4-23.

Cutting the weld on the shielded lid of a MESC while it is still in the shipping or transfer cask should be feasible with minimum radiation exposure of personnel. The cutting fixture would have to be designed to be able to be positioned on the MESC with minimum residence of personnel in the proximity of the cask, and with cutting operation being controlled at a remote station. The MESC will be sealed in this manner at the reactor and thus should be able to be cut open similarly. Moreover, it will be necessary to remove all the cutting chips so that they do not fall into the cask or MESC when the lid is subsequently removed. This could be accomplished using a vacuum follower around the cutting tool, followed by a final cleaning after the cutting is complete. The incremental unit costs included in Table 4-23 should be sufficient to cover the cost of the radiation protection and cleaning operations.

5.0 SUMMARY OF INCREMENTAL UNIT COSTS TO THE FWMS

A summary of the incremental unit costs to the FWMS resulting from the receipt of SNF in MESC's, for both a system which has a MRS facility included in it and one which does not, is set forth in Tables 5-1 and 5-2. These incremental unit costs are those resulting from the use of special MESC shipping casks that are used to replace some (1 or 2) reference shipping casks in the presently planned DOE fleet and are used exclusively for shipment of MESC's, and the use of the most economical scenarios of handling MESC's in the FWMS facilities.

From the cost data shown in the tables it can be seen that receipt of SNF in MESC's into the FWMS results in cost increases over those which would have been otherwise incurred had the SNF been received in the form of individual PWR assemblies -- except where 900 MTU or more of SNF was received in 24 PWR assembly MESC's in time to store it in MRS facilities (2005 or thereabouts). In all cases, the cost of from-reactor transport is higher as a result of the need to include a special-purpose cask to the DOE fleet. However, in the limited instances cited above (where 900 MTU or more of SNF was received in 24 PWR assembly MESC's early enough to commit it to storage in the MRS facility), the cost savings resulting from the use of low cost HSMs more than offset the added cost of shipment.

TABLE 5-1
ESTIMATED INCREMENTAL UNIT COSTS TO THE FWMS RESULTING
FROM RECEIPT OF SNF IN MESC'S AT A MRS FACILITY^a
(1988 Dollars)

Type of MESC	Quantity of SNF Received in MESC'S (MTU)	Incremental Unit Costs (\$/kgU)				
		FWMS Facilities	From Reactor Transport In		Total W/DOE Cask	Total W/Utility Cask
			DOE- Furnished Cask	Utility- Furnished Cask		
24 PWR Assembly	564	\$(9.46)	\$16.69	-	\$ 7.23	-
(Received in time	940	(10.96)	10.18	-	(0.78)	-
for storage at MRS	1,504	(11.86)	6.54	-	(5.32)	-
facility)	1,880	(12.18)	5.32	-	(6.86)	-
24 PWR Assembly	564	3.73	16.69	-	20.42	-
(Not received in	940	3.42	10.18	-	13.60	-
time for storage	1,504	3.26	6.54	-	9.80	-
at MRS facility)	1,880	3.20	5.32	-	8.52	-
7 PWR Assembly	58	6.31	93.26	\$3.63	99.57	\$9.94
(Received any time)	116	5.37	51.72	3.63	57.09	9.00
	232	4.92	30.96	3.63	35.88	8.55

^aAssumes a 500-mile one-way shipment

TABLE 5-2
ESTIMATED INCREMENTAL UNIT COSTS TO THE FWMS RESULTING
FROM RECEIPT OF SNF IN MESC_s AT A REPOSITORY^a
(1988 Dollars)

5-3

		Incremental Unit Costs (\$/kgU)				
Type of MESC	Quantity of SNF Received in MESCs (MTU)	FWMS Facilities	From Reactor Transport In		Total W/DOE Cask	Total W/Utility Cask
			DOE- Furnished Cask	Utility- Furnished Cask		
24 PWR Assembly	534	\$ 3.77	\$ 24.04	-	\$ 27.81	-
	890	3.45	14.46	-	17.91	-
	1,424	3.28	9.08	-	12.36	-
	1,780	3.22	7.30	-	10.52	-
7 PWR Assembly	52	6.51	118.90	\$13.17	125.41	\$19.68
	104	5.46	72.58	13.17	78.04	18.63
	208	4.95	49.47	13.17	54.42	18.12

^aAssumes a 2,800-mile one-way shipment

The incremental unit costs set forth in the tables are those covering the range of quantities of SNF that could be delivered to DOE in MESC's as a result of firm utility plans to use MESC's. It is not expected that any additional utility usage of 7 PWR assembly MESC's for at-reactor storage will occur, however, additional usage of 24 PWR assembly MESC's may take place. If such does occur, the added costs to the FWMS can be expected to decrease (or the savings to the FWMS can be expected to increase), as follows:

- (1) For 24 PWR assembly MESC's that are received by DOE in time for storage in HSM's at the MRS facility -- the savings to the FWMS could amount to as much as \$13/kgU if 10,000 MTU were so received.
- (2) For 24 PWR assembly MESC's, that are not received by DOE in time for storage in HSM's at the MRS facility -- the added costs to the FWMS could be as low as \$5-6/kgU, if 10,000 MTU were so received.
- (3) For 24 PWR assembly MESC's received at the repository -- the added costs to the FWMS could be as low as \$6/kgU, if 10,000 MTU were so received.

The relationship of the added costs to the FWMS as a function of the amount of SNF received in MESC's for the three scenarios described above is shown in Figure 5-1.

FIGURE 5-1
 INCREMENTAL UNIT COSTS TO THE FWMS
 RESULTING FROM THE RECEIPT OF SNF IN
 MESC'S AS A FUNCTION OF THE AMOUNT OF SNF SO RECEIVED

6.0 POLICY ALTERNATIVES AVAILABLE TO DOE REGARDING MESCs

There are several policy alternatives that might be followed by DOE in dealing with the prospective acceptance of SNF in MESCs for transport and disposal. The DOE could either decline to accept SNF in such a form (package) or it could agree to accept it. If it agreed to accept MESCs, it could either do so without charge, or it could charge for the added costs to the FWMS resulting from such acceptance (or provide credits if costs were lower). The intent of this section is to briefly discuss the considerations associated with each of these choices in a balanced way, without advocacy for or opposition to any of the alternatives. It should be pointed out, however, that selection of a policy alternative for dealing with MESC acceptance may have implications for a DOE position regarding other voluntary actions by utilities which decrease their own storage costs, but increase costs to the FWMS.

6.1 DECLINE TO ACCEPT MESCs

If DOE were to decline acceptance of SNF in MESCs, the utility would still have the reasonable recourse of opening the MESC at the reactor site, removing the contained assemblies, and loading them into a reference shipping cask. The cost of this to the utility would be only slightly higher than the costs described in Items (1) and (3) of Table 4-23. On the other hand if DOE accepts SNF in MESCs, not only does the FWMS incur these costs, but it incurs significant added transport costs for the MESCs as well. Moreover, overall radiation exposure of personnel is not reduced because DOE must open the MESCs at FWMS facilities, unless they are opened inside a hot cell where somewhat less exposure might be expected -- but at significant additional cost. Only in the single instance where 24 PWR assembly MESCs are received at a MRS facility early enough to be included in the interim storage inventory does the MESC provide a possible advantage to the FWMS.

The equity implication of this option is that the utility that chooses the MESC option bears the full costs of that option -- none of the costs are shifted to other utilities through the fee.

6.2 ACCEPTANCE OF MESCS

6.2.1 Acceptance With No Charge For Added Costs

DOE could agree to accept MESCS the same as it has agreed to accept other fuel forms under the 10CFR961 Standard Disposal Contract within the 1 mill/kWh charge. In establishing this charge, the Nuclear Waste Policy Act made no differential in fee for differences in attributes of the spent fuel or the shipping distance between the individual reactors and DOE facilities. Fuel assemblies vary widely in uranium content and burnup, and these variations can cause wide differences in the cost of transport and disposal of the assemblies. Moreover, the variance in transportation distance can easily make a \$10/kgU difference in cost as shown in Table 4-14. Thus, it could be argued that acceptance of MESCS, and the absorption of the added costs therefor by the Nuclear Waste Fund, are justified on the basis that the cost increase associated therewith was no greater than the increases already tolerated without adjustment, as a result of:

- o a utility delivering 10,000 MWD/MTU burnup fuel compared with one delivering 50,000 MWD/MTU burnup fuel, or
- o a utility delivering BWR assemblies each containing 180 kgU compared with one delivering PWR assemblies each containing 460 kgU, or
- o a utility being 3,000 miles away from the DOE receiving facility compared with one only a few miles away.

On the other hand, it is noted that the receipt of MESCS containing SNF having any single set of characteristics, and shipped over any single distance, would be more costly to the FWMS than the receipt of that same fuel in the form of individual fuel assemblies. Thus, the acceptance of SNF in MESCS with no charge for the added costs to the FWMS is, in effect, a subsidy for the use of that storage option relative to other options. Further, the cost increase to the FWMS for delivery of a MESC would be a discretionary one to the utility, in the sense that the utility could also deliver individual assemblies without a cost increase to the FWMS. There is clearly an important utility equity issue involved --whether a utility should be able to save costs at its reactor site as a result of not having to open the MESCS, at the expense of all users of the FWMS. It may be arguable that the established precedent

of accepting other cost increases without fee adjustment does not apply because the other increases are not discretionary to the same degree as the delivery of MESCs.

6.2.2 Acceptance With A Charge For Added Costs

DOE could establish a surcharge for receipt of SNF in MESCs to cover the added costs to the FWMS as a result thereof, as follows:

- (1) Separate charges (or credits) could be established for the 24 PWR and 7 PWR assembly MESCs, for a FWMS that contains a MRS facility and for one that does not, and for delivery of 24 PWR assembly MESCs in time to be included in interim storage at a MRS facility. For each of the foregoing instances the charges (or credits) could be established as a function of the quantity of SNF received in a given type of MESC. These charges would be similar to those set forth in Tables 5-1 and 5-2.
- (2) Whenever a utility decides to use MESCs for storage at its reactor site, and wants to guarantee acceptance thereof by the FWMS for the then-prevailing charges (or credits), it would be required to (i) notify the DOE of its plans, (ii) submit a description of the MESCs and their contents to DOE for acceptance approval, and (iii) commit to deliver a specific quantity of SNF to DOE in MESCs. Upon DOE approval of the MESC description, the DOE charge (or credit) schedule then prevailing for the total quantity of SNF committed to be delivered to DOE in MESCs to that point in time would be applicable and would not be subject to change thereafter except as a result of escalation using a specifically identified index. In this way, the utility would be able to fully evaluate the economic aspects of using MESCs for storage at the reactor site prior to committing SNF to storage therein -- the charge (or credit) would be fixed based on when the commitment was made and subject only to escalation. A utility could decide to provide such notification and delivery commitment at any time, but it would be at risk with respect to DOE approval and delivery of the DOE-approved MESCs would be subject to the charge (or credit) schedule applicable at the time of its commitment.
- (3) Whenever a utility has committed to deliver a fixed amount of SNF in MESCs at the then prevailing charge (or credit) for the total quantities committed to DOE (including the utility's commitments), and further commitments are subsequently received by DOE from others for delivery of the same MESC type, the utility would be due an adjustment in charges (or credits) as follows:

- (a) If the additional commitments were made under the same charge (or credit) schedule -- the charge (or credit) schedule applicable to the delivery of the utility's MESCs would be reduced to that applicable for the total quantities committed.
- (b) If the additional commitments were made under a revised charge (or credit) schedule -- the charge (or credit) schedule applicable to delivery of the utility's MESCs would be the lower of:
 - (i) the charge (or credit) schedule prevailing at the time of the utility's commitment that is applicable to all such commitments received to the time of the commitment (including that of the utility's)
 - (ii) the charge (or credit) schedule prevailing at the time the additional commitments were made (including the additional commitments).
- (4) Until such time as a decision is finally made regarding whether or not a MRS facility is to be included in the FWMS, the charge (or credit) schedule applicable to the repository would be applicable. If it is finally determined that a MRS facility is to be included in the FWMS, the schedule of charges (or credits) applicable to delivery of MESCs to the repository would be discontinued. However, if it is determined that no MRS facility is to be included in the FWMS, the schedule of charges (or credits) applicable to delivery of MESCs to a MRS facility would be discontinued.
- (5) From time to time, DOE could review the costs associated with receipt of MESCs into the FWMS and modify its schedule of charges (or credits) to reflect changes in costs for FWMS transportation equipment and facilities, and the operation thereof. Included in these cost changes would be any additional costs or savings resulting from the difference between the charges (or credits) applicable to earlier commitments and the current estimates of charges (or credits) therefor.

6.2.3 Conditions of Acceptance

The acceptance of SNF in MESCs would be subject to the following conditions:

- (1) The design of the MESC shall be subject to the approval of DOE for acceptance. The utility shall submit a full set of drawings, specifications and other descriptive material so as to provide DOE with a description that is sufficiently complete and accurate to permit DOE to properly evaluate the impact of receipt of the MESC on the FWMS transportation system and facilities.

- (2) The MESC's delivered by a utility shall meet the specifications approved by DOE in (1), above, within the tolerances set forth in the specifications and must contain only intact and non-defective SNF assemblies. At the time of delivery of the MESC shipment to DOE, the utility shall provide a written certification that the foregoing requirements have been met.
- (3) The utility shall have a capability to receive and handle DOE-furnished shipping casks for MESC's having the following maximum weights, excluding the weight of MESC and contained SNF:
 - (a) For a 24 PWR assembly MESC shipping cask
 - On transport vehicle 105 tons
 - On reactor crane hook 87 tons
 - (b) For a 7 PWR assembly MESC shipping cask
 - On transport vehicle 61 tons
 - On reactor crane hook 49 tons
- (4) Alternatively to (3) the utility may deliver MESC's to DOE in utility-furnished shipping casks provided:
 - (a) The shipment is fully certified by NRC
 - (b) The MESC's are delivered in full conformance to the other conditions set forth herein
 - (c) No payments shall be due the utility by DOE for use of the cask.

The design of the utility-furnished shipping casks shall be subject to the approval of DOE. The utility shall submit a full set of drawings, specifications and other descriptive material so as to provide DOE with a description that is sufficiently complete and accurate to permit DOE to properly evaluate the impact of receipt of MESC's in the cask on the FWMS transportation system and facilities.

- (5) The DOE or its designated representative shall have been present to witness the loading of the MESC and the sealing thereof unless DOE specifically waives its right to do so.
- (6) The MESC, when loaded into the DOE-furnished or utility-furnished shipping cask, shall be capable of being removed readily therefrom either by lifting vertically out of the cask or by pulling it out in a horizontal position into a horizontal storage module. The utility shall supply any special handling tools that are required for such removal.
- (7) The MESC, when loaded into the DOE-furnished or other utility-furnished shipping cask, shall constitute a certified shipment

under NRC regulations. The utility shall have the responsibility to apply for and obtain NRC approval for use of the MESC in connection with the shipping cask without cost to DOE.

- (8) Delivery of the 24 PWR assembly MESC's to a MRS facility shall be effected no later than December 31, 2005, in order to qualify for the credits set forth in Table 5-1 for delivery in time for storage at the MRS facility.

6.3 SUMMARY OF ALTERNATIVES

This Section 6.0 has outlined the three basic alternatives for dealing with the prospective acceptance of SNF in MESC's. The basic issues that must be addressed arise because the acceptance of MESC's directly increases FWMS costs, and hence the collective costs shared by all utilities. Further, such cost increases are at the discretion of the individual utility delivering the MESC's, which has the viable alternative of delivering fuel assemblies. The discretionary nature of this cost increase directly raises the issue of inter-utility equity, and the three alternatives deal with this issue in the following ways:

- (1) DOE declines to accept MESC's. This approach avoids the issue of inter-utility equity by foreclosing the possibility of incurring MESC-related cost increases in the FWMS.
- (2) DOE accepts MESC's without charge for added costs (or credits). This approach implicitly accepts and tolerates any inter-utility inequity that may be incurred.
- (3) DOE accepts MESC's with payment for added costs (or credits for avoided costs). This approach avoids inter-utility inequities by charging the full amount of the increased costs that are incurred.

It should be emphasized here that any alternative that shifts costs of any spent fuel management option from the individual utility to the FWMS, subsidizes the option and, therefore, encourages its use over other available options.

7.0 REFERENCES

- (1) Title 10, Code of Federal Regulations, Part 961
- (2) U. S. Nuclear Regulatory Commission, Commission Briefing on Cask Designs for Shipping and Storage of Nuclear Materials (Transcript), October 19, 1988
- (3) Electric Power Research Institute, NUHOMS Spent-Fuel Storage Demonstration: Program Overview, EPRI NP-5174, April 1987
- (4) Pacific Northwest Laboratory, Commercial Spent Fuel Management Program Monthly Progress Report, PNL-4947-58, July 1988
- (5) R. W. Rasmussen, Status of Concrete Storage Module Concept for At-Reactor Storage, Proceedings of INMM Spent Fuel Management Seminar V, Washington, D.C., January 20-22, 1988
- (6) Duke Power Company/NUTECH, NUHOMS Horizontal Modular Storage System, Presentation to DOE at Spent Fuel Systems Interface Meeting, September 19, 1988
- (7) Duke Power Company, Safety Analysis Report, Independent Spent Fuel Storage Installation, submittal to NRC
- (8) U. S. Department of Energy, Dry Cask Storage Study, DOE/RW-0196, December 1988
- (9) Letter J. A. Tiernan (BG&E) to Charles Head (DOE), dated October 27, 1988
- (10) H&R Technical Associates, Inc. and E. R. Johnson Associates, Inc., Use of Transportable Storage Casks in the Nuclear Waste Management System, ORNL/Sub/85-SA094, December 1987
- (11) Chem-Nuclear Systems Inc., Barnwell Low-Level Radioactive Waste Management Facility Rate Schedule, effective January 15, 1988
- (12) The Ralph M. Parsons Company, Integral Monitored Retrievable Storage (MRS) Facility Conceptual Design Report, MRS-11, July 1985
- (13) Sandia National Laboratories, Site Characterization Plan Conceptual Design Report, SAND84-2641, September 1987
- (14) E. R. Johnson Associates, Inc., Results of Preliminary Analysis of Differences in MRS Facility Costs Between the DOE MRS Facility Design And That Contained in the Draft JAI PRDA Report, JAI-263, October 1985

8.0 DEFINITIONS

- (1) "SNF" means spent nuclear fuel
- (2) "FWMS" means the Federal Waste Management System as described in Figure 2-1 of the U. S. Department of Energy, Draft 1988 Mission Plan Amendment, DOE-RW-0187, June 1988
- (3) "FWMS facilities" means the fixed-base facilities associated with the FWMS (excludes shipping cask, and maintenance and support facilities therefor)
- (4) "PWR" means pressurized water reactor
- (5) "MRS" means monitored retrievable storage
- (6) "MRS facility" means a facility that is independently located from a repository site that receives, stores, and processes and/or packages SNF. SNF received at a MRS facility will be subsequently shipped to a repository for disposal.
- (7) "HSM" means a horizontal concrete module that can be used to store MESC's
- (8) "MESC's" means multiple element sealed canisters. A MESC is generally cylindrical in shape and contains either 7 or 24 PWR assemblies positioned in an orthogonal array in a basket assembly
- (9) "ACD" means the advanced conceptual design of a MRS facility that was prepared in 1985 by The Ralph M. Parsons Company (Reference 12).
- (10) "Consolidated fuel rods" means fuel rods that have been removed from their original assembly structure and packaged in a high density array
- (11) "Consolidated fuel" means fuel rods and compacted structural parts.
- (12) "MTU" means metric tons of uranium contained in the fuel prior to introduction into the reactor (1,000 kg or 2,205 lb).

APPENDIX A

LIFE CYCLE TRANSPORT COSTS AND UNIT COST CALCULATIONS
ASSOCIATED WITH THE USE OF A SINGLE REFERENCE SHIPPING CASK
OR MESC SHIPPING CASK -- CASKS FULLY UTILIZED EITHER
EXCLUSIVELY FOR SHIPMENT OF INDIVIDUAL PWR ASSEMBLIES OR
FOR MESC_s CONTAINING PWR ASSEMBLIES

APPENDIX A
LIFE CYCLE TRANSPORT COSTS AND UNIT COST CALCULATIONS
ASSOCIATED WITH THE USE OF A SINGLE REFERENCE SHIPPING CASK
OR MESC SHIPPING CASK -- CASKS FULLY UTILIZED EITHER
EXCLUSIVELY FOR SHIPMENT OF INDIVIDUAL PWR ASSEMBLIES OR
FOR MESC'S CONTAINING PWR ASSEMBLIES

The total life cycle costs associated with the use of a single reference shipping cask and MESC shipping casks for shipments from reactors to DOE facilities were developed for the following cases, assuming that the casks would be used either exclusively for shipment of individual PWR assemblies or exclusively for MESC's containing PWR assemblies:

- Case 1 -- Transport of 21 PWR Assemblies in a Reference Shipping Cask
- Case 2 -- Transport of 24 PWR Assembly MESC's in a MESC Shipping Cask (One MESC Cask in DOE Fleet)
- Case 3 -- Transport of 24 PWR Assembly MESC's in a MESC Shipping Cask (Two MESC Casks in DOE Fleet)
- Case 4 -- Transport of PWR Assemblies in a 24 PWR Assembly MESC Shipping Cask (One MESC Cask in DOE Fleet)
- Case 5 -- Transport of PWR Assemblies in a 24 PWR Assembly MESC Shipping Cask (Two MESC Casks in DOE Fleet)
- Case 6 -- Transport of 7 PWR Assembly MESC's in a 7 PWR Assembly MESC Shipping Cask (One MESC Cask in DOE Fleet)
- Case 7 -- Transport of 7 PWR Assemblies in a 7 PWR Assembly MESC Shipping Cask (One MESC Cask in DOE Fleet)
- Case 8 -- Transport of 2/7 PWR Assembly MESC's in a 2/7 PWR Assembly MESC Shipping Cask (One MESC Cask in DOE Fleet)
- Case 9 -- Transport of 26 PWR Assemblies in a 2/7 PWR Assembly MESC Shipping Cask (One MESC Cask in DOE Fleet)

For each of the foregoing cases, life cycle costs were developed for transport over distances of 500 miles and 2800 miles (one-way). These are designated subcases A and B, respectively for each of the cases described above.

The life cycle costs and resulting unit costs for each of the foregoing cases are shown in Tables A-1 through A-18. The figures set forth in the tables were developed as follows:

- (1) The total costs were assumed to be incurred over the period 1997 to 2023, inclusive. During the period 1997 through 2002 the capital cost of the cask would be incurred; during the period 2003 through 2022 the cost of operations, freight and escorts would be incurred; and in 2023 the cost of decommissioning would be incurred.
- (2) With regard to the capital cost of the cask, it was assumed that the cost of design and development would be incurred in 1997, the cost of model fabrication and testing would be incurred in 1998, the NRC Certification Fee would be paid in 1999, half of the cost of cask fabrication would be incurred in 2001, and the other half of the cost of fabrication plus the cost of acceptance testing and auxiliary equipment would be incurred in 2002. It was assumed that 1999 and 2000 would be required by NRC to make the necessary safety reviews, and that certification would be made at the end of 2000.
- (3) The annual quantities shipped each year were assumed to be as follows:

<u>Cask Type</u>	<u>Form of Fuel Shipped</u>	<u>MTU in Single Shipment</u>	<u>Annual Quantity Shipped (MTU)^a</u>	
			<u>500 Miles</u>	<u>2800 Miles</u>
Reference Rail Cask	Assemblies	9.68	174	77
24 PWR Assembly MESC Cask	MESCs	11.06	188*	89
24 PWR Assembly MESC Cask	Assemblies	11.06	199	89
7 PWR Assembly MESC Cask	MESCs	3.23	55*	26
7 PWR Assembly MESC Cask	Assemblies	3.23	58	26
2/7 PWR Assembly MESC Cask	MESCs	6.45	110*	52
2/7 PWR Assembly MESC Cask	Assemblies	11.99	216	96

^a Based on 18 shipments/year for 500-mile shipments (17 shipments/year for those cases marked with an asterisk), and 8 shipments/year for 2800-mile shipments.

- (4) The annual cost of operation, freight, escorts and decommissioning were determined as described in Section 4.1.2.3.
- (5) The total costs were discounted by 3%/year to 1988 to get the total discounted costs.
- (6) The unit costs were determined by dividing the total discounted costs by the total discounted amount (MTU) of spent fuel shipped, as follows:

Discounted Costs = Discounted (Unit Costs x MTU Shipped)

Discounted Costs = Unit Costs x Discounted MTU Shipped

Unit Cost = $\frac{\text{Discounted Costs}}{\text{Discounted MTU Shipped}}$

A more detailed explanation of the methodology used for the unit cost calculation is set forth in Appendix F.

TABLE A-1
CASE 1A -- LIFE CYCLE COST OF TRANSPORT OF PWR ASSEMBLIES FROM REACTORS TO DOE FACILITIES
500 MILES AWAY IN A 21 PWR ASSEMBLY REFERENCE SHIPPING CASK
(10 CASKS IN FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3Z/Yr.	ANNUAL QUAN SHIP. @ 3Z/Yr	DISC TO 1988
1997	390					390	299		
1998	209					209	156		
1999	16					16	12		
2000									
2001	1,395					1,395	950		
2002	2,613					2,613	1,728		
2003		210	538	92		840	539	174	112
2004		210	538	92		840	523	174	108
2005		210	538	92		840	508	174	105
2006		210	538	92		840	493	174	102
2007		210	538	92		840	479	174	99
2008		210	538	92		840	465	174	96
2009		210	538	92		840	452	174	94
2010		210	538	92		840	438	174	91
2011		210	538	92		840	426	174	88
2012		210	538	92		840	413	174	86
2013		210	538	92		840	401	174	83
2014		210	538	92		840	390	174	81
2015		210	538	92		840	378	174	78
2016		210	538	92		840	367	174	76
2017		210	538	92		840	356	174	74
2018		210	538	92		840	346	174	72
2019		210	538	92		840	336	174	70
2020		210	538	92		840	326	174	68
2021		210	538	92		840	317	174	66
2022		210	538	92		840	307	174	64
2023					70	70	25		
TOTAL	4,623	4,200	10,760	1,840	70	21,493	11,430	3,460	1,711
DISC TOTAL	3,143	2,066	5,292	905	25	11,430			
UNIT COST (per kgU)	1.84	1.21	3.09	.53	.01	6.68			
% OF TOTAL DISC COST	28%	18%	46%	8%	0%	100%			

TABLE A-2
CASE 1F -- LIFE CYCLE COST OF TRANSPORT OF PWR ASSEMBLIES FROM REACTORS TO DOE FACILITIES
2800 MILES AWAY IN A 21 PWR ASSEMBLY REFERENCE SHIPPING CASK
(10 CASKS IN FLEET)

YEAR	COSTS (\$000, 1988)							QUANTITIES (MTU)	
	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN SHIPPED	DISC TO 1988 @ 3%/Yr.
1997	390					390	299		
1998	209					209	156		
1999	16					16	12		
2000									
2001	1,395					1,395	950		
2002	2,613					2,613	1,728		
2003		163	649	111		923	592	77	49
2004		163	649	111		923	575	77	48
2005		163	649	111		923	558	77	47
2006		163	649	111		923	542	77	45
2007		163	649	111		923	526	77	44
2008		163	649	111		923	511	77	43
2009		163	649	111		923	496	77	41
2010		163	649	111		923	482	77	40
2011		163	649	111		923	468	77	39
2012		163	649	111		923	454	77	38
2013		163	649	111		923	441	77	37
2014		163	649	111		923	428	77	36
2015		163	649	111		923	416	77	35
2016		163	649	111		923	403	77	34
2017		163	649	111		923	392	77	33
2018		163	649	111		923	380	77	32
2019		163	649	111		923	369	77	31
2020		163	649	111		923	358	77	30
2021		163	649	111		923	348	77	29
2022		163	649	111		923	338	77	28
2023					70	70	25		
TOTAL	4,623	3,260	12,980	2,220	70	23,153	12,247	1,540	757
DISC TOTAL	3,143	1,603	6,383	1,092	25	12,247			
UNIT COST (per kgU)	4.15	2.12	8.43	1.44	.03	16.17			
% OF TOTAL DISC COST	26%	13%	52%	9%	0%	100%			

TABLE A-3
CASE 2A -- LIFE CYCLE COST OF TRANSPORT OF 24 PWR ASSEMBLY MESCS FROM REACTORS TO DOE FACILITIES
500 MILES AWAY IN A MESC SHIPPING CASE
(ONE MESC CASE IN FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN SHIPPED	DISC TO 1988
1997	993					993	761		
1998	2,798					2,798	2,082		
1999	184					184	133		
2000									
2001	1,937					1,937	1,319		
2002	3,472					3,472	2,295		
2003		205	552	87		844	542	188	121
2004		205	552	87		844	526	188	117
2005		205	552	87		844	511	188	114
2006		205	552	87		844	496	188	110
2007		205	552	87		844	481	188	107
2008		205	552	87		844	467	188	104
2009		205	552	87		844	454	188	101
2010		205	552	87		844	440	188	98
2011		205	552	87		844	428	188	95
2012		205	552	87		844	415	188	92
2013		205	552	87		844	403	188	90
2014		205	552	87		844	391	188	87
2015		205	552	87		844	380	188	85
2016		205	552	87		844	369	188	82
2017		205	552	87		844	358	188	80
2018		205	552	87		844	348	188	77
2019		205	552	87		844	338	188	75
2020		205	552	87		844	328	188	73
2021		205	552	87		844	318	188	71
2022		205	552	87		844	309	188	69
2023					84	84	30		
TOTAL	9,384	4,100	11,040	1,740	84	26,348	14,922	3,760	1,849
DISC TOTAL	6,590	2,016	5,429	856	30	14,922			
UNIT COST (per kgU)	3.56	1.09	2.94	.46	.02	8.07			
% OF TOTAL DISC COST	44%	14%	36%	6%	0%	100%			

TABLE A-4
CASE 2D -- LIFE CYCLE COST OF TRANSPORT OF 24 PWR ASSEMBLY MESCS FROM REACTORS TO DOE FACILITIES
2800 MILES AWAY IN A MESC SHIPPING CASK
(ONE MESC CASE IN FLEET)

YEAR	COSTS (\$000, 1988)						QUANTITIES (MTU)	
	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN DISC QUAN. @ 3%/Yr. SHIPPED TO 1988
1997	993					993	761	
1998	2,798					2,798	2,082	
1999	184					184	133	
2000								
2001	1,937					1,937	1,319	
2002	3,472					3,472	2,295	
2003		163	706	111		980	629	89 57
2004		163	706	111		980	611	89 55
2005		163	706	111		980	593	89 54
2006		163	706	111		980	576	89 52
2007		163	706	111		980	559	89 51
2008		163	706	111		980	543	89 49
2009		163	706	111		980	527	89 48
2010		163	706	111		980	511	89 46
2011		163	706	111		980	497	89 45
2012		163	706	111		980	482	89 44
2013		163	706	111		980	468	89 43
2014		163	706	111		980	454	89 41
2015		163	706	111		980	441	89 40
2016		163	706	111		980	428	89 39
2017		163	706	111		980	416	89 38
2018		163	706	111		980	404	89 37
2019		163	706	111		980	392	89 36
2020		163	706	111		980	381	89 35
2021		163	706	111		980	369	89 34
2022		163	706	111		980	359	89 33
2023						84	84	30
TOTAL	9,384	3,260	14,120	2,220	84	29,068	16,259	1,700 875
DISC TOTAL	6,590	1,603	6,944	1,092	30	16,259		
UNIT COST (per kgU)	7.53	1.83	7.93	1.25	.03	18.57		
% OF TOTAL DISC COST	41%	10%	43%	7%	0%	100%		

TABLE A-5
CASE 3A -- LIFE CYCLE COST OF TRANSPORT OF 24 PWR ASSEMBLY MESCS FROM REACTORS TO DOE FACILITIES
500 MILES AWAY IN A MESC SHIPPING CASK
(TWO MESC CASKS IN FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECONM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN SHIPPED	DISC @ 3%/Yr TO 1988
1997	720					720	552		
1998	1,519					1,519	1,130		
1999	102					102	74		
2000									
2001	1,582					1,582	1,077		
2002	2,938					2,938	1,942		
2003		205	552	87		844	542	188	121
2004		205	552	87		844	526	188	117
2005		205	552	87		844	511	188	114
2006		205	552	87		844	496	188	110
2007		205	552	87		844	481	188	107
2008		205	552	87		844	467	188	104
2009		205	552	87		844	454	188	101
2010		205	552	87		844	440	188	98
2011		205	552	87		844	428	188	95
2012		205	552	87		844	415	188	92
2013		205	552	87		844	403	188	90
2014		205	552	87		844	391	188	87
2015		205	552	87		844	380	188	85
2016		205	552	87		844	369	188	82
2017		205	552	87		844	358	188	80
2018		205	552	87		844	348	188	77
2019		205	552	87		844	338	188	75
2020		205	552	87		844	328	188	73
2021		205	552	87		844	318	188	71
2022		205	552	87		844	309	188	69
2023					84	84	30		
TOTAL	6,861	4,100	11,040	1,740	84	23,825	13,107	3,760	1,849
DISC TOTAL	4,775	2,016	5,429	856	30	13,107			
UNIT COST (per kgU)	2.58	1.09	2.94	.46	.02	7.09			
% OF TOTAL DISC COST	37%	15%	41%	7%	0%	100%			

TABLE A-6
CASE 3B -- LIFE CYCLE COST OF TRANSPORT OF 24 PWR ASSEMBLY MESCS FROM REACTORS TO DOE FACILITIES
2800 MILES AWAY IN A MESC SHIPPING CASK
(TWO MESC CASKS IN FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'M COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN SHIPPED	DISC TO 1988 @ 3%/Yr.
1997	720					720	552		
1998	1,519					1,519	1,130		
1999	102					102	74		
2000									
2001	1,582					1,582	1,077		
2002	2,938					2,938	1,942		
2003		163	706	111		980	629	89	57
2004		163	706	111		980	611	89	55
2005		163	706	111		980	593	89	54
2006		163	706	111		980	576	89	52
2007		163	706	111		980	559	89	51
2008		163	706	111		980	543	89	49
2009		163	706	111		980	527	89	48
2010		163	706	111		980	511	89	46
2011		163	706	111		980	497	89	45
2012		163	706	111		980	482	89	44
2013		163	706	111		980	468	89	43
2014		163	706	111		980	454	89	41
2015		163	706	111		980	441	89	40
2016		163	706	111		980	428	89	39
2017		163	706	111		980	416	89	38
2018		163	706	111		980	404	89	37
2019		163	706	111		980	392	89	36
2020		163	706	111		980	381	89	35
2021		163	706	111		980	369	89	34
2022		163	706	111		980	359	89	33
2023					84	84	30		
TOTAL	6,861	3,260	14,120	2,220	84	26,545	14,444	1,780	875
DISC TOTAL	4,775	1,603	6,944	1,092	30	14,444			
UNIT COST (per kgU)	5.46	1.83	7.93	1.25	.03	16.50			
% OF TOTAL DISC COST	33%	11%	48%	8%	0%	100%			

TABLE A-7
CASE 4A -- LIFE CYCLE COST OF TRANSPORT OF PWR ASSEMBLIES FROM REACTORS TO DOE FACILITIES
500 MILES AWAY IN A 24 PWR ASSEMBLY NESC SHIPPING CASK
(ONE NESC CASK IN FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN SHIPPED	QUAN DISC TO 1988 @ 3%/Yr
1997	1,227					1,227	940		
1998	2,798					2,798	2,082		
1999	184					184	133		
2000									
2001	2,476					2,476	1,686		
2002	4,169					4,169	2,756		
2003		210	553	92		855	549	199	128
2004		210	553	92		855	533	199	124
2005		210	553	92		855	517	199	120
2006		210	553	92		855	502	199	117
2007		210	553	92		855	488	199	113
2008		210	553	92		855	473	199	110
2009		210	553	92		855	460	199	107
2010		210	553	92		855	446	199	104
2011		210	553	92		855	433	199	101
2012		210	553	92		855	421	199	98
2013		210	553	92		855	408	199	95
2014		210	553	92		855	396	199	92
2015		210	553	92		855	385	199	90
2016		210	553	92		855	374	199	87
2017		210	553	92		855	363	199	84
2018		210	553	92		855	352	199	82
2019		210	553	92		855	342	199	80
2020		210	553	92		855	332	199	77
2021		210	553	92		855	322	199	75
2022		210	553	92		855	313	199	73
2023					85	85	30		
TOTAL	10,854	4,200	11,060	1,840	85	28,039	16,037	3,980	1,957
DISC TOTAL	7,598	2,066	5,439	905	30	16,037			
UNIT COST (per kgU)	3.88	1.06	2.78	.46	.02	8.20			
% OF TOTAL DISC COST	47%	13%	34%	6%	0%	100%			

TABLE A-8
CASE 4B -- LIFE CYCLE COST OF TRANSPORT OF PWR ASSEMBLIES FROM REACTORS TO DOE FACILITIES
2800 MILES AWAY IN A 24 PWR ASSEMBLY MESC SHIPPING CASE
(ONE MESC CASE IN FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN SHIPPED	DISC TO 1988 @ 3%/Yr.
1997	1,227					1,227	940		
1998	2,798					2,798	2,082		
1999	184					184	133		
2000									
2001	2,476					2,476	1,686		
2002	4,169					4,169	2,756		
2003		163	668	111		942	605	89	57
2004		163	668	111		942	587	89	55
2005		163	668	111		942	570	89	54
2006		163	668	111		942	553	89	52
2007		163	668	111		942	537	89	51
2008		163	668	111		942	522	89	49
2009		163	668	111		942	506	89	48
2010		163	668	111		942	492	89	46
2011		163	668	111		942	477	89	45
2012		163	668	111		942	463	89	44
2013		163	668	111		942	450	89	43
2014		163	668	111		942	437	89	41
2015		163	668	111		942	424	89	40
2016		163	668	111		942	412	89	39
2017		163	668	111		942	400	89	38
2018		163	668	111		942	388	89	37
2019		163	668	111		942	377	89	36
2020		163	668	111		942	366	89	35
2021		163	668	111		942	355	89	34
2022		163	668	111		942	345	89	33
2023					85	85	30		
TOTAL	10,854	3,260	13,360	2,220	85	29,779	16,893	1,780	875
DISC TOTAL	7,598	1,603	8,570	1,092	30	16,893			
UNIT COST (per kgU)	8.68	1.83	7.51	1.25	.03	19.30			
% OF TOTAL DISC COST	45%	9%	39%	6%	0%	100%			

TABLE A-9
CASE 5A -- LIFE CYCLE COST OF TRANSPORT OF PWR ASSEMBLIES FROM REACTORS TO DOE FACILITIES
500 MILES AWAY IN A 24 PWR ASSEMBLY MESC SHIPPING CASK
(TWO MESC CASKS IN FLEET)

COSTS (\$000, 1989)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN. SHIPPED	DISC @ 3%/Yr TO 1988
1997	837					837	641		
1998	1,519					1,519	1,130		
1999	102					102	74		
2000									
2001	2,066					2,066	1,407		
2002	3,547					3,547	2,345		
2003		210	553	92		855	549	199	128
2004		210	553	92		855	533	199	124
2005		210	553	92		855	517	199	120
2006		210	553	92		855	502	199	117
2007		210	553	92		855	488	199	113
2008		210	553	92		855	473	199	110
2009		210	553	92		855	460	199	107
2010		210	553	92		855	446	199	104
2011		210	553	92		855	433	199	101
2012		210	553	92		855	421	199	98
2013		210	553	92		855	408	199	95
2014		210	553	92		855	396	199	92
2015		210	553	92		855	385	199	90
2016		210	553	92		855	374	199	87
2017		210	553	92		855	363	199	84
2018		210	553	92		855	352	199	82
2019		210	553	92		855	342	199	80
2020		210	553	92		855	332	199	77
2021		210	553	92		855	322	199	75
2022		210	553	92		855	313	199	73
2023					85	85	30		
TOTAL	8,071	4,200	11,060	1,840	85	25,256	14,037	2,980	1,957
DISC TOTAL	5,597	2,066	5,439	905	30	14,037			
UNIT COST (per kgU)	2.86	1.06	2.78	.46	.02	7.18			
% OF TOTAL DISC COST	40%	15%	39%	6%	0%	100%			

TABLE A-10
CASE 5B -- LIFE CYCLE COST OF TRANSPORT OF PWR ASSEMBLIES FROM REACTORS TO DOE FACILITIES
2800 MILES AWAY IN A 24 PWR ASSEMBLY MESC SHIPPING CASK
(TWO MESC CASKS IN FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN SHIPPED	DISC @ 3%/Yr TO 1988
1997	837					837	641		
1998	1,519					1,519	1,130		
1999	102					102	74		
2000									
2001	2,066					2,066	1,407		
2002	3,547					3,547	2,345		
2003		163	668	111		942	605	89	57
2004		163	668	111		942	587	89	55
2005		163	668	111		942	570	89	54
2006		163	668	111		942	553	89	52
2007		163	668	111		942	537	89	51
2008		163	668	111		942	522	89	49
2009		163	668	111		942	506	89	48
2010		163	668	111		942	492	89	46
2011		163	668	111		942	477	89	45
2012		163	668	111		942	463	89	44
2013		163	668	111		942	450	89	43
2014		163	668	111		942	437	89	41
2015		163	668	111		942	424	89	40
2016		163	668	111		942	412	89	39
2017		163	668	111		942	400	89	38
2018		163	668	111		942	388	89	37
2019		163	668	111		942	377	89	36
2020		163	668	111		942	366	89	35
2021		163	668	111		942	355	89	34
2022		163	668	111		942	345	89	33
2023					85	85	30		
TOTAL	8,071	3,260	13,360	2,220	85	26,996	14,893	1,780	875
DISC TOTAL	5,597	1,603	6,570	1,092	30	14,893			
UNIT COST (per kgU)	6.39	1.83	7.51	1.25	.03	17.01			
% OF TOTAL DISC COST	38%	11%	44%	7%	0%	100%			

TABLE A-11
CASE 6A -- LIFE CYCLE COST OF TRANSPORT OF 7 PWR ASSEMBLY NESCO FROM REACTORS TO DOE FACILITIES
500 MILES AWAY IN A NESC SHIPPING CASK
(ONE NESC CASE IN FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997	677					677	519		
1998	70					70	52		
1999	6					6	4		
2000									
2001	1,362					1,362	927		
2002	2,714					2,714	1,794		
2003		205	508	87		800	513	55	35
2004		205	508	87		800	499	55	34
2005		205	508	87		800	484	55	33
2006		205	508	87		800	470	55	32
2007		205	508	87		800	456	55	31
2008		205	508	87		800	443	55	30
2009		205	508	87		800	430	55	30
2010		205	508	87		800	418	55	29
2011		205	508	87		800	405	55	28
2012		205	508	87		800	394	55	27
2013		205	508	87		800	382	55	26
2014		205	508	87		800	371	55	26
2015		205	508	87		800	360	55	25
2016		205	508	87		800	350	55	24
2017		205	508	87		800	339	55	23
2018		205	508	87		800	330	55	23
2019		205	508	87		800	320	55	22
2020		205	508	87		800	311	55	21
2021		205	508	87		800	302	55	21
2022		205	508	87		800	293	55	20
2023					55	55	20		
TOTAL	4,829	4,100	10,160	1,740	55	20,884	11,185	1,100	541
DISC TOTAL	3,297	2,016	4,997	856	20	11,185			
UNIT COST (per kgU)	6.09	3.73	9.24	1.58	.04	20.68			
% OF TOTAL DISC COST	29%	18%	45%	8%	0%	100%			

TABLE A-12
CASE 6B -- LIFE CYCLE COST OF TRANSPORT OF 7 PWR ASSEMBLY MESCS FROM REACTORS TO DOE FACILITIES
2800 MILES AWAY IN A MESC SHIPPING CASK
(ONE MESC CASK IN FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCCRT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN SHIPPED	DISC TO 1988 @ 3%/Yr.
1997	677					677	519		
1998	70					70	52		
1999	6					6	4		
2000									
2001	1,362					1,362	927		
2002	2,714					2,714	1,794		
2003		163	649	111		923	592	26	17
2004		163	649	111		923	575	26	16
2005		163	649	111		923	558	26	16
2006		163	649	111		923	542	26	15
2007		163	649	111		923	526	26	15
2008		163	649	111		923	511	26	14
2009		163	649	111		923	496	26	14
2010		163	649	111		923	482	26	14
2011		163	649	111		923	468	26	13
2012		163	649	111		923	454	26	13
2013		163	649	111		923	441	26	12
2014		163	649	111		923	428	26	12
2015		163	649	111		923	416	26	12
2016		163	649	111		923	403	26	11
2017		163	649	111		923	392	26	11
2018		163	649	111		923	380	26	11
2019		163	649	111		923	369	26	10
2020		163	649	111		923	358	26	10
2021		163	649	111		923	348	26	10
2022		163	649	111		923	338	26	10
2023					55	55	20		
TOTAL	4,829	3,260	12,980	2,220	55	23,344	12,395	520	256
DISC TOTAL	3,297	1,603	6,383	1,092	20	12,395			
UNIT COST (per kgU)	12.89	6.27	24.96	4.27	.08	48.47			
% OF TOTAL DISC COST	27%	13%	52%	9%	0%	100%			

TABLE A-13
CASE 7A -- LIFE CYCLE COST OF TRANSPORT OF 7 PWR ASSEMBLIES FROM REACTORS TO DOE FACILITIES
500 MILES AWAY IN A 7 PWR ASSEMBLY MESC SHIPPING CASK
(ONE MESC CASK IN FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997	911					911	698		
1998	70					70	52		
1999	6					6	4		
2000									
2001	1,634					1,634	1,113		
2002	3,145					3,145	2,079		
2003		210	538	92		840	539	58	37
2004		210	538	92		840	523	58	36
2005		210	538	92		840	508	58	35
2006		210	538	92		840	493	58	34
2007		210	538	92		840	479	58	33
2008		210	538	92		840	465	58	32
2009		210	538	92		840	452	58	31
2010		210	538	92		840	438	58	30
2011		210	538	92		840	426	58	29
2012		210	538	92		840	413	58	29
2013		210	538	92		840	401	58	28
2014		210	538	92		840	390	58	27
2015		210	538	92		840	378	58	26
2016		210	538	92		840	367	58	25
2017		210	538	92		840	356	58	25
2018		210	538	92		840	346	58	24
2019		210	538	92		840	336	58	23
2020		210	538	92		840	326	58	23
2021		210	538	92		840	317	58	22
2022		210	538	92		840	307	58	21
2023					56	56	20		
TOTAL	5,766	4,200	10,760	1,940	56	22,622	12,228	1,160	570
DISC TOTAL	3,947	2,066	5,292	905	20	12,228			
UNIT COST (per kgU)	6.92	3.62	9.28	1.59	.03	21.44			
% OF TOTAL DISC COST	32%	17%	43%	7%	0%	100%			

TABLE A-14
CASE 7B -- LIFE CYCLE COST OF TRANSPORT OF 7 PWR ASSEMBLIES FROM REACTORS TO DOE FACILITIES
2800 MILES AWAY IN A 7 PWR ASSEMBLY MESC SHIPPING CASK
(ONE MESC CASK IN FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMH COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997	911					911	698		
1998	70					70	52		
1999	6					6	4		
2000									
2001	1,634					1,634	1,113		
2002	3,145					3,145	2,079		
2003		163	649	111		923	592	26	17
2004		163	649	111		923	575	26	16
2005		163	649	111		923	558	26	16
2006		163	649	111		923	542	26	15
2007		163	649	111		923	526	26	15
2008		163	649	111		923	511	26	14
2009		163	649	111		923	496	26	14
2010		163	649	111		923	482	26	14
2011		163	649	111		923	468	26	13
2012		163	649	111		923	454	26	13
2013		163	649	111		923	441	26	12
2014		163	649	111		923	428	26	12
2015		163	649	111		923	416	26	12
2016		163	649	111		923	403	26	11
2017		163	649	111		923	392	26	11
2018		163	649	111		923	380	26	11
2019		163	649	111		923	369	26	10
2020		163	649	111		923	358	26	10
2021		163	649	111		923	348	26	10
2022		163	649	111		923	338	26	10
2023					56	56	20		
TOTAL	5,766	3,260	12,980	2,220	56	24,282	13,045	520	256
DISC TOTAL	3,947	1,603	6,383	1,092	20	13,045			
UNIT COST (per kgU)	15.43	6.27	24.96	4.27	.08	51.01			
% OF TOTAL DISC COST	30%	12%	49%	8%	0%	100%			

TABLE A-15
CASE 6A -- LIFE CYCLE COST OF TRANSPORT OF 2/7 PWR ASSEMBLY MESCS FROM REACTORS TO DOE FACILITIES
500 MILES AWAY IN A 2/7 PWR ASSEMBLY MESC SHIPPING CASE
(ONE MESC CASE IN FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECONN COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN DISC SHIPPED TO 1988	DISC @ 3%/Yr TO 1988
1997	1,264					1,264	969		
1998	259					259	193		
1999	21					21	15		
2000									
2001	2,264					2,264	1,542		
2002	3,874					3,874	2,561		
2003		205	559	87		851	546	110	71
2004		205	559	87		851	530	110	69
2005		205	559	87		851	515	110	67
2006		205	559	87		851	500	110	65
2007		205	559	87		851	485	110	63
2008		205	559	87		851	471	110	61
2009		205	559	87		851	457	110	59
2010		205	559	87		851	444	110	57
2011		205	559	87		851	431	110	56
2012		205	559	87		851	419	110	54
2013		205	559	87		851	406	110	53
2014		205	559	87		851	395	110	51
2015		205	559	87		851	383	110	50
2016		205	559	87		851	372	110	48
2017		205	559	87		851	361	110	47
2018		205	559	87		851	351	110	45
2019		205	559	87		851	340	110	44
2020		205	559	87		851	330	110	43
2021		205	559	87		851	321	110	41
2022		205	559	87		851	312	110	40
2023					92	92	33		
TOTAL	7,682	4,100	11,180	1,740	92	24,794	13,682	2,200	1,082
DISC TOTAL	5,279	2,016	5,498	856	33	13,682			
UNIT COST (per kgU)	4.88	1.87	5.08	.79	.03	12.65			
% OF TOTAL DISC COST	39%	15%	40%	6%	0%	100%			

TABLE A-16
CASE 88 -- LIFE CYCLE COST OF TRANSPORT OF 2/7 PWR ASSEMBLY MESCS FROM REACTORS TO DOE FACILITIES
2800 MILES AWAY IN A 2/7 PWR ASSEMBLY MESC SHIPPING CASE
(ONE MESC CASE IN FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN SHIPPED	DISC TO 1988 @ 3%/Yr.
1997	1,264					1,264	969		
1998	259					259	193		
1999	21					21	15		
2000									
2001	2,264					2,264	1,542		
2002	3,874					3,874	2,561		
2003		163	715	111		989	635	52	33
2004		163	715	111		989	616	52	32
2005		163	715	111		989	598	52	31
2006		163	715	111		989	581	52	31
2007		163	715	111		989	564	52	30
2008		163	715	111		989	548	52	29
2009		163	715	111		989	532	52	28
2010		163	715	111		989	516	52	27
2011		163	715	111		989	501	52	26
2012		163	715	111		989	487	52	26
2013		163	715	111		989	472	52	25
2014		163	715	111		989	459	52	24
2015		163	715	111		989	445	52	23
2016		163	715	111		989	432	52	23
2017		163	715	111		989	420	52	22
2018		163	715	111		989	407	52	21
2019		163	715	111		989	396	52	21
2020		163	715	111		989	384	52	20
2021		163	715	111		989	373	52	20
2022		163	715	111		989	362	52	19
2023					92	92	33		
TOTAL	7,682	3,260	14,300	2,220	92	27,554	15,040	1,040	511
DISC TOTAL	5,279	1,603	7,033	1,092	33	15,040			
UNIT COST (per kgU)	10.33	3.14	13.75	2.13	.06	29.41			
% OF TOTAL DISC COST	35%	11%	47%	7%	0%	100%			

TABLE A-17
CASE 9A -- LIFE CYCLE COST OF TRANSPORT OF 26 PWR ASSEMBLIES FROM REACTORS TO DOE FACILITIES
500 MILES AWAY IN A 2/7 PWR ASSEMBLY NESC SHIPPING CASK
(ONE NESC CASE IN FLEET)

YEAR	COSTS (\$000, 1988)						QUANTITIES (MTU)	
	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	ANNUAL QUAN SHIPPED	DISC TO 1988 @ 3%/Yr
1997	1,499					1,499		1,149
1998	259					259		193
1999	21					21		15
2000								
2001	3,022					3,022		2,050
2002	4,845					4,845		3,203
2003		210	607	92		909	216	139
2004		210	607	92		909	216	135
2005		210	607	92		909	216	131
2006		210	607	92		909	216	127
2007		210	607	92		909	216	123
2008		210	607	92		909	216	120
2009		210	607	92		909	216	116
2010		210	607	92		909	216	113
2011		210	607	92		909	216	109
2012		210	607	92		909	216	106
2013		210	607	92		909	216	103
2014		210	607	92		909	216	100
2015		210	607	92		909	216	97
2016		210	607	92		909	216	94
2017		210	607	92		909	216	92
2018		210	607	92		909	216	89
2019		210	607	92		909	216	86
2020		210	607	92		909	216	84
2021		210	607	92		909	216	81
2022		210	607	92		909	216	79
2023					109	109		39
TOTAL	9,646	4,200	12,140	1,840	109	27,935	4,320	2,125
DISC TOTAL	6,618	2,066	5,970	905	39	15,597		
UNIT COST (per kgU)	3.11	.97	2.81	.43	.02	7.34		
% OF TOTAL DISC COST	42%	13%	38%	6%	0%	100%		

TABLE A-18
CASE 98 -- LIFE CYCLE COST OF TRANSPORT OF 26 PWR ASSEMBLIES FROM REACTORS TO DOE FACILITIES
2800 MILES AWAY IN A 2/7 PWR ASSEMBLY MESC SHIPPING CASE
(ONE MESC CASE IN FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'M COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN SHIPPED	DISC @ 3%/Yr TO 1988
1997	1,499					1,499	1,149		
1998	259					259	193		
1999	21					21	15		
2000									
2001	3,022					3,022	2,058		
2002	4,845					4,845	3,203		
2003		163	733	111		1,007	646	96	62
2004		163	733	111		1,007	628	96	60
2005		163	733	111		1,007	609	96	58
2006		163	733	111		1,007	592	96	56
2007		163	733	111		1,007	574	96	55
2008		163	733	111		1,007	558	96	53
2009		163	733	111		1,007	541	96	52
2010		163	733	111		1,007	526	96	50
2011		163	733	111		1,007	510	96	49
2012		163	733	111		1,007	495	96	47
2013		163	733	111		1,007	481	96	46
2014		163	733	111		1,007	467	96	45
2015		163	733	111		1,007	453	96	43
2016		163	733	111		1,007	440	96	42
2017		163	733	111		1,007	427	96	41
2018		163	733	111		1,007	415	96	40
2019		163	733	111		1,007	403	96	38
2020		163	733	111		1,007	391	96	37
2021		163	733	111		1,007	380	96	36
2022		163	733	111		1,007	369	96	35
2023					109	109	39		
<hr/>									
TOTAL	9,646	3,260	14,660	2,220	109	29,895	16,561	1,920	944
<hr/>									
DISC TOTAL	6,618	1,603	7,210	1,092	39	16,561			
<hr/>									
UNIT COST (per kgU)	7.01	1.70	7.64	1.16	.04	17.55			
<hr/>									
% OF TOTAL DISC COST	40%	10%	44%	7%	0%	100%			

APPENDIX B

LIFE CYCLE TRANSPORT COSTS AND UNIT COST CALCULATIONS
ASSOCIATED WITH THE USE OF A SINGLE 24 PWR ASSEMBLY
MESC SHIPPING CASK -- CASKS USED EITHER EXCLUSIVELY FOR
SHIPMENT OF MESC_s TO EXTENT AVAILABLE OR FULLY UTILIZED FOR
SHIPMENT OF INDIVIDUAL FUEL ASSEMBLIES AND MESC_s .

APPENDIX B
LIFE CYCLE TRANSPORT COSTS AND UNIT COST CALCULATIONS
ASSOCIATED WITH THE USE OF A SINGLE 24 PWR ASSEMBLY
MESC SHIPPING CASK -- CASKS USED EITHER EXCLUSIVELY FOR
SHIPMENT OF MESC'S TO EXTENT AVAILABLE OR FULLY UTILIZED FOR
SHIPMENT OF INDIVIDUAL FUEL ASSEMBLIES AND MESC'S

The total life cycle costs associated with the use of a single 24 PWR assembly MESC shipping cask for shipment of varying quantities of spent nuclear fuel from reactors to DOE facilities were developed for instances where (i) the cask would be used to ship individual PWR assemblies to the extent there were insufficient MESC's available to fully utilize the cask capacity over its assumed 20-year lifetime, and (ii) the cask would be used to ship only MESC's and thus utilized only to the extent MESC's were available for shipment. The specific cases examined are listed below.

<u>Case No.</u>	<u>Shipping Distance (Miles)</u>	<u>Cask Usage</u>	<u>Total Quantity Shipped (MTU)</u>		
			<u>Individual PWR Assemblies</u>	<u>MESC's</u>	
10	500	Mixed	3,383	564	} Full Utilization of Cask
11			2,985	940	
12			2,388	1,504	
13			1,990	1,880	
14	2,800	Mixed	3,026	534	
15			2,670	890	
16			2,136	1,424	
17			1,780	1,780	
18	500	MESC's Only	-	564	} Utilization of Cask Only to Extent MESC's are Available for Shipment
19			-	940	
20			-	1,504	
21			-	1,880	
22	2,800	MESC's Only	-	534	
23			-	890	
24			-	1,424	
25			-	1,780	

The life cycle costs and resulting unit costs for each of the foregoing cases are shown in Tables B-1 through B-16. The figures set forth in the tables were developed as follows:

- (1) For Cases 10 through 17 where full utilization of the cask over its lifetime was assumed to be achieved, the total costs were assumed to be incurred over the period 1997 to 2023, inclusive. During the period 1997 through 2002 the capital cost of the cask would be incurred; during the period 2003 through 2022 the cost of operations, freight and escorts would be incurred; and in 2023 the cost of decommissioning would be incurred.
- (2) For Cases 18 through 25 where the cask was used for shipment of MESCs only to the extent such were available, the total costs were assumed to be incurred commencing six years prior to the year in which shipments were initiated through 2023. During the first 6 years the capital cost of the cask would be incurred; during the years in which shipments were made the cost of operations, freight and escorts would be incurred; and in 2023 the cost of decommissioning would be incurred.
- (3) With regard to the capital cost of the cask, it was assumed that the cost of design and development would be incurred in the first year, the cost of model fabrication and testing would be incurred in the second year, the NRC Certification Fee would be paid in the third year, half of the cost of cask fabrication would be incurred in the fifth year, and the other half of the cost of fabrication plus the cost of acceptance testing and auxiliary equipment would be incurred in the sixth year. It was assumed that the third and fourth year would be required by NRC to make the necessary safety reviews, and that certification would be made at the end of the fourth year.
- (4) The capital cost of the casks for the various cases considered were developed as follows:
 - (a) For Cases 10-13 in which both shipments of individual fuel assemblies as well as MESCs were involved to achieve full utilization of the cask over its lifetime, in 500-mile shipments -- the single cask (with basket) capital cost set forth in Table 4-4 was used.
 - (b) For Cases 14-17 in which both shipments of individual fuel assemblies as well as MESCs were involved to achieve full utilization of the cask over its lifetime, in 2,800-mile shipments -- the two-cask (without basket) capital cost set forth in Table 4-4 was used. Since two casks would be used (so that the total quantities would be about the same as the 500-mile case), the quantity

shipped would be double that shown in the tables, each of which show the life cycle costs for a single cask.

- (c) For Cases 18-21 in which shipments of MESCs only were involved and full utilization of the cask was not achieved over its lifetime, in 500-mile shipments -- the single cask (without basket) capital cost set forth in Table 4-4 was used, less the allocation for the added costs of the reference cask. Since this cask did not replace a reference cask, but rather constituted an added cask in the fleet, this allocation was not required.
 - (d) For Cases 22-25 in which shipments of MESCs only were involved and full utilization of the cask was not achieved over its lifetime, in 2,800-mile shipments -- the two-cask (without basket) capital cost set forth in Table 4-4 was used, less the allocation for the added costs of the reference cask. Since this cask did not replace a reference cask, but rather constituted an added cask in the fleet, this allocation was not required. Moreover, since two casks would be used (so that the total quantities shipped would be about the same as the 500-mile case), the quantity shipped would be double that shown in the tables, each of which show the life cycle costs for a single cask.
- (5) The annual quantities shipped each year were assumed to be as follows:

<u>Form of Fuel Shipped</u>	<u>MTU in Single Shipment</u>	<u>Annual Quantity Shipped (MTU)^a</u>	
		<u>500 Miles</u>	<u>2800 Miles</u>
MESCs	11.06	188*	89
Assemblies	11.06	199	89

^a Based on 18 shipments/year for 500-mile shipments (17 shipments/year for those cases marked with an asterisk), and 8 shipments/year for 2800-mile shipments.

- (6) The annual cost of operation, freight, escorts and decommissioning were determined as described in Section 4.1.2.3.
- (7) The total costs were discounted by 3%/year to 1988 to get the total discounted costs.

- (8) The unit costs were determined by dividing the total discounted costs by the total discounted amount (MTU) of spent fuel shipped, as follows:

Discounted Costs = Discounted (Unit Costs x MTU Shipped)

Discounted Costs = Unit Costs x Discounted MTU Shipped

Unit Cost = $\frac{\text{Discounted Costs}}{\text{Discounted MTU Shipped}}$

A more detailed explanation of the methodology used for the unit cost calculation is set forth in Appendix F.

TABLE B-1
CASE 1C -- LIFE CYCLE COST OF TRANSPORT OF 3383 MTU AS PWR ASSEMBLIES AND 564 MTU AS PWR ASSEMBLIES IN WESCS
FROM REACTORS TO DOE FACILITIES 500 MILES AWAY IN 24 PWR ASSEMBLY WESC SHIPPING CASE
(ONE WESC CASE IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. SHIPPED	DISC @ 3%/Yr TO 1988
1997	1,227					1,227	940		
1998	2,798					2,798	2,082		
1999	184					184	133		
2000									
2001	2,476					2,476	1,686		
2002	4,169					4,169	2,756		
2003		210	553	92		855	549	199	128
2004		210	553	92		855	533	199	124
2005		210	553	92		855	517	199	120
2006		210	553	92		855	502	199	117
2007		210	553	92		855	488	199	113
2008		210	553	92		855	473	199	110
2009		210	553	92		855	460	199	107
2010		210	553	92		855	446	199	104
2011		210	553	92		855	433	199	101
2012		210	553	92		855	421	199	98
2013		210	553	92		855	408	199	95
2014		210	553	92		855	396	199	92
2015		210	553	92		855	385	199	90
2016		210	553	92		855	374	199	87
2017		210	553	92		855	363	199	84
2018		210	553	92		855	352	199	82
2019		210	553	92		855	342	199	80
2020		205	552	87		844	328	WESCS	73
2021		205	552	87		844	318		71
2022		205	552	87		844	309		69
2023					85	85	30		
TOTAL	10,854	4,185	11,057	1,825	85	28,006	16,025	3,947	1,945
DISC TOTAL	7,598	2,060	5,438	899	30	16,025			
UNIT COST (per kgU)	3.91	1.06	2.80	.46	.02	8.25			
% OF TOTAL DISC COST	47%	13%	34%	6%	0%	100%			

TABLE B-2
CASE 11 -- LIFE CYCLE COST OF TRANSPORT OF 2985 MTU AS PWR ASSEMBLIES AND 940 MTU AS PWR ASSEMBLIES IN NESCS
FROM REACTORS TO DOE FACILITIES 500 MILES AWAY IN 24 PWR ASSEMBLY NESC SHIPPING CASK
(ONE NESC CASK IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997	1,227					1,227	940		
1998	2,798					2,798	2,082		
1999	184					184	133		
2000									
2001	2,476					2,476	1,686		
2002	4,169					4,169	2,756		
2003		210	553	92		855	549	199	128
2004		210	553	92		855	533	199	124
2005		210	553	92		855	517	199	120
2006		210	553	92		855	502	199	117
2007		210	553	92		855	488	199	113
2008		210	553	92		855	473	199	110
2009		210	553	92		855	460	199	107
2010		210	553	92		855	446	199	104
2011		210	553	92		855	433	199	101
2012		210	553	92		855	421	199	98
2013		210	553	92		855	408	199	95
2014		210	553	92		855	396	199	92
2015		210	553	92		855	385	199	90
2016		210	553	92		855	374	199	87
2017		210	553	92		855	363	199	84
								ASSEMBLIES ONLY	
2018		205	552	87		844	348	NESCS	188
2019		205	552	87		844	338		77
2020		205	552	87		844	328		75
2021		205	552	87		844	318		73
2022		205	552	87		844	309		71
2023					85	85	30		69
TOTAL	10,854	4,175	11,055	1,815	85	27,984	16,016	3,925	1,936
DISC TOTAL	7,598	2,056	5,437	995	30	16,016			
UNIT COST (per kgU)	3.93	1.06	2.81	.46	.02	8.28			
% OF TOTAL DISC COST	47%	13%	34%	6%	0%	100%			

TABLE B-3
CASE 12 -- LIFE CYCLE COST OF TRANSPORT OF 2388 MTU AS PWR ASSEMBLIES AND 1504 MTU AS PWR ASSEMBLIES IN NESCO
FROM REACTORS TO DOE FACILITIES 500 MILES AWAY IN 24 PWR ASSEMBLY NESC SHIPPING CASK
(ONE NESC CASK IN DOE FLEET)

COSTS (\$000, 1998)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'M COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3Yr SHIPPED TO 1988	DISC
1997	1,227					1,227	940		
1998	2,798					2,798	2,082		
1999	184					184	133		
2000									
2001	2,476					2,476	1,686		
2002	4,169					4,169	2,756		
2003		210	553	92		855	549	199	128
2004		210	553	92		855	533	199	124
2005		210	553	92		855	517	199	120
2006		210	553	92		855	502	199	117
2007		210	553	92		855	488	199	113
2008		210	553	92		855	473	199	110
2009		210	553	92		855	460	199	107
2010		210	553	92		855	446	199	104
2011		210	553	92		855	433	199	101
2012		210	553	92		855	421	199	98
2013		210	553	92		855	408	ASSEMBLIES ONLY	95
2014		210	553	92		855	396	199	92
2015		205	552	87		844	380	NESCO	85
2016		205	552	87		844	369	188	82
2017		205	552	87		844	358	188	80
2018		205	552	87		844	348	188	77
2019		205	552	87		844	338	188	75
2020		205	552	87		844	328	188	73
2021		205	552	87		844	318	188	71
2022		205	552	87		844	309	188	69
2023					85	85	30		
TOTAL	10,854	4,160	11,052	1,800	85	27,951	16,002	3,892	1,922
DISC TOTAL	7,598	2,049	5,436	889	30	16,002			
UNIT COST (per kgU)	3.96	1.07	2.83	.46	.02	8.34			
% OF TOTAL DISC COST	47%	13%	34%	6%	0%	100%			

TABLE B-4
CASE 13 -- LIFE CYCLE COST OF TRANSPORT OF 1990 MTU AS PWR ASSEMBLIES AND 1880 MTU AS PWR ASSEMBLIES IN MESCS
FROM REACTORS TO DOE FACILITIES 500 MILES AWAY IN 24 PWR ASSEMBLY MESC SHIPPING CASK
(ONE MESC CASK IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECONN COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN. SHIPPED TO 1988	DISC @ 3%/Yr
1997	1,227					1,227	940		
1998	2,798					2,798	2,082		
1999	184					184	133		
2000									
2001	2,476					2,476	1,686		
2002	4,169					4,169	2,756		
2003		210	553	92		855	549	199	128
2004		210	553	92		855	533	199	124
2005		210	553	92		855	517	199	120
2006		210	553	92		855	502	199	117
2007		210	553	92		855	488	199	113
2008		210	553	92		855	473	199	110
2009		210	553	92		855	460	199	107
2010		210	553	92		855	446	199	104
2011		210	553	92		855	433	ASSEMBLIES ONLY	101
2012		210	553	92		855	421	199	98
2013		205	552	87		844	403	MESCS	90
2014		205	552	87		844	391	188	87
2015		205	552	87		844	380	188	85
2016		205	552	87		844	369	188	82
2017		205	552	87		844	358	188	80
2018		205	552	87		844	348	188	77
2019		205	552	87		844	338	188	75
2020		205	552	87		844	328	188	73
2021		205	552	87		844	318	188	71
2022		205	552	87		844	309	188	69
2023						85	85		30
TOTAL	10,854	4,150	11,050	1,790	85	27,929	15,991	3,870	1,911
DISC TOTAL	7,598	2,045	5,435	884	30	15,991			
UNIT COST (per kgU)	3.98	1.07	2.84	.46	.02	8.37			
% OF TOTAL DISC COST	48%	13%	34%	6%	0%	100%			

TABLE B-5
CASE 14 -- LIFE CYCLE COST OF TRANSPORT OF 1513 MTU AS PWR ASSEMBLIES AND 267 MTU AS PWR ASSEMBLIES IN WESCS
FROM REACTORS TO DOE FACILITIES 2000 MILES AWAY IN 24 PWR ASSEMBLY WESC SHIPPING CASE
(TWO WESC CASKS IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'M COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997	837					837	641		
1998	1,519					1,519	1,130		
1999	102					102	74		
2000									
2001	2,066					2,066	1,407		
2002	3,547					3,547	2,345		
2003		163	668	111		942	605	89	57
2004		163	668	111		942	587	89	55
2005		163	668	111		942	570	89	54
2006		163	668	111		942	553	89	52
2007		163	668	111		942	537	89	51
2008		163	668	111		942	522	89	49
2009		163	668	111		942	506	89	48
2010		163	668	111		942	492	89	46
2011		163	668	111		942	477	89	45
2012		163	668	111		942	463	89	44
2013		163	668	111		942	450	89	43
2014		163	668	111		942	437	89	41
2015		163	668	111		942	424	89	40
2016		163	668	111		942	412	89	39
2017		163	668	111		942	400	89	38
2018		163	668	111		942	388	ASSEMBLIES ONLY	89 37
2019		163	668	111		942	377		89 36
2020		163	706	111		980	381	WESCS	89 35
2021		163	706	111		980	369		89 34
2022		163	706	111		980	359		89 33
2023					85	85	30		
TOTAL	8,071	3,260	13,474	2,220	85	27,110	14,936	1,780	875
DISC TOTAL	5,597	1,603	6,613	1,092	30	14,936			
UNIT COST (per kgU)	6.40	1.83	7.55	1.25	.03	17.06			
% OF TOTAL DISC COST	37%	11%	44%	7%	0%	100%			

TABLE B-6
CASE 15 -- LIFE CYCLE COST OF TRANSPORT OF 1335 MTU AS PWR ASSEMBLIES AND 445 MTU AS PWR ASSEMBLIES IN MESCS
FROM REACTORS TO DOE FACILITIES 2000 MILES AWAY IN 24 PWR ASSEMBLY MESC SHIPPING CASK
(TWO MESC CASKS IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC TO 1988
1997	837					837	641		
1998	1,519					1,519	1,130		
1999	102					102	74		
2000									
2001	2,066					2,066	1,407		
2002	3,547					3,547	2,345		
2003		163	668	111		942	605	89	57
2004		163	668	111		942	587	89	55
2005		163	668	111		942	570	89	54
2006		163	668	111		942	553	89	52
2007		163	668	111		942	537	89	51
2008		163	668	111		942	522	89	49
2009		163	668	111		942	506	89	48
2010		163	668	111		942	492	89	46
2011		163	668	111		942	477	89	45
2012		163	668	111		942	463	89	44
2013		163	668	111		942	450	89	43
2014		163	668	111		942	437	89	41
2015		163	668	111		942	424	89	40
2016		163	668	111		942	412	ASSEMBLIES ONLY	89 39
2017		163	668	111		942	400		89 38
2018		163	706	111		980	404	MESCS	89 37
2019		163	706	111		980	392		89 36
2020		163	706	111		980	381		89 35
2021		163	706	111		980	369		89 34
2022		163	706	111		980	359		89 33
2023					85	85	30		
TOTAL	8,071	3,260	13,550	2,220	85	27,186	14,967	1,780	875
DISC TOTAL	5,597	1,603	6,644	1,092	30	14,967			
UNIT COST (per kgU)	6.40	1.83	7.59	1.25	.03	17.10			
% OF TOTAL DISC COST	38%	11%	44%	7%	0%	100%			

TABLE B-7
CASE 14 -- LIFE CYCLE COST OF TRANSPORT OF 1068 MTU AS PWR ASSEMBLIES AND 712 MTU AS PWR ASSEMBLIES IN MESCS
FROM REACTORS TO DOE FACILITIES 2800 MILES AWAY IN 24 PWR ASSEMBLY MESC SHIPPING CASK
(TWO MESC CASKS IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997	837					837	641		
1998	1,519					1,519	1,130		
1999	102					102	74		
2000									
2001	2,066					2,066	1,407		
2002	3,547					3,547	2,345		
2003		163	668	111		942	605	89	57
2004		163	668	111		942	587	89	55
2005		163	668	111		942	570	89	54
2006		163	668	111		942	553	89	52
2007		163	668	111		942	537	89	51
2008		163	668	111		942	522	89	49
2009		163	668	111		942	506	89	48
2010		163	668	111		942	492	89	46
2011		163	668	111		942	477	89	45
2012		163	668	111		942	463	89	44
2013		163	668	111		942	450	ASSEMBLIES ONLY	89 43
2014		163	668	111		942	437		89 41
2015		163	706	111		980	441	MESCS	89 40
2016		163	706	111		980	428		89 39
2017		163	706	111		980	416		89 38
2018		163	706	111		980	404		89 37
2019		163	706	111		980	392		89 36
2020		163	706	111		980	381		89 35
2021		163	706	111		980	369		89 34
2022		163	706	111		980	359		89 33
2023					85	85	30		
TOTAL	8,071	3,260	13,664	2,220	85	27,300	15,016	1,780	875
DISC TOTAL	5,597	1,603	6,694	1,092	30	15,016			
UNIT COST (per kgU)	6.40	1.83	7.65	1.25	.03	17.16			
% OF TOTAL DISC COST	37%	11%	45%	7%	0%	100%			

TABLE B-8
CASE 17 -- LIFE CYCLE COST OF TRANSPORT OF 890 MTU AS PWR ASSEMBLIES AND 890 MTU AS PWR ASSEMBLIES IN MESCS
FROM REACTORS TO DOE FACILITIES 2800 MILES AWAY IN 24 PWR ASSEMBLY MESC SHIPPING CASE
(TWO MESC CASKS IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMN COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997	837					837	641		
1998	1,519					1,519	1,130		
1999	102					102	74		
2000									
2001	2,066					2,066	1,407		
2002	3,547					3,547	2,345		
2003		163	668	111		942	605	89	57
2004		163	668	111		942	587	89	53
2005		163	668	111		942	570	89	54
2006		163	668	111		942	553	89	52
2007		163	668	111		942	537	89	51
2008		163	668	111		942	522	89	49
2009		163	668	111		942	506	89	48
2010		163	668	111		942	492	89	46
2011		163	668	111		942	477	89	45
2012		163	668	111		942	463	89	44
2013		163	706	111		980	468	MESCS	43
2014		163	706	111		980	454		41
2015		163	706	111		980	441		40
2016		163	706	111		980	428		39
2017		163	706	111		980	416		38
2018		163	706	111		980	404		37
2019		163	706	111		980	392		36
2020		163	706	111		980	381		35
2021		163	706	111		980	369		34
2022		163	706	111		980	359		33
2023					85	85	30		
TOTAL	8,071	3,260	13,740	2,220	85	27,376	15,052	1,780	875
DISC TOTAL	5,597	1,603	6,730	1,092	30	15,052			
UNIT COST (per kgU)	6.40	1.83	7.69	1.25	.03	17.20			
% OF TOTAL DISC COST	37%	11%	45%	7%	0%	100%			

TABLE B-9
CASE 18 -- LIFE CYCLE COST OF TRANSPORT OF 564 MTU AS PWR ASSEMBLIES IN MESCS FROM REACTORS TO DOE
FACILITIES 500 MILES AWAY IN A DEDICATED 24 PWR ASSEMBLY MESC SHIPPING CASE
(ONE MESC CASE IN DOE FLEET)

YEAR	COSTS (\$000, 1988)							QUANTITIES (MTU)	
	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									
2009									
2010									
2011									
2012									
2013									
2014	547					547	254		
2015	2,559					2,559	1,152		
2016	165					165	72		
2017									
2018	1,870					1,870	770		
2019	3,347					3,347	1,339		
2020		210	552	87		849	330	188	73
2021		210	552	87		849	320	188	71
2022		210	552	87		849	311	188	69
2023					84	84	30		
TOTAL	8,488	630	1,656	261	84	11,119	4,577	564	213
DISC TOTAL	3,587	238	625	98	30	4,577			
UNIT COST (per kgU)	16.86	1.12	2.94	.46	.14	21.52			
% OF TOTAL DISC COST	78%	5%	14%	2%	1%	100%			

TABLE B-10
CASE 19 -- LIFE CYCLE COST OF TRANSPORT OF 940 MTU A3 PWR ASSEMBLIES IN MESCS FROM REACTORS TO DOE
FACILITIES 500 MILES AWAY IN A DEDICATED 24 PWR ASSEMBLY MESC SHIPPING CASK
(ONE MESC CASK IN DOE FLEET)

YEAR	COSTS (\$000, 1988)						QUANTITIES (MTU)	
	CAPITAL COST	ANNUAL OPER'M COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988
1997								
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006								
2007								
2008								
2009								
2010								
2011								
2012	547					547	269	
2013	2,559					2,559	1,222	
2014	165					165	77	
2015								
2016	1,870					1,870	817	
2017	3,347					3,347	1,420	
2018		210	552	87		849	350	188 77
2019		210	552	87		849	340	188 75
2020		210	552	87		849	330	188 73
2021		210	552	87		849	320	188 71
2022		210	552	87		849	311	188 69
2023					84	84	30	
TOTAL	8,488	1,050	2,760	435	84	12,817	5,485	940 365
DISC TOTAL	3,805	408	1,073	169	30	5,485		
UNIT COST (per kgU)	10.41	1.12	2.94	.46	.08	15.01		
% OF TOTAL DISC COST	69%	7%	20%	3%	1%	100%		

TABLE D-11
CASE 20 -- LIFE CYCLE COST OF TRANSPORT OF 1504 MTU AS PWR ASSEMBLIES IN MESCS FROM REACTORS TO DOE
FACILITIES 500 MILES AWAY IN A DEDICATED 24 PWR ASSEMBLY MESC SHIPPING CASE
(ONE MESC CASE IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									
2009	547					547	294		
2010	2,559					2,559	1,336		
2011	165					165	84		
2012									
2013	1,870					1,870	893		
2014	3,347					3,347	1,552		
2015		210	552	87		849	382	188	85
2016		210	552	87		849	371	188	82
2017		210	552	87		849	360	188	80
2018		210	552	87		849	350	188	77
2019		210	552	87		849	340	188	75
2020		210	552	97		849	330	188	73
2021		210	552	87		849	320	188	71
2022		210	552	87		849	311	188	69
2023					84	84	30		
TOTAL	8,488	1,680	4,416	696	84	15,364	6,952	1,504	612
DISC TOTAL	4,158	684	1,797	283	30	6,952			
UNIT COST (per kgU)	6.80	1.12	2.94	.46	.05	11.37			
% OF TOTAL DISC COST	60%	10%	26%	4%	0%	100%			

TABLE B-12
CASE 21 -- LIFE CYCLE COST OF TRANSPORT OF 1880 MTL AS PWR ASSEMBLIES IN MESCS FROM REACTORS TO DOE
FACILITIES 500 MILES AWAY IN A DEDICATED 24 PWR ASSEMBLY MESC SHIPPING CASK
(ONE MESC CASK IN DOE FLEET)

YEAR	COSTS (\$000, 1988)						QUANTITIES (MTU)	
	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMH COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN DISC QUAN. @ 3%/Yr SHIPPED TO 1988
1997								
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006								
2007	547					547	312	
2008	2,559					2,559	1,417	
2009	165					165	89	
2010								
2011	1,870					1,870	948	
2012	3,347					3,347	1,647	
2013		210	552	87		849	405	188 90
2014		210	552	87		849	394	188 87
2015		210	552	87		849	382	188 85
2016		210	552	87		849	371	188 82
2017		210	552	97		849	360	188 80
2018		210	552	87		849	350	188 77
2019		210	552	87		849	340	188 75
2020		210	552	87		849	330	188 73
2021		210	552	87		849	320	188 71
2022		210	552	87		849	311	188 69
2023					84	84	30	
TOTAL	8,488	2,100	5,520	870	84	17,062	8,004	1,880 789
DISC TOTAL	4,412	881	2,316	365	30	8,004		
UNIT COST (per kgU)	5.59	1.12	2.94	.46	.04	10.15		
% OF TOTAL DISC COST	55%	11%	29%	5%	0%	100%		

TABLE B-13
CASE 22 -- LIFE CYCLE COST OF TRANSPORT OF 267 MTU AS PWR ASSEMBLIES IN MESCS FROM REACTORS TO DOE
FACILITIES 2800 MILES AWAY IN A DEDICATED 24 PWR ASSEMBLY MESC SHIPPING CASE
(TWO MESC CASKS IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									
2009									
2010									
2011									
2012									
2013									
2014	274					274	127		
2015	1,280					1,280	576		
2016	83					83	36		
2017									
2018	1,515					1,515	624		
2019	2,813					2,813	1,125		
2020		163	706	111		980	381	89	35
2021		163	706	111		980	369	89	34
2022		163	706	111		980	359	89	33
2023					84	84	30		
TOTAL	5,965	489	2,118	333	84	8,989	3,628	267	101
DISC TOTAL	2,489	184	799	126	30	3,628			
UNIT COST (per kgU)	24.72	1.83	7.93	1.25	.30	36.03			
% OF TOTAL DISC COST	69%	5%	22%	3%	1%	100%			

TABLE B-14
CASE 23 -- LIFE CYCLE COST OF TRANSPORT OF 445 MTU A3 PWR ASSEMBLIES IN MESCS FROM REACTORS TO DOE
FACILITIES 2800 MILES AWAY IN A DEDICATED 24 PWR ASSEMBLY MESC SHIPPING CASK
(TWO MESC CASKS IN DOE FLEET)

YEAR	COSTS (\$000, 1988)							QUANTITIES (MTU)	
	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									
2009									
2010									
2011									
2012	274					274	135		
2013	1,280					1,280	611		
2014	83					83	38		
2015									
2016	1,515					1,515	662		
2017	2,813					2,813	1,194		
2018		163	706	111		980	404	89	37
2019		163	706	111		980	392	89	36
2020		163	706	111		980	381	89	35
2021		163	706	111		980	369	89	34
2022		163	706	111		980	359	89	33
2023					84	84	30		
TOTAL	5,965	815	3,530	555	84	10,949	4,575	445	173
DISC TOTAL	2,640	317	1,372	216	30	4,575			
UNIT COST (per kgU)	15.27	1.83	7.93	1.25	.17	26.45			
% OF TOTAL DISC COST	58%	7%	30%	5%	1%	100%			

TABLE D-15
CASE 24 -- LIFE CYCLE COST OF TRANSPORT OF 712 MTU AS PWR ASSEMBLIES IN WESCS FROM REACTORS TO DOE
FACILITIES 2800 MILES AWAY IN A DEDICATED 24 PWR ASSEMBLY WESC SHIPPING CASK
(TWO WESC CASKS IN DOE FLEET)

YEAR	COSTS (\$000, 1988)							QUANTITIES (MTU)	
	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN SHIPPED	DISC @ 3%/Yr TO 1988
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									
2009	274					274	147		
2010	1,280					1,280	668		
2011	83					83	42		
2012									
2013	1,515					1,515	724		
2014	2,813					2,813	1,304		
2015		163	706	111		980	441	89	40
2016		163	706	111		980	428	89	39
2017		163	706	111		980	416	89	38
2018		163	706	111		980	404	89	37
2019		163	706	111		980	392	89	36
2020		163	706	111		980	381	89	35
2021		163	706	111		980	369	89	34
2022		163	706	111		980	359	89	33
2023					84	84	30		
TOTAL	5,965	1,304	5,648	888	84	13,889	6,105	712	290
DISC TOTAL	2,885	531	2,298	361	30	6,105			
UNIT COST (per kgU)	9.96	1.83	7.93	1.25	.10	21.07			
% OF TOTAL DISC COST	47%	9%	38%	6%	0%	100%			

TABLE B-16
CASE 25 -- LIFE CYCLE COST OF TRANSPORT OF 890 MTU AS PWR ASSEMBLIES IN NESCO FROM REACTORS TO DOE
FACILITIES 2800 MILES AWAY IN A DEDICATED 24 PWR ASSEMBLY NESC SHIPPING CASK
(TWO NESC CASKS IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007	274					274	156		
2008	1,280					1,280	709		
2009	83					83	45		
2010									
2011	1,515					1,515	768		
2012	2,813					2,813	1,384		
2013		163	706	111		980	468	89	43
2014		163	706	111		980	454	89	41
2015		163	706	111		980	441	89	40
2016		163	706	111		980	428	89	39
2017		163	706	111		980	416	89	38
2018		163	706	111		980	404	89	37
2019		163	706	111		980	392	89	36
2020		163	706	111		980	381	89	35
2021		163	706	111		980	369	89	34
2022		163	706	111		980	359	89	33
2023						84	84	30	
TOTAL	5,965	1,630	7,060	1,110	84	15,849	7,203	890	373
DISC TOTAL	3,061	684	2,963	466	30	7,203			
UNIT COST (per kgU)	8.20	1.83	7.93	1.25	.08	19.29			
% OF TOTAL DISC COST	44%	9%	41%	6%	0%	100%			

APPENDIX C

LIFE CYCLE TRANSPORT COSTS AND UNIT COST CALCULATIONS
ASSOCIATED WITH THE USE OF A SINGLE 7 PWR ASSEMBLY
MESC SHIPPING CASK -- CASKS USED EITHER EXCLUSIVELY FOR
SHIPMENT OF MESC_s TO EXTENT AVAILABLE OR FULLY UTILIZED FOR
SHIPMENT OF INDIVIDUAL FUEL ASSEMBLIES AND MESC_s

APPENDIX C
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SHIPMENT OF INDIVIDUAL FUEL ASSEMBLIES AND MESC'S

The total life cycle costs associated with the use of a single 7 PWR assembly MESC shipping cask for shipment of varying quantities of spent nuclear fuel from reactors to DOE facilities were developed for instances where (i) the cask would be used to ship individual PWR assemblies to the extent there were insufficient MESC's available to fully utilize the cask capacity over its assumed 20-year lifetime, and (ii) the cask would be used to ship only MESC's and thus utilized only to the extent MESC's were available for shipment. The specific cases examined are listed below.

Case No.	Shipping Distance (Miles)	Cask Usage	Total Quantity Shipped (MTU)			
			Individual			
			PWR Assemblies	MESCs		
26	500	Mixed	1,045	58	} Full Utilization of Cask	
27			990	116		
28			880	232		

29	2,800	Mixed	468	52		
30			416	104		
31			312	208		

32	500	MESCs Only	-	58	} Utilization of Cask Only to Extent MESCs are Available for Shipment	
33			-	116		
34			-	232		

35	2,800	MESCs Only	-	52		
36			-	104		
37			-	208		

The life cycle costs and resulting unit costs for each of the foregoing cases are shown in Tables C-1 through C-12. The figures set forth in the tables were developed as follows:

- (1) For Cases 26 through 31 where full utilization of the cask over its lifetime was assumed to be achieved, the total costs were assumed to be incurred over the period 1997 to 2023, inclusive. During the period 1997 through 2002 the capital cost of the cask would be incurred; during the period 2003 through 2022 the cost of operations, freight and escorts would be incurred; and in 2023 the cost of decommissioning would be incurred.
- (2) For Cases 32 through 37 where the cask was used for shipment of MESCs only to the extent such were available, the total costs were assumed to be incurred commencing six years prior to the year in which shipments were initiated through 2023. During the first 6 years the capital cost of the cask would be incurred; during the years in which shipments were made the cost of operations, freight and escorts would be incurred; and in 2023 the cost of decommissioning would be incurred.
- (3) With regard to the capital cost of the cask, it was assumed that the cost of design and development would be incurred in the first year, the cost of model fabrication and testing would be incurred in the second year (where applicable), the NRC Certification Fee would be paid in the third year (where applicable), half of the cost of cask fabrication would be incurred in the fifth year, and the other half of the cost of fabrication plus the cost of acceptance testing and auxiliary equipment would be incurred in the sixth year. It was assumed that the third and fourth year would be required by NRC to make the necessary safety reviews, and that certification would be made at the end of the fourth year.
- (4) The capital cost of the casks for the various cases considered were developed as follows:
 - (a) For Cases 26-31 in which both shipments of individual fuel assemblies as well as MESCs were involved to achieve full utilization of the cask over its lifetime -- the single cask (with basket) capital cost set forth in Table 4-4 was used.
 - (b) For Cases 32-37 in which shipments of MESCs only were involved and full utilization of the cask was not achieved over its lifetime -- the single cask (without basket) capital cost set forth in Table 4-4 was used, less the allocation for the added costs of the reference cask. Since this cask did not replace a reference cask,

but rather constituted an added cask in the fleet, this allocation was not required.

- (5) The annual quantities shipped each year were assumed to be as follows:

<u>Form of Fuel Shipped</u>	<u>MTU in Single Shipment</u>	<u>Annual Quantity Shipped (MTU)^a</u>	
		<u>500 Miles</u>	<u>2800 Miles</u>
MESCs	3.23	55*	26
Assemblies	3.23	58	26

^a Based on 18 shipments/year for 500-mile shipments (17 shipments/year for those cases marked with an asterisk), and 8 shipments/year for 2800-mile shipments.

- (6) The annual cost of operation, freight, escorts and decommissioning were determined as described in Section 4.1.2.3.
- (7) The total costs were discounted by 3%/year to 1988 to get the total discounted costs.
- (8) The unit costs were determined by dividing the total discounted costs by the total discounted amount (MTU) of spent fuel shipped, as follows:

Discounted Costs = Discounted (Unit Costs x MTU Shipped)

Discounted Costs = Unit Costs x Discounted MTU Shipped

Unit Cost = $\frac{\text{Discounted Costs}}{\text{Discounted MTU Shipped}}$

A more detailed explanation of the methodology used for the unit cost calculation is set forth in Appendix F.

TABLE C-1
CASE 26 -- LIFE CYCLE COST OF TRANSPORT OF 1045 MTU AS PWR ASSEMBLIES AND 58 MTU AS PWR ASSEMBLIES IN MESCS
FROM REACTORS TO DOE FACILITIES 500 MILES AWAY IN A 7 PWR ASSEMBLY MESC SHIPPING CASK
(ONE MESC CASK IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'M COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997	911					911	698		
1998	70					70	52		
1999	6					6	4		
2000									
2001	1,634					1,634	1,113		
2002	3,145					3,145	2,079		
2003		210	538	92		840	539	55	35
2004		210	538	92		840	523	55	34
2005		210	538	92		840	508	55	33
2006		210	538	92		840	493	55	32
2007		210	538	92		840	479	55	31
2008		210	538	92		840	465	55	30
2009		210	538	92		840	452	55	30
2010		210	538	92		840	438	55	29
2011		210	538	92		840	426	55	28
2012		210	538	92		840	413	55	27
2013		210	538	92		840	401	55	26
2014		210	538	92		840	390	55	26
2015		210	538	92		840	378	55	25
2016		210	538	92		840	367	55	24
2017		210	538	92		840	356	55	23
2018		210	538	92		840	346	55	23
2019		210	538	92		840	336	55	22
2020		210	538	92		840	326	ASSEMBLIES ONLY	21
2021		210	538	92		840	317		21
2022		205	508	87		800	293	MESCS	21
2023					56	56	20		
TOTAL	5,766	4,195	10,730	1,835	56	22,582	12,214	1,103	542
DISC TOTAL	3,947	2,064	5,281	903	20	12,214			
UNIT COST (per kgU)	7.29	3.81	9.74	1.67	.04	22.55			
% OF TOTAL DISC COST	33%	17%	43%	7%	0%	100%			

TABLE C-2

CASE 27 -- LIFE CYCLE COST OF TRANSPORT OF 990 MTU AS PWR ASSEMBLIES AND 116 MTU AS PWR ASSEMBLIES IN MESCS
FROM REACTORS TO DOE FACILITIES 500 MILES AWAY IN A 7 PWR ASSEMBLY MESC SHIPPING CASK
(ONE MESC CASK IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997	911					911	698		
1998	70					70	52		
1999	6					6	4		
2000									
2001	1,634					1,634	1,113		
2002	3,145					3,145	2,079		
2003		210	538	92		840	539	55	35
2004		210	538	92		840	523	55	34
2005		210	538	92		840	508	55	33
2006		210	538	92		840	493	55	32
2007		210	538	92		840	479	55	31
2008		210	538	92		840	465	55	30
2009		210	538	92		840	452	55	30
2010		210	538	92		840	438	55	29
2011		210	538	92		840	426	55	28
2012		210	538	92		840	413	55	27
2013		210	538	92		840	401	55	26
2014		210	538	92		840	390	55	26
2015		210	538	92		840	378	55	25
2016		210	538	92		840	367	55	24
2017		210	538	92		840	356	55	23
2018		210	538	92		840	346	55	23
2019		210	538	92		840	336	ASSEMBLIES ONLY	22
2020		210	538	92		840	326	55	21
2021		205	508	87		800	302	MESCS	22
2022		205	508	87		800	293	58	21
2023					56	56	20		
TOTAL	5,766	4,190	10,700	1,830	56	22,542	12,199	1,106	543
DISC TOTAL	3,947	2,062	5,269	901	20	12,199			
UNIT COST (per kgU)	7.27	3.80	9.70	1.66	.04	22.47			
% OF TOTAL DISC COST	33%	17%	43%	7%	0%	100%			

TABLE C-3
CASE 28 -- LIFE CYCLE COST OF TRANSPORT OF 880 MTU AS PWR ASSEMBLIES AND 232 MTU AS PWR ASSEMBLIES IN MESCS
FROM REACTORS TO DOE FACILITIES 500 MILES AWAY IN A 7 PWR ASSEMBLY MESC SHIPPING CASK
(ONE MESC CASK IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997	911					911	698		
1998	70					70	52		
1999	6					6	4		
2000									
2001	1,634					1,634	1,113		
2002	3,145					3,145	2,079		
2003		210	538	92		840	539	55	35
2004		210	538	92		840	523	55	34
2005		210	538	92		840	508	55	33
2006		210	538	92		840	493	55	32
2007		210	538	92		840	479	55	31
2008		210	538	92		840	465	55	30
2009		210	538	92		840	452	55	30
2010		210	538	92		840	438	55	29
2011		210	538	92		840	426	55	28
2012		210	538	92		840	413	55	27
2013		210	538	92		840	401	55	26
2014		210	538	92		840	390	55	26
2015		210	538	92		840	378	55	25
2016		210	538	92		840	367	55	24
2017		210	538	92		840	356	55	23
2018		210	538	92		840	346	55	23
								ASSEMBLIES ONLY	
2019		205	508	87		800	320	MESCS	58
2020		205	508	87		800	311		23
2021		205	508	87		800	302		22
2022		205	508	87		800	293		21
2023						56	20		
TOTAL	5,766	4,180	10,640	1,820	56	22,462	12,167	1,112	546
DISC TOTAL	3,947	2,058	5,246	897	20	12,167			
UNIT COST (per kgU)	7.24	3.77	9.62	1.64	.04	22.31			
% OF TOTAL DISC COST	33%	17%	43%	7%	0%	100%			

TABLE C-4

CASE 29 -- LIFE CYCLE COST OF TRANSPORT OF 468 MTU AS PWR ASSEMBLIES AND 52 MTU AS PWR ASSEMBLIES IN MESCS
FROM REACTORS TO DOE FACILITIES 2800 MILES AWAY IN A 7 PWR ASSEMBLY MESC SHIPPING CASK
(ONE MESC CASK IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3Z/Yr.	ANNUAL QUAN QUAN. @ 3Z/Yr SHIPPED TO 1988	DISC
1997	911					911	698		
1998	70					70	52		
1999	6					6	4		
2000									
2001	1,634					1,634	1,113		
2002	3,145					3,145	2,079		
2003		163	649	111		923	592	26	17
2004		163	649	111		923	575	26	16
2005		163	649	111		923	558	26	16
2006		163	649	111		923	542	26	15
2007		163	649	111		923	526	26	15
2008		163	649	111		923	511	26	14
2009		163	649	111		923	496	26	14
2010		163	649	111		923	482	26	14
2011		163	649	111		923	468	26	13
2012		163	649	111		923	454	26	13
2013		163	649	111		923	441	26	12
2014		163	649	111		923	428	26	12
2015		163	649	111		923	416	26	12
2016		163	649	111		923	403	26	11
2017		163	649	111		923	392	26	11
2018		163	649	111		923	380	26	11
2019		163	649	111		923	369	26	10
2020		163	649	111		923	358	26	10
								ASSEMBLIES ONLY	
2021		163	649	111		923	348	MESCS	26
2022		163	649	111		923	338		10
2023					56	56	20		
TOTAL	5,766	3,260	12,980	2,220	56	24,282	13,045	520	256
DISC TOTAL	3,947	1,603	6,383	1,092	20	13,045			
UNIT COST (per kgU)	15.43	6.27	24.96	4.27	.08	51.01			
% OF TOTAL DISC COST	31%	12%	49%	8%	0%	100%			

TABLE C-5
CASE 30 -- LIFE CYCLE COST OF TRANSPORT OF 416 MTU AS PWR ASSEMBLIES AND 104 MTU AS PWR ASSEMBLIES IN NESCS
FROM REACTORS TO DOE FACILITIES 2800 MILES AWAY IN A 7 PWR ASSEMBLY MESC SHIPPING CASE
(ONE MESC CASE IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'M COST	FREIGHT CHARGES	ESCORT CHARGES	DECONM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997	911					911	698		
1998	70					70	52		
1999	6					6	4		
2000									
2001	1,634					1,634	1,113		
2002	3,145					3,145	2,079		
2003		163	649	111		923	592	26	17
2004		163	649	111		923	575	26	16
2005		163	649	111		923	558	26	16
2006		163	649	111		923	542	26	15
2007		163	649	111		923	526	26	15
2008		163	649	111		923	511	26	14
2009		163	649	111		923	496	26	14
2010		163	649	111		923	482	26	14
2011		163	649	111		923	468	26	13
2012		163	649	111		923	454	26	13
2013		163	649	111		923	441	26	12
2014		163	649	111		923	428	26	12
2015		163	649	111		923	416	26	12
2016		163	649	111		923	403	26	11
2017		163	649	111		923	392	26	11
2018		163	649	111		923	380	26	11
								ASSEMBLIES ONLY	
2019		163	649	111		923	369	26	10
2020		163	649	111		923	358	26	10
2021		163	649	111		923	348	26	10
2022		163	649	111		923	338	26	10
2023					56	56	20		
								NESCS	
2019		163	649	111		923	369	26	10
2020		163	649	111		923	358	26	10
2021		163	649	111		923	348	26	10
2022		163	649	111		923	338	26	10
2023					56	56	20		
TOTAL	5,766	3,260	12,980	2,220	56	24,282	13,045	520	256
DISC TOTAL	3,947	1,603	6,383	1,092	20	13,045			
UNIT COST (per kgU)	15.43	6.27	24.96	4.27	.08	51.01			
% OF TOTAL DISC COST	31%	12%	49%	8%	0%	100%			

TABLE C-6
CASE 31 -- LIFE CYCLE COST OF TRANSPORT OF 312 MTU AS PWR ASSEMBLIES AND 208 MTU AS PWR ASSEMBLIES IN NESCS
FROM REACTORS TO DOE FACILITIES 2800 MILES AWAY IN A 7 PWR ASSEMBLY NESC SHIPPING CASK
(ONE NESC CASK IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'G COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997	911					911	698		
1998	70					70	52		
1999	6					6	4		
2000									
2001	1,634					1,634	1,113		
2002	3,145					3,145	2,079		
2003		163	649	111		923	592	26	17
2004		163	649	111		923	575	26	16
2005		163	649	111		923	558	26	16
2006		163	649	111		923	542	26	15
2007		163	649	111		923	526	26	15
2008		163	649	111		923	511	26	14
2009		163	649	111		923	496	26	14
2010		163	649	111		923	482	26	14
2011		163	649	111		923	468	26	13
2012		163	649	111		923	454	26	13
2013		163	649	111		923	441	26	12
2014		163	649	111		923	428	26	12
								ASSEMBLIES ONLY	
2015		163	649	111		923	416	26	12
2016		163	649	111		923	403	26	11
2017		163	649	111		923	392	26	11
2018		163	649	111		923	380	26	11
2019		163	649	111		923	369	26	10
2020		163	649	111		923	358	26	10
2021		163	649	111		923	348	26	10
2022		163	649	111		923	338	26	10
2023					56	56	20		
TOTAL	5,766	3,260	12,980	2,220	56	24,282	13,045	520	256
DISC TOTAL	3,947	1,603	6,383	1,092	20	13,045			
UNIT COST (per kgU)	15.43	6.27	24.96	4.27	.08	51.01			
% OF TOTAL DISC COST	31%	12%	49%	8%	0%	100%			

TABLE C-7
CASE 32 -- LIFE CYCLE COST OF TRANSPORT OF 58 MTU AS PWR ASSEMBLIES IN MESCS FROM REACTORS TO DOE
FACILITIES 500 MILES AWAY IN A DEDICATED 7 PWR ASSEMBLY MESC SHIPPING CASE
(ONE MESC CASK IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									
2009									
2010									
2011									
2012									
2013									
2014									
2015									
2016	547					547	239		
2017									
2018									
2019									
2020	1,343					1,343	522		
2021	2,678					2,678	1,010		
2022		205	508	87		800	293	58	21
2023					55	55	20		
TOTAL	4,568	205	508	87	55	5,423	2,083	58	21
DISC TOTAL	1,770	75	186	32	20	2,083			
UNIT COST (per kgU)	83.38	3.53	8.76	1.50	.92	98.09			
% OF TOTAL DISC COST	84%	4%	9%	2%	1%	100%			

TABLE C-8

CASE 33 -- LIFE CYCLE COST OF TRANSPORT OF 116 MTU AS PWR ASSEMBLIES IN MESCS FROM REACTORS TO DOE FACILITIES 500 MILES AWAY IN A DEDICATED 7 PWR ASSEMBLY MESC SHIPPING CASK (ONE MESC CASK IN DOE FLEET)

YEAR	COSTS (\$000, 1988)						QUANTITIES (MTU)		
	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN SHIPPED	DISC TO 1988 @ 3%/Yr.
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									
2009									
2010									
2011									
2012									
2013									
2014									
2015	547					547	246		
2016									
2017									
2018									
2019	1,343					1,343	537		
2020	2,678					2,678	1,040		
2021		205	508	87		800	302	58	22
2022		205	508	87		800	293	58	21
2023					55	55	20		
TOTAL	4,568	410	1,016	174	55	6,223	2,437	116	43
DISC TOTAL	1,823	152	377	65	20	2,437			
UNIT COST (per kgU)	42.31	3.53	8.76	1.50	.45	56.55			
% OF TOTAL DISC COST	75%	6%	15%	3%	1%	100%			

TABLE C-9
CASE 34 -- LIFE CYCLE COST OF TRANSPORT OF 232 MTU AS PWR ASSEMBLIES IN MESCS FROM REACTORS TO DOE
FACILITIES 500 MILES AWAY IN A DEDICATED 7 PWR ASSEMBLY MESC SHIPPING CASE
(ONE MESC CASK IN DOE FLEET)

YEAR	COSTS (\$000, 1988)							QUANTITIES (MTU)	
	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECONM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									
2009									
2010									
2011									
2012									
2013	547					547	261		
2014									
2015									
2016									
2017	1,343					1,343	570		
2018	2,678					2,678	1,103		
2019		205	508	87		800	320	58	23
2020		205	508	87		800	311	58	23
2021		205	508	87		800	302	58	22
2022		205	508	87		800	293	58	21
2023					55	55	20		
TOTAL	4,568	820	2,032	348	55	7,823	3,179	232	89
DISC TOTAL	1,934	314	778	133	20	3,179			
UNIT COST (per kgU)	21.78	3.53	8.76	1.50	.22	35.79			
% OF TOTAL DISC COST	61%	10%	24%	4%	1%	100%			

TABLE C-10
CASE 35 -- LIFE CYCLE COST OF TRANSPORT OF 52 MTU AS PWR ASSEMBLIES IN MESCS FROM REACTORS TO DOE
FACILITIES 2800 MILES AWAY IN A DEDICATED 7 PWR ASSEMBLY MESC SHIPPING CASK
(ONE MESC CASK IN DOE FLEET)

YEAR	COSTS (\$000, 1988)							QUANTITIES (MTU)	
	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN SHIPPED	DISC TO 1988 @ 3%/Yr.
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									
2009									
2010									
2011									
2012									
2013									
2014									
2015	547					547	246		
2016									
2017									
2018									
2019	1,343					1,343	537		
2020	2,678					2,678	1,040		
2021		163	649	111		923	348	26	10
2022		163	649	111		923	338	26	10
2023					55	55	20		
TOTAL	4,568	326	1,298	222	55	6,469	2,529	52	19
DISC TOTAL	1,823	121	482	82	20	2,529			
UNIT COST (per kgU)	94.38	6.27	24.96	4.27	1.01	130.89			
% OF TOTAL DISC COST	72%	5%	19%	3%	1%	100%			

TABLE C-11
CASE 36 -- LIFE CYCLE COST OF TRANSPORT OF 104 MTU AS PWR ASSEMBLIES IN MESCS FROM REACTORS TO DOE
FACILITIES 2800 MILES AWAY IN A DEDICATED 7 PWR ASSEMBLY MESC SHIPPING CASK
(ONE MESC CASK IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'M COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									
2009									
2010									
2011									
2012									
2013	547					547	261		
2014									
2015									
2016									
2017	1,343					1,343	570		
2018	2,678					2,678	1,103		
2019		163	649	111		923	369	26	10
2020		163	649	111		923	358	26	10
2021		163	649	111		923	348	26	10
2022		163	649	111		923	338	26	10
2023						55	20		
TOTAL	4,568	652	2,596	444	55	8,315	3,367	104	40
DISC TOTAL	1,934	250	994	170	20	3,367			
UNIT COST (per kgU)	48.58	6.27	24.96	4.27	.49	84.57			
% OF TOTAL DISC COST	57%	7%	30%	5%	1%	100%			

TABLE C-12

CASE 37 -- LIFE CYCLE COST OF TRANSPORT OF 208 MTU AS PWR ASSEMBLIES IN NESCO FROM REACTORS TO DOE
FACILITIES 2800 MILES AWAY IN A DEDICATED 7 PWR ASSEMBLY NESC SHIPPING CASK
(ONE NESC CASK IN DOE FLEET)

YEAR	COSTS (\$000, 1988)							QUANTITIES (MTU)	
	CAPITAL COST	ANNUAL OPER'G COST	FREIGHT CHARGES	ESCORT CHARGES	DECONN COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									
2009	547					547	294		
2010									
2011									
2012									
2013	1,343					1,343	641		
2014	2,678					2,678	1,242		
2015		163	649	111		923	416	26	12
2016		163	649	111		923	403	26	11
2017		163	649	111		923	392	26	11
2018		163	649	111		923	380	26	11
2019		163	649	111		923	369	26	10
2020		163	649	111		923	358	26	10
2021		163	649	111		923	348	26	10
2022		163	649	111		923	338	26	10
2023					55	55	20		
TOTAL	4,568	1,304	5,192	888	55	12,007	5,201	208	85
DISC TOTAL	2,177	531	2,112	361	20	5,201			
UNIT COST (per kgU)	25.73	6.27	24.96	4.27	.23	61.46			
% OF TOTAL DISC COST	42%	10%	41%	7%	0%	100%			

APPENDIX D

LIFE CYCLE TRANSPORT COSTS AND UNIT COST CALCULATIONS
ASSOCIATED WITH THE USE OF A SINGLE 2/7 PWR ASSEMBLY
MESC SHIPPING CASK -- CASKS USED EITHER EXCLUSIVELY FOR
SHIPMENT OF MESC_s TO EXTENT AVAILABLE OR FULLY UTILIZED FOR
SHIPMENT OF INDIVIDUAL FUEL ASSEMBLIES AND MESC_s

APPENDIX D
LIFE CYCLE TRANSPORT COSTS AND UNIT COST CALCULATIONS
ASSOCIATED WITH THE USE OF A SINGLE 2/7 PWR ASSEMBLY
MESC SHIPPING CASK -- CASKS USED EITHER EXCLUSIVELY FOR
SHIPMENT OF MESCs TO EXTENT AVAILABLE OR FULLY UTILIZED FOR
SHIPMENT OF INDIVIDUAL FUEL ASSEMBLIES AND MESCs

The total life cycle costs associated with the use of a single 2/7 PWR assembly MESC shipping cask for shipment of varying quantities of spent nuclear fuel from reactors to DOE facilities were developed for instances where (i) the cask would be used to ship individual PWR assemblies to the extent there were insufficient MESCs available to fully utilize the cask capacity over its assumed 20-year lifetime, and (ii) the cask would be used to ship only MESCs and thus utilized only to the extent MESCs were available for shipment. The specific cases examined are listed below.

Case No.	Shipping Distance (Miles)	Cask Usage	Total Quantity Shipped (MTU)		
			Individual PWR Assemblies	MESCs	
38	500	Mixed	4,212	55	} Full Utilization of Cask
39			4,104	110	
40			3,888	220	
41	2,800	Mixed	1,824	52	
42			1,728	104	
43			1,536	208	
44	500	MESCs Only	-	55	} Utilization of Cask Only to Extent MESCs are Available for Shipment
45			-	110	
46			-	220	
47	2,800	MESCs Only	-	52	
48			-	104	
49			-	208	

The life cycle costs and resulting unit costs for each of the foregoing cases are shown in Tables D-1 through D-12. The figures set forth in the tables were developed as follows:

- (1) For Cases 38 through 43 where full utilization of the cask over its lifetime was assumed to be achieved, the total costs were assumed to be incurred over the period 1997 to 2023, inclusive. During the period 1997 through 2002 the capital cost of the cask would be incurred; during the period 2003 through 2022 the cost of operations, freight and escorts would be incurred; and in 2023 the cost of decommissioning would be incurred.
- (2) For Cases 44 through 49 where the cask was used for shipment of MESCs only to the extent such were available, the total costs were assumed to be incurred commencing six years prior to the year in which shipments were initiated through 2023. During the first 6 years the capital cost of the cask would be incurred; during the years in which shipments were made the cost of operations, freight and escorts would be incurred; and in 2023 the cost of decommissioning would be incurred.
- (3) With regard to the capital cost of the cask, it was assumed that the cost of design and development would be incurred in the first year, the cost of model fabrication and testing would be incurred in the second year (where applicable), the NRC Certification Fee would be paid in the third year (where applicable), half of the cost of cask fabrication would be incurred in the fifth year, and the other half of the cost of fabrication plus the cost of acceptance testing and auxiliary equipment would be incurred in the sixth year. It was assumed that the third and fourth year would be required by NRC to make the necessary safety reviews, and that certification would be made at the end of the fourth year.
- (4) The capital cost of the casks for the various cases considered were developed as follows:
 - (a) For Cases 38-43 in which both shipments of individual fuel assemblies as well as MESCs were involved to achieve full utilization of the cask over its lifetime -- the single cask (with basket) capital cost set forth in Table 4-4 was used.
 - (b) For Cases 44-49 in which shipments of MESCs only were involved and full utilization of the cask was not achieved over its lifetime -- the single cask (without basket) capital cost set forth in Table 4-4 was used, less the allocation for the added costs of the reference cask. Since this cask did not replace a reference cask, but rather constituted an added cask in the fleet, this allocation was not required.

- (5) The annual quantities shipped each year were assumed to be as follows:

<u>Form of Fuel Shipped</u>	<u>MTU in Single Shipment</u>	<u>Annual Quantity Shipped (MTU)^a</u>	
		<u>500 Miles</u>	<u>2800 Miles</u>
MESCs	6.45	110*	52
Assemblies	11.99	216	96

^a Based on 18 shipments/year for 500-mile shipments (17 shipments/year for those cases marked with an asterisk), and 8 shipments/year for 2800-mile shipments.

- (6) The annual cost of operation, freight, escorts and decommissioning were determined as described in Section 4.1.2.3.
- (7) The total costs were discounted by 3%/year to 1988 to get the total discounted costs.
- (8) The unit costs were determined by dividing the total discounted costs by the total discounted amount (MTU) of spent fuel shipped, as follows:

Discounted Costs = Discounted (Unit Costs x MTU Shipped)

Discounted Costs = Unit Costs x Discounted MTU Shipped

Unit Cost = $\frac{\text{Discounted Costs}}{\text{Discounted MTU Shipped}}$

A more detailed explanation of the methodology used for the unit cost calculation is set forth in Appendix F.

TABLE D-1
CASE 3B -- LIFE CYCLE COST OF TRANSPORT OF 4212 MTU AS PWR ASSEMBLIES AND 55 MTU AS PWR ASSEMBLIES IN MESCS
FROM REACTORS TO DOE FACILITIES 500 MILES AWAY IN A 2/7 PWR ASSEMBLY MESC SHIPPING CASE
(ONE MESC CASK IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'M COST	FREIGHT CHARGES	ESCORT CHARGES	DECONN COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997	1,499					1,499	1,149		
1998	259					259	193		
1999	21					21	15		
2000									
2001	3,022					3,022	2,058		
2002	4,845					4,845	3,203		
2003		210	607	92		909	583	216	139
2004		210	607	92		909	566	216	135
2005		210	607	92		909	550	216	131
2006		210	607	92		909	534	216	127
2007		210	607	92		909	518	216	123
2008		210	607	92		909	503	216	120
2009		210	607	92		909	489	216	116
2010		210	607	92		909	474	216	113
2011		210	607	92		909	461	216	109
2012		210	607	92		909	447	216	106
2013		210	607	92		909	434	216	103
2014		210	607	92		909	421	216	100
2015		210	607	92		909	409	216	97
2016		210	607	92		909	397	216	94
2017		210	607	92		909	386	216	92
2018		210	607	92		909	374	216	89
2019		210	607	92		909	364	216	86
2020		210	607	92		909	353	216	84
2021		210	607	92		909	343	216	81
2022		208	583	90		881	322	163	60
2023					109	109	39		
TOTAL	9,646	4,198	12,116	1,838	109	27,907	15,587	4,267	2,105
DISC TOTAL	6,618	2,065	5,962	904	39	15,587			
UNIT COST (per kgU)	3.14	.98	2.83	.43	.02	7.40			
% OF TOTAL DISC COST	43%	13%	38%	6%	0%	100%			

TABLE D-2

CASE 39 -- LIFE CYCLE COST OF TRANSPORT OF 4104 MTU AS PWR ASSEMBLIES AND 110 MTU AS PWR ASSEMBLIES IN MESCS
FROM REACTORS TO DOE FACILITIES 500 MILES AWAY IN A 2/7 PWR ASSEMBLY MESC SHIPPING CASK
(ONE MESC CASK IN DOE FLEET)

YEAR	COSTS (\$000, 1988)							QUANTITIES (MTU)	
	CAPITAL COST	ANNUAL OPER'M COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN SHIPPED	DISC TO 1988 @ 3%/Yr
1997	1,499					1,499	1,149		
1998	259					259	193		
1999	21					21	15		
2000									
2001	3,022					3,022	2,058		
2002	4,845					4,845	3,203		
2003		210	607	92		909	583	216	139
2004		210	607	92		909	566	216	135
2005		210	607	92		909	550	216	131
2006		210	607	92		909	534	216	127
2007		210	607	92		909	518	216	123
2008		210	607	92		909	503	216	120
2009		210	607	92		909	489	216	116
2010		210	607	92		909	474	216	113
2011		210	607	92		909	461	216	109
2012		210	607	92		909	447	216	106
2013		210	607	92		909	434	216	103
2014		210	607	92		909	421	216	100
2015		210	607	92		909	409	216	97
2016		210	607	92		909	397	216	94
2017		210	607	92		909	386	216	92
2018		210	607	92		909	374	216	89
2019		210	607	92		909	364	216	86
2020		210	607	92		909	353	216	84
2021		210	607	92		909	343	216	81
2022		205	559	87		851	312	110	40
2023					109	109	39		
TOTAL	9,646	4,195	12,092	1,835	109	27,877	15,576	4,214	2,086
DISC TOTAL	6,618	2,064	5,953	903	39	15,576			
UNIT COST (per kgU)	3.18	.99	2.85	.43	.02	7.47			
% OF TOTAL DISC COST	43%	13%	38%	6%	0%	100%			

TABLE D-3
CASE 40 -- LIFE CYCLE COST OF TRANSPORT OF 3888 MTU AS PWR ASSEMBLIES AND 220 MTU AS PWR ASSEMBLIES IN MESCS
FROM REACTORS TO DOE FACILITIES 500 MILES AWAY IN A 2/7 PWR ASSEMBLY MESC SHIPPING CASK
(ONE MESC CASK IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997	1,499					1,499	1,149		
1998	259					259	193		
1999	21					21	15		
2000									
2001	3,022					3,022	2,058		
2002	4,845					4,845	3,203		
2003		210	607	92		909	583	216	139
2004		210	607	92		909	566	216	135
2005		210	607	92		909	550	216	131
2006		210	607	92		909	534	216	127
2007		210	607	92		909	518	216	123
2008		210	607	92		909	503	216	120
2009		210	607	92		909	489	216	116
2010		210	607	92		909	474	216	113
2011		210	607	92		909	461	216	109
2012		210	607	92		909	447	216	106
2013		210	607	92		909	434	216	103
2014		210	607	92		909	421	216	100
2015		210	607	92		909	409	216	97
2016		210	607	92		909	397	216	94
2017		210	607	92		909	386	216	92
2018		210	607	92		909	374	216	89
2019		210	607	92		909	364	216	86
2020		210	607	92		909	353	216	84
2021		205	559	87		851	321	110	41
2022		205	559	87		851	312	110	40
2023					109	109	39		
TOTAL	9,646	4,190	12,044	1,830	109	27,819	15,554	4,108	2,046
DISC TOTAL	6,618	2,062	5,935	901	39	15,554			
UNIT COST (per kgU)	3.23	1.01	2.90	.44	.02	7.60			
% OF TOTAL DISC COST	43%	13%	38%	6%	0%	100%			

TABLE D-4
CASE 41 -- LIFE CYCLE COST OF TRANSPORT OF 1824 MTU AS PWR ASSEMBLIES AND 52 MTU AS PWR ASSEMBLIES IN MESCS
FROM REACTORS TO DOE FACILITIES 2500 MILES AWAY IN A 2/7 PWR ASSEMBLY MESC SHIPPING CASK
(ONE MESC CASK IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997	1,499					1,499	1,149		
1998	259					259	193		
1999	21					21	15		
2000									
2001	3,022					3,022	2,058		
2002	4,845					4,845	3,203		
2003		163	733	111		1,007	646	96	62
2004		163	733	111		1,007	628	96	60
2005		163	733	111		1,007	609	96	58
2006		163	733	111		1,007	592	96	56
2007		163	733	111		1,007	574	96	55
2008		163	733	111		1,007	556	96	53
2009		163	733	111		1,007	541	96	52
2010		163	733	111		1,007	526	96	50
2011		163	733	111		1,007	510	96	49
2012		163	733	111		1,007	495	96	47
2013		163	733	111		1,007	481	96	46
2014		163	733	111		1,007	467	96	45
2015		163	733	111		1,007	453	96	43
2016		163	733	111		1,007	440	96	42
2017		163	733	111		1,007	427	96	41
2018		163	733	111		1,007	415	96	40
2019		163	733	111		1,007	403	96	38
2020		163	733	111		1,007	391	96	37
2021		163	733	111		1,007	380	96	36
2022		163	715	111		989	362	52	19
2023					109	109	39		
TOTAL	9,646	3,260	14,642	2,220	109	29,877	16,554	1,876	928
DISC TOTAL	6,618	1,603	7,203	1,092	39	16,554			
UNIT COST (per kgU)	7.13	1.73	7.76	1.18	.04	17.84			
% OF TOTAL DISC COST	40%	10%	43%	7%	0%	100%			

TABLE D-5
CASE 42 -- LIFE CYCLE COST OF TRANSPORT OF 1728 MTU AS PWR ASSEMBLIES AND 104 MTU AS PWR ASSEMBLIES IN MESCS
FROM REACTORS TO DOE FACILITIES 2800 MILES AWAY IN A 2/7 PWR ASSEMBLY MESC SHIPPING CASK
(ONE MESC CASK IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997	1,499					1,499	1,149		
1998	259					259	193		
1999	21					21	15		
2000									
2001	3,022					3,022	2,058		
2002	4,845					4,845	3,203		
2003		163	733	111		1,007	646	96	62
2004		163	733	111		1,007	628	96	60
2005		163	733	111		1,007	609	96	58
2006		163	733	111		1,007	592	96	56
2007		163	733	111		1,007	574	96	55
2008		163	733	111		1,007	558	96	53
2009		163	733	111		1,007	541	96	52
2010		163	733	111		1,007	526	96	50
2011		163	733	111		1,007	510	96	49
2012		163	733	111		1,007	495	96	47
2013		163	733	111		1,007	481	96	46
2014		163	733	111		1,007	467	96	45
2015		163	733	111		1,007	453	96	43
2016		163	733	111		1,007	440	96	42
2017		163	733	111		1,007	427	96	41
2018		163	733	111		1,007	415	96	40
2019		163	733	111		1,007	403	96	38
2020		163	733	111		1,007	391	96	37
2021		163	715	111		989	373	52	20
2022		163	715	111		989	362	52	19
2023					109	109	39		
TOTAL	9,646	3,260	14,624	2,220	109	29,859	16,548	1,832	912
DISC TOTAL	6,618	1,603	7,196	1,092	39	16,548			
UNIT COST (per kgU)	7.26	1.76	7.89	1.20	.04	18.15			
% OF TOTAL DISC COST	40%	10%	43%	7%	0%	100%			

TABLE D-6
CASE 43 -- LIFE CYCLE COST OF TRANSPORT OF 1536 MTU AS PWR ASSEMBLIES AND 208 MTU AS PWR ASSEMBLIES IN MESCS
FROM REACTORS TO DOE FACILITIES 2800 MILES AWAY IN A 2/7 PWR ASSEMBLY MESC SHIPPING CASK
(ONE MESC CASK IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997	1,499					1,499	1,149		
1998	259					259	193		
1999	21					21	15		
2000									
2001	3,022					3,022	2,058		
2002	4,845					4,845	3,203		
2003		163	733	111		1,007	646	96	62
2004		163	733	111		1,007	628	96	60
2005		163	733	111		1,007	609	96	58
2006		163	733	111		1,007	592	96	56
2007		163	733	111		1,007	574	96	55
2008		163	733	111		1,007	558	96	53
2009		163	733	111		1,007	541	96	52
2010		163	733	111		1,007	526	96	50
2011		163	733	111		1,007	510	96	49
2012		163	733	111		1,007	495	96	47
2013		163	733	111		1,007	481	96	46
2014		163	733	111		1,007	467	96	45
2015		163	733	111		1,007	453	96	43
2016		163	733	111		1,007	440	96	42
2017		163	733	111		1,007	427	96	41
2018		163	733	111		1,007	415	96	40
2019		163	715	111		989	396	52	21
2020		163	715	111		989	384	52	20
2021		163	715	111		989	373	52	20
2022		163	715	111		989	362	52	19
2023					109	109	39		
TOTAL	9,646	3,260	14,588	2,220	109	29,823	16,533	1,744	877
DISC TOTAL	6,618	1,603	7,182	1,092	39	16,533			
UNIT COST (per kgU)	7.55	1.83	8.19	1.25	.04	18.86			
% OF TOTAL DISC COST	40%	10%	43%	7%	0%	100%			

TABLE D-7

CASE 44 -- LIFE CYCLE COST OF TRANSPORT OF 55 MTU AS PWR ASSEMBLIES IN MESCS FROM REACTORS TO DOE FACILITIES 500 MILES AWAY IN A DEDICATED 2/7 PWR ASSEMBLY MESC SHIPPING CASE (ONE MESC CASE IN DOE FLEET)

YEAR	COSTS (\$000, 1988)						QUANTITIES (MTU)		
	CAPITAL COST	ANNUAL OPER'M COST	FREIGHT CHARGES	ESCORT CHARGES	DECONM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN SHIPPED	DISC @ 3%/Yr TO 1988
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									
2009									
2010									
2011									
2012									
2013									
2014									
2015									
2016	781					781	341		
2017									
2018									
2019									
2020	2,191					2,191	851		
2021	3,739					3,739	1,410		
2022		103	280	44		427	156	55	20
2023					92	92	33		
TOTAL	6,711	103	280	44	92	7,230	2,791	55	20
DISC TOTAL	2,602	38	102	16	33	2,791			
UNIT COST (per kgU)	129.24	1.87	5.09	.80	1.62	138.62			
% OF TOTAL DISC COST	93%	1%	4%	1%	1%	100%			

TABLE D-8

CASE 45 -- LIFE CYCLE COST OF TRANSPORT OF 110 MTU AS PWR ASSEMBLIES IN NESCO FROM REACTORS TO DOE FACILITIES 500 MILES AWAY IN A DEDICATED 2/7 PWR ASSEMBLY NESC SHIPPING CASK (ONE NESC CASK IN DOE FLEET)

YEAR	COSTS (\$000, 1988)							QUANTITIES (MTU)	
	CAPITAL COST	ANNUAL OPER'M COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN. SHIPPED	DISC @ 3%/Yr TO 1988
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									
2009									
2010									
2011									
2012									
2013									
2014									
2015									
2016	781					781	341		
2017									
2018									
2019									
2020	2,191					2,191	851		
2021	3,739					3,739	1,410		
2022		205	559	87		851	312	110	40
2023					92	92	33		
TOTAL	4,711	205	559	87	92	7,654	2,946	110	40
DISC TOTAL	2,602	75	205	32	33	2,946			
UNIT COST (per kgU)	64.62	1.86	5.08	.79	.81	73.16			
% OF TOTAL DISC COST	88%	3%	7%	1%	1%	100%			

TABLE D-9
CASE 46 -- LIFE CYCLE COST OF TRANSPORT OF 220 MTU AS PWR ASSEMBLIES IN MESCS FROM REACTORS TO DOE
FACILITIES 500 MILES AWAY IN A DEDICATED 2/7 PWR ASSEMBLY MESC SHIPPING CASE
(ONE MESC CASE IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECONH COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC QUAN
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									
2009									
2010									
2011									
2012									
2013									
2014									
2015	781					781	352		
2016									
2017									
2018									
2019	2,191					2,191	876		
2020	3,739					3,739	1,452		
2021		205	559	87		851	321	110	41
2022		205	559	87		851	312	110	40
2023					92	92	33		
TOTAL	6,711	410	1,118	174	92	8,505	3,345	220	82
DISC TOTAL	2,680	152	415	65	33	3,345			
UNIT COST (per kgU)	32.79	1.86	5.08	.79	.40	40.92			
% OF TOTAL DISC COST	80%	5%	12%	2%	1%	100%			

TABLE D-10
CASE 47 -- LIFE CYCLE COST OF TRANSPORT OF 52 MTU AS PWR ASSEMBLIES IN MESCS FROM REACTORS TO DOE
FACILITIES 2800 MILES AWAY IN A DEDICATED 2/7 PWR ASSEMBLY MESC SHIPPING CASK
(ONE MESC CASK IN DOE FLEET)

YEAR	COSTS (\$000, 1988)						QUANTITIES (MTU)		
	CAPITAL COST	ANNUAL OPER'M COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC, TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC TO 1988
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									
2009									
2010									
2011									
2012									
2013									
2014									
2015									
2016	781					781	341		
2017									
2018									
2019									
2020	2,191					2,191	851		
2021	3,739					3,739	1,410		
2022		163	715	111		989	362	52	19
2023					92	92	33		
TOTAL	6,711	163	715	111	92	7,792	2,997	52	19
DISC TOTAL	2,602	60	262	41	33	2,997			
UNIT COST (per kgU)	136.70	3.13	13.75	2.13	1.72	157.43			
% OF TOTAL DISC COST	87%	2%	9%	1%	1%	100%			

TABLE D-11
CASE 4B -- LIFE CYCLE COST OF TRANSPORT OF 104 MTU AS PWR ASSEMBLIES IN MESCS FROM REACTORS TO DOE
FACILITIES 2800 MILES AWAY IN A DEDICATED 2/7 PWR ASSEMBLY MESC SHIPPING CASK
(ONE MESC CASK IN DOE FLEET)

COSTS (\$000, 1988)								QUANTITIES (MTU)	
YEAR	CAPITAL COST	ANNUAL OPER'M COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	DISC. TO 1988 @ 3%/Yr.	ANNUAL QUAN QUAN. @ 3%/Yr SHIPPED TO 1988	DISC
1997									
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									
2009									
2010									
2011									
2012									
2013									
2014									
2015	781					781	352		
2016									
2017									
2018									
2019	2,191					2,191	876		
2020	3,739					3,739	1,452		
2021		163	715	111		989	373	52	20
2022		163	715	111		989	362	52	19
2023					92	92	33		
TOTAL	6,711	326	1,430	222	92	8,781	3,448	104	39
DISC TOTAL	2,680	121	531	82	33	3,448			
UNIT COST (per kgU)	69.36	3.13	13.75	2.13	.85	89.22			
% OF TOTAL DISC COST	78%	4%	15%	2%	1%	100%			

TABLE D-12

CASE 49 -- LIFE CYCLE COST OF TRANSPORT OF 208 MTU AS PWR ASSEMBLIES IN NESCO FROM REACTORS TO DOE FACILITIES 2800 MILES AWAY IN A DEDICATED 2/7 PWR ASSEMBLY NESC SHIPPING CASK (ONE NESC CASK IN DOE FLEET)

YEAR	COSTS (\$000, 1988)						QUANTITIES (MTU)	
	CAPITAL COST	ANNUAL OPER'N COST	FREIGHT CHARGES	ESCORT CHARGES	DECOMM COSTS	TOTAL COSTS	ANNUAL QUAN @ 3%/Yr SHIPPED TO 1988	DISC TO 1988 @ 3%/Yr.
1997								
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006								
2007								
2008								
2009								
2010								
2011								
2012								
2013	781					781		373
2014								
2015								
2016								
2017	2,191					2,191		930
2018	3,739					3,739		1,540
2019		163	715	111		989	52	21
2020		163	715	111		989	52	20
2021		163	715	111		989	52	20
2022		163	715	111		989	52	19
2023					92	92		33
TOTAL	6,711	652	2,860	444	92	10,759	208	80
DISC TOTAL	2,843	250	1,095	170	33	4,390		
UNIT COST (per kgU)	35.70	3.13	13.75	2.13	.41	55.12		
% OF TOTAL DISC COST	64%	6%	25%	4%	1%	100%		

APPENDIX E

INCREMENTAL LIFE CYCLE COSTS AND UNIT COST CALCULATIONS
ASSOCIATED WITH THE PROCESSING OF MESCS IN FWMS FACILITIES

APPENDIX E
INCREMENTAL LIFE CYCLE COSTS AND UNIT COST CALCULATIONS
ASSOCIATED WITH THE PROCESSING OF MESCs IN FWMS FACILITIES

The total incremental life cycle costs associated with the processing of MESCs in FWMS facilities were developed for the following cases.

Table No.	Type of MESC Received	MRS Status	Total Quantity SNF Received in MESCs (MTU)	MESC Opening Operation	
				Location	Time
E-1	24 PWR Assy	With MRS	564	Outside of Hot Cell	Upon Receipt
E-2			940		
E-3			1,504		
E-4			1,880		
E-5	24 PWR Assy	No MRS	534	Outside of Hot Cell	Upon Receipt
E-6			890		
E-7			1,424		
E-8			1,780		
E-9	7 PWR Assy	With MRS	58	Outside of Hot Cell	Upon Receipt
E-10			116		
E-11			232		
E-12	7 PWR Assy	No MRS	52	Outside of Hot Cell	Upon Receipt
E-13			104		
E-14			208		
E-15	24 PWR Assy	With MRS (Vertical Concrete Cask)*	564	In Hot Cell	After Storage
E-16			940		
E-17			1,504		
E-18			1,880		
E-19	24 PWR Assy	No MRS	534	In Hot Cell	After Storage
E-20			890		
E-21			1,424		
E-22			1,780		
E-23	7 PWR Assy	With MRS (Vertical Concrete Cask)*	58	In Hot Cell	After Storage
E-24			116		
E-25			232		
E-26	7 PWR Assy	No MRS	52	In Hot Cell	After Storage
E-27			104		
E-28			208		
E-29	24 PWR Assy	With MRS (HSM)*	564	In Hot Cell	After Storage
E-30			940		
E-31			1,504		
E-32			1,880		
E-33	7 PWR Assy	With MRS (HSM)*	58	In Hot Cell	After Storage
E-34			116		
E-35			232		
E-36	24 PWR Assy	With MRS (HSM)*	563	Outside of Hot Cell	After Storage
E-37			940		
E-38			1,504		
E-39			1,880		
E-40	7 PWR Assy	With MRS (HSM)*	58	Outside of Hot Cell	After Storage
E-41			116		
E-42			232		

*MESCs are stored in vertical concrete casks or horizontal storage modules (HSM).

The quantities used in the cases described above were the same as those used in developing the life cycle transportation costs for MESC shipping casks in Appendices A through D inasmuch as they represented representative amounts of SNF that might be delivered to FWMS facilities in MESC's using a reasonable transportation strategy.

The incremental life cycle costs and resulting incremental unit costs for each of the foregoing cases were developed as follows:

- (1) For cases where the MESC's are opened outside of hot cell facilities, the cost of the MESC opening equipment was assumed to be shared between the 24 PWR assembly MESC's (80% of the cost) and 7 PWR assembly MESC's (20% of the cost). This split also was applied to the cost of disposal. This division of costs was based on the assumptions that 10 percent of the cost of the equipment was due to special features that were incorporated in order to be able to handle the 7 PWR assembly MESC's, and that the quantity of fuel received in 7 PWR assembly MESC's would represent 10 percent of the total SNF received in MESC's.
 - (a) For cases where the MESC's are opened upon receipt, it was assumed that the cost of the equipment would be incurred in the year immediately prior to the first receipt of 24 PWR assembly MESC's; with the pro rata portion of the cost allocated to 7 PWR assembly MESC's being incurred in the year immediately prior to the first receipt of 24 PWR assembly MESC's for cases where the total amount of SNF received therein was about 10 times the total quantity received in 7 PWR assembly MESC's. The pro rata share of disposal costs was assumed to be incurred in 2023.
 - (b) For cases where the MESC's are opened after storage at the MRS facility, it was assumed that the cost of the equipment would be incurred in 2026. The pro rata share of the disposal costs was assumed to be incurred in 2028.
- (2) For cases where the MESC's are opened inside the hot cell facilities, the cost of the additional hot cell facilities and equipment was assumed to be shared between the 24 PWR assembly MESC's (90% of the cost) and 7 PWR assembly MESC's (10% of the cost). This split was also applied to the cost of decommissioning. This division of cost was based on the assumption that 10 percent of the SNF in MESC's would be received in 7 PWR assembly MESC's and the remainder would be received in 24 PWR assembly MESC's. Moreover, it was assumed that the cost of the hot cells would be incurred during the period 1998 through 2002, and that the costs would be equally distributed during that period. The pro rata share of the decommissioning costs was assumed to be incurred in 2033, 30 years after the startup of the hot cell facilities.

- (3) For cases where MESCs are stored in vertical concrete storage casks in MRS facilities, the costs of additional concrete pads were determined using the formulas described in Section 4.3.2.7. It was assumed that the costs of these casks and HSMs were incurred in the year they were first used for storage.
- (4) For cases where MESCs are opened inside the hot cell facilities, the fixed operating costs were assumed to be shared between the 24 PWR assembly MESCs (90% of the cost) and 7 PWR assembly MESCs (10% of the cost), on the assumption that 10 percent of the SNF in MESCs would be received in 7 PWR assembly MESCs and the remainder would be received in 24 PWR assembly MESCs. It was assumed that these costs would be incurred from the time the construction of the hot cell facility was completed until it was decommissioned. Further, it was assumed that all MESCs in storage at a MRS facility would be removed therefrom in 2027 and opened then; the unit costs developed in Section 4.2.3.5 were applied against the total quantity of SNF contained in MESCs in storage at the MRS facility. However, the cost of opening the MESCs was assumed to be incurred as they were received when there was no MRS facility in the FWMS.
- (5) For cases involving storage in a MRS facility, the additional storage area operating costs were assumed to be incurred in both the years of emplacement and the years of removal, except where the MESCs are stored in HSMs where the costs are incurred only in the year of removal.
- (6) MESC disposal costs were assumed to be incurred in the year the MESCs are opened and the contained SNF unloaded therefrom.
- (7) MRS cask/HSM and concrete pad decommissioning or disposal costs would be incurred in the year after removal of the MESCs therefrom (2028).
- (8) For cases where MESCs are stored in HSMs, the cost of HSM loading equipment was assumed to be shared between the 24 PWR assembly MESCs (90% of the cost) and 7 PWR assembly MESCs (10% of the cost), on the assumption that 10 percent of the SNF in MESCs would be received in 7 PWR assembly MESCs and the remainder would be received in 24 PWR assembly MESCs. This split was also applied to disposal costs of the equipment. Moreover, it was assumed that the cost of the equipment would be incurred in the year immediately prior to the first receipt of 24 PWR assembly MESCs; with the pro rata portion of the cost allocated to 7 PWR assembly MESCs being incurred in the year immediately prior to the first receipt of 24 PWR assembly MESCs for cases where the total amount of SNF received therein was about 10 times the total quantity received in 7 PWR assembly MESCs. The pro rata share of disposal costs was assumed to be incurred in 2028.

- (9) For cases where HSMs are used for MESC storage, it was assumed that the cost of the transfer cask would be incurred in the year immediately preceding the removal of SNF from storage (2026). It was further assumed that the cost of disposal of the cask would be incurred in 2028. Separate transfer casks were assumed to be required for 24 PWR assembly MESC's and 7 PWR assembly MESC's.
- (10) The costs used to develop the incremental life cycle costs are summarized below (1988 dollars):

<u>Variable Costs</u>	<u>(\$/kgU)*</u>
Operating Costs for Opening MESC's Outside Hot Cell	
24 PWR Assembly MESC's	\$ 0.33
7 PWR Assembly MESC's	0.86
MESC Disposal	
24 PWR Assembly MESC's	2.61
7 PWR Assembly MESC's	3.49
Variable Cost of Operation of Hot Cell	
24 PWR Assembly MESC's	0.21
7 PWR Assembly MESC's	0.67
MRS Concrete Casks	
24 PWR Assembly MESC's	(1.70)
7 PWR Assembly MESC's	7.13
HSM	
24 PWR Assembly MESC's	(14.90)
7 PWR Assembly MESC's	(4.34)
Storage Area Operating Costs (For either loading or unloading)	
24 PWR Assembly MESC's	0.01
7 PWR Assembly MESC's	0.04

*Figures in parentheses denote savings

<u>Fixed Costs</u>	<u>(\$000)</u>
Equipment for Opening MESC's Outside Hot Cell	\$ 499
Hot Cell Additions	5,720
Fixed Annual Operating Costs of Hot Cell	194
HSM Loading Equipment	760
Transfer Cask	1,000
Storage Pads for 24 PWR Assembly MESC Casks	
564 MTU	104
940 MTU	163
1,504 MTU	252
1,880 MTU	310
Storage Pads for 7 PWR Assembly MESC Casks	
58 MTU	32
116 MTU	49
232 MTU	82

- (11) The total costs were discounted by 3%/year to 1988 to get the total discounted costs.
- (12) The unit costs were determined by dividing the total discounted costs by the total discounted amount (MTU) of SNF received in MESCs, as follows:

Discounted Costs = Discounted (Unit Costs x MTU Received)

Discounted Costs - Unit Costs x Discounted MTU Received

$$\text{Unit Cost} = \frac{\text{Discounted Costs}}{\text{Discounted MTU Received}}$$

A more detailed explanation of the methodology used for the unit cost calculation is set forth in Appendix F.

TABLE E-1
INCREMENTAL LIFE CYCLE COST OF FOMS FACILITIES RESULTING FROM RECEIPT OF 564 MTU
AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY NESCS AT MRS FACILITY
(NESCS OPENED OUTSIDE OF HOT CELL FACILITIES UPON RECEIPT)

COSTS (\$000, 1988)							QUANTITIES (MTU)	
YEAR	CAPITAL	COSTS	OPERATING	COSTS	TOTAL COSTS	DISC. @ 3%/Yr TO 1988	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
	NESC OPENING EQUIP		NESC OPENING	NESC DISPOSAL DECONN COSTS				
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006								
2007								
2008								
2009								
2010								
2011								
2012								
2013								
2014								
2015								
2016								
2017								
2018								
2019	399				399	160		
2020			62	491	553	215	188	73
2021			62	491	553	208	188	71
2022			62	491	553	202	188	69
2023					20	7		
TOTAL	399		186	1,473	2,078	792	564	213
DISC TOTAL	160		70	556	7	792		
UNIT COST (per kgU)	.75		.33	2.61	.03	3.73		
% OF TOTAL DISC COST	20%		9%	70%	1%	100%		

TABLE E-2
INCREMENTAL LIFE CYCLE COST OF FWMs FACILITIES RESULTING FROM RECEIPT OF 940 MTU
AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT MRS FACILITY
(MESCS OPENED OUTSIDE OF HOT CELL FACILITIES UPON RECEIPT)

COSTS (\$000, 1988)							QUANTITIES (MTU)	
YEAR	CAPITAL	COSTS	OPERATING	COSTS	TOTAL	DISC. @	ANNUAL	QUAN DISC
	MESC OPENING EQUIP		MESC OPENING	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	3Z/Yr TO 1988	QUAN. RECEIVED TO 1988
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006								
2007								
2008								
2009								
2010								
2011								
2012								
2013								
2014								
2015								
2016								
2017	399					399	169	
2018			62	491		553	228	188
2019			62	491		553	221	188
2020			62	491		553	215	188
2021			62	491		553	208	188
2022			62	491		553	202	188
2023					20	20	7	69
TOTAL	399		310	2,455	20	3,184	1,251	940
DISC TOTAL	169		120	954	7	1,251		365
UNIT COST (per kgU)	.46		.33	2.61	.02	3.42		
% OF TOTAL DISC COST	14%		10%	76%	1%	100%		

TABLE E-3
INCREMENTAL LIFE CYCLE COST OF FOMS FACILITIES RESULTING FROM RECEIPT OF 1504 MTU
AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY NESCO AT MRS FACILITY
(NESCO OPENED OUTSIDE OF HOT CELL FACILITIES UPON RECEIPT)

COSTS (\$000, 1980)							QUANTITIES (MTU)	
YEAR	CAPITAL COSTS	OPERATING COSTS		DECOM COSTS	TOTAL COSTS	TOTAL COSTS DISC. @ 3% Yr TO 1980	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3% Yr TO 1980
	NESC OPENING EQUIP	NESC OPENING	NESC DISPOSAL					
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006								
2007								
2008								
2009								
2010								
2011								
2012								
2013								
2014	399				399	185		
2015		62	491		553	249	188	85
2016		62	491		553	242	188	82
2017		62	491		553	235	188	80
2018		62	491		553	228	188	77
2019		62	491		553	221	188	75
2020		62	491		553	215	188	73
2021		62	491		553	208	188	71
2022		62	491		553	202	188	69
2023				20	20	7		
TOTAL	399	496	3,928	20	4,843	1,992	1,504	612
DISC TOTAL	185	202	1,598	7	1,992			
UNIT COST (per kgU)	.30	.33	2.61	.01	3.26			
% OF TOTAL DISC COST	9%	10%	80%	0%	100%			

TABLE E-4
 INCREMENTAL LIFE CYCLE COST OF FWMs FACILITIES RESULTING FROM RECEIPT OF 1880 MTU
 AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT MRS FACILITY
 (MESCS OPENED OUTSIDE OF HOT CELL FACILITIES UPON RECEIPT)

YEAR	COSTS (\$000, 1988)						QUANTITIES (MTU)	
	CAPITAL	COSTS	OPERATING	COSTS		TOTAL	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
	MESC OPENING EQUIP		MESC OPENING	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS		
						DISC. @ 3%/Yr TO 1988		
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006								
2007								
2008								
2009								
2010								
2011								
2012	399					399	196	
2013			62	491		553	264	188 90
2014			62	491		553	256	188 87
2015			62	491		553	249	188 85
2016			62	491		553	242	188 82
2017			62	491		553	235	188 80
2018			62	491		553	228	188 77
2019			62	491		553	221	188 75
2020			62	491		553	215	188 73
2021			62	491		553	208	188 71
2022			62	491		553	202	188 69
2023					20	20	7	
TOTAL	399		620	4,910	20	5,949	2,524	1,880 789
DISC TOTAL	196		260	2,060	7	2,524		
UNIT COST (per kgU)	.25		.33	2.61	.01	3.20		
% OF TOTAL DISC COST	8%		10%	82%	0%	100%		

TABLE E-5
INCREMENTAL LIFE CYCLE COST OF FOMS FACILITIES RESULTING FROM RECEIPT OF 534 MTU
AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT REPOSITORY
(MESCS OPENED OUTSIDE OF HOT CELL FACILITIES UPON RECEIPT)

COSTS (\$000, 1988)							QUANTITIES (MTU)	
YEAR	CAPITAL COSTS	OPERATING COSTS		TOTAL COSTS		TOTAL COSTS	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
	MESC OPENING EQUIP	MESC OPENING	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 3%/Yr TO 1988		
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006								
2007								
2008								
2009								
2010								
2011								
2012								
2013								
2014								
2015								
2016								
2017								
2018								
2019	399				399	160		
2020		59	465		524	203	178	69
2021		59	465		524	198	178	67
2022		59	465		524	192	178	65
2023				20	20	7		
TOTAL	399	177	1,395	20	1,991	760	534	201
DISC TOTAL	160	67	526	7	760			
UNIT COST (per kgU)	.79	.33	2.61	.04	3.77			
% OF TOTAL DISC COST	21%	9%	69%	1%	100%			

TABLE E-6
 INCREMENTAL LIFE CYCLE COST OF FWS FACILITIES RESULTING FROM RECEIPT OF 890 MTU
 AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT REPOSITORY
 (MESCS OPENED OUTSIDE OF HOT CELL FACILITIES UPON RECEIPT)

YEAR	COSTS (\$000, 1988)						QUANTITIES (MTU)	
	CAPITAL	COSTS	OPERATING	COSTS		TOTAL	ANNUAL	QUAN DISC
						COSTS		
	MESC OPENING EQUIP		MESC OPENING	MESC DISPOSAL	DECCOM COSTS	TOTAL COSTS	DISC. @ 3%/Yr TO 1988	
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006								
2007								
2008								
2009								
2010								
2011								
2012								
2013								
2014								
2015								
2016								
2017	399					399	169	
2018			59	465		524	216	178 73
2019			59	465		524	210	178 71
2020			59	465		524	203	178 69
2021			59	465		524	198	178 67
2022			59	465		524	192	178 65
2023					20	20	7	
TOTAL	399		295	2,325	20	3,039	1,195	890 346
DISC TOTAL	169		115	904	7	1,195		
UNIT COST (per kgU)	.49		.33	2.61	.02	3.45		
% OF TOTAL DISC COST	14%		10%	76%	1%	100%		

TABLE E-7
 INCREMENTAL LIFE CYCLE COST OF FWMG FACILITIES RESULTING FROM RECEIPT OF 1424 MTU
 AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT REPOSITORY
 (MESCS OPENED OUTSIDE OF HOT CELL FACILITIES UPON RECEIPT)

COSTS (\$000, 1988)							QUANTITIES (MTU)	
YEAR	CAPITAL COSTS	OPERATING COSTS			TOTAL COSTS		ANNUAL QUAN. RECEIVED	DISC @ 3%/Yr TO 1988
	MESC OPENING EQUIP	MESC OPENING	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 3%/Yr TO 1988		
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006								
2007								
2008								
2009								
2010								
2011								
2012								
2013								
2014	399				399	185		
2015		59	465		524	236	178	80
2016		59	465		524	229	178	78
2017		59	465		524	222	178	76
2018		59	465		524	216	178	73
2019		59	465		524	210	178	71
2020		59	465		524	203	178	69
2021		59	465		524	198	178	67
2022		59	465		524	192	178	65
2023				20	20	7		
TOTAL	399	472	3,720	20	4,611	1,898	1,424	579
DISC TOTAL	185	192	1,514	7	1,898			
UNIT COST (per kgU)	.32	.33	2.61	.01	3.28			
% OF TOTAL DISC COST	10%	10%	80%	0%	100%			

TABLE E-8
 INCREMENTAL LIFE CYCLE COST OF FWMs FACILITIES RESULTING FROM RECEIPT OF 1780 MTU
 AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT REPOSITORY
 (MESCS OPENED OUTSIDE OF HOT CELL FACILITIES UPON RECEIPT)

COSTS (\$000, 1988)							QUANTITIES (MTU)		
YEAR	CAPITAL	COSTS	OPERATING		TOTAL COSTS	TOTAL COSTS	DISC. @ 3%/Yr TO 1988	ANNUAL QUAM. RECEIVED	QUAM DISC @ 3%/Yr TO 1988
	MESC OPENING EQUIP		MESC	MESC					
			OPENING	DISPOSAL					
1998									
1999									
2000									
2001									
2002									
2003									
2004									
2005									
2006									
2007									
2008									
2009									
2010									
2011									
2012	399				399	196			
2013			59	465	524	250	178	85	
2014			59	465	524	243	178	83	
2015			59	465	524	236	178	80	
2016			59	465	524	229	178	78	
2017			59	465	524	222	178	76	
2018			59	465	524	216	178	73	
2019			59	465	524	210	178	71	
2020			59	465	524	203	178	69	
2021			59	465	524	198	178	67	
2022			59	465	524	192	178	65	
2023					20	20	7		
TOTAL	399		590	4,650	20	5,659	2,402	1,780	747
DISC TOTAL	196		248	1,951	7	2,402			
UNIT COST (per kgU)	.26		.33	2.61	.01	3.22			
% OF TOTAL DISC COST	8%		10%	81%	0%	100%			

TABLE E-9
 INCREMENTAL LIFE CYCLE COST OF FWMs FACILITIES RESULTING FROM RECEIPT OF 58 MTU
 AS PWR ASSEMBLIES IN 7 PWR ASSEMBLY NESCOs AT MRS FACILITY
 (NESCOs OPENED OUTSIDE OF HOT CELL FACILITIES UPON RECEIPT)

COSTS (\$000, 1988)							QUANTITIES (MTU)	
YEAR	CAPITAL	COSTS	OPERATING	COSTS	TOTAL COSTS	DISC. @ 3%/Yr TO 1988	ANNUAL	QUAN DISC
	NESC OPENING EQUIP		NESC OPENING	NESC DISPOSAL DECONN COSTS			QUAN. RECEIVED	@ 3%/Yr TO 1988
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006								
2007								
2008								
2009								
2010								
2011								
2012								
2013								
2014								
2015								
2016								
2017								
2018								
2019	100				100	40		
2020								
2021								
2022			50	202	252	92	58	21
2023				5	5	2		
TOTAL	100		50	202	357	134	58	21
DISC TOTAL	40		18	74	2	134		
UNIT COST (per kgU)	1.88		.86	3.48	.08	6.31		
% OF TOTAL DISC COST	30%		14%	55%	1%	100%		

TABLE E-10
 INCREMENTAL LIFE CYCLE COST OF PWR FACILITIES RESULTING FROM RECEIPT OF 116 MTU
 AS PWR ASSEMBLIES IN 7 PWR ASSEMBLY MESCS AT MES FACILITY
 (MESCS OPENED OUTSIDE OF HOT CELL FACILITIES UPON RECEIPT)

COSTS (\$000 1988)							QUANTITIES (MTU)	
CAPITAL COSTS		OPERATING COSTS			TOTAL COSTS			
MESC OPENING		MESC OPENING		MESC DECOMM	TOTAL DISC. @ 3%/Yr TO 1988		ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
YEAR	EQUIP		DISPOSAL	COSTS	COSTS			
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006								
2007								
2008								
2009								
2010								
2011								
2012								
2013								
2014								
2015								
2016								
2017	100				100	42		
2018								
2019								
2020								
2021		50	202		252	95	58	22
2022		50	202		252	92	58	21
2023				5	5	2		
TOTAL	100	100	404	5	609	231	116	43
DISC TOTAL	42	37	150	2	231			
UNIT COST (per kgU)	.98	.86	3.48	.04	5.37			
% OF TOTAL DISC COST	18%	16%	65%	1%	100%			

TABLE E-11
 INCREMENTAL LIFE CYCLE COST OF FOMS FACILITIES RESULTING FROM RECEIPT OF 232 MTU
 AS PWR ASSEMBLIES IN 7 PWR ASSEMBLY MESCS AT MRS FACILITY
 (MESCS OPENED OUTSIDE OF HOT CELL FACILITIES UPON RECEIPT)

COSTS (\$000, 1988)							QUANTITIES (MTU)	
YEAR	CAPITAL COSTS	OPERATING COSTS			TOTAL COSTS	DISC. @ 3%/Yr TO 1988	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
	MESC OPENING EQUIP	MESC OPENING	MESC DISPOSAL	DECONN COSTS	TOTAL COSTS			
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006								
2007								
2008								
2009								
2010								
2011								
2012	100				100	49		
2013								
2014								
2015								
2016								
2017								
2018								
2019		50	202		252	101	58	23
2020		50	202		252	98	58	23
2021		50	202		252	95	58	22
2022		50	202		252	92	58	21
2023				5	5	2		
<hr/>								
TOTAL	100	200	808	5	1,113	437	232	89
<hr/>								
DISC TOTAL	49	77	309	2	437			
<hr/>								
UNIT COST (per kgU)	.55	.86	3.48	.02	4.92			
<hr/>								
% OF TOTAL DISC COST	11%	18%	71%	0%	100%			

TABLE E-12
 INCREMENTAL LIFE CYCLE COST OF FOMS FACILITIES RESULTING FROM RECEIPT OF 52 MTU
 AS FWR ASSEMBLIES IN 7 FWR ASSEMBLY MESCS AT REPOSITORY
 (MESCS OPENED OUTSIDE OF HOT CELL FACILITIES UPON RECEIPT)

COSTS (\$000, 1988)							QUANTITIES (MTU)	
YEAR	CAPITAL COSTS	OPERATING COSTS			TOTAL COSTS	DISC. @ 3%/Yr TO 1988	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
	MESC OPENING EQUIP	MESC OPENING	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS			
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006								
2007								
2008								
2009								
2010								
2011								
2012								
2013								
2014								
2015								
2016								
2017								
2018								
2019	100				100	40		
2020								
2021		22	91		113	43	26	10
2022		22	91		113	41	26	10
2023				5	5	2		
TOTAL	100	44	182	5	331	126	52	19
DISC TOTAL	40	16	68	2	126			
UNIT COST (per kgU)	2.07	.85	3.50	.09	6.51			
% OF TOTAL DISC COST	32%	13%	54%	1%	100%			

TABLE E-13
 INCREMENTAL LIFE CYCLE COST OF FWMs FACILITIES RESULTING FROM RECEIPT OF 104 MTU
 AS PWR ASSEMBLIES IN 7 PWR ASSEMBLY MESCS AT REPOSITORY
 (MESCS OPENED OUTSIDE OF HOT CELL FACILITIES UPON RECEIPT)

COSTS (\$000, 1988)							QUANTITIES (MTU)	
YEAR	CAPITAL COSTS	OPERATING COSTS		DECOMM COSTS	TOTAL COSTS	TOTAL COSTS DISC. @ 3%/Yr TO 1988	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
	MESC OPENING EQUIP	MESC OPENING	MESC DISPOSAL					
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006								
2007								
2008								
2009								
2010								
2011								
2012								
2013								
2014								
2015								
2016								
2017	100				100	42		
2018								
2019		22	91		113	45	26	10
2020		22	91		113	44	26	10
2021		22	91		113	43	26	10
2022		22	91		113	41	26	10
2023				5	5	2		
TOTAL	100	88	364	5	557	217	104	40
DISC TOTAL	42	34	139	2	217			
UNIT COST (per kgU)	1.07	.85	3.50	.04	5.46			
% OF TOTAL DISC COST	20%	16%	64%	1%	100%			

TABLE E-14
INCREMENTAL LIFE CYCLE COST OF FWM FACILITIES RESULTING FROM RECEIPT OF 208 MTU
AS FWR ASSEMBLIES IN 7 FWR ASSEMBLY MESCS AT REPOSITORY
(MESCS OPENED OUTSIDE OF HOT CELL FACILITIES UPON RECEIPT)

COSTS (\$000, 1988)							QUANTITIES (MTU)	
YEAR	CAPITAL COSTS	OPERATING COSTS			TOTAL COSTS		ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
	MESC OPENING EQUIP	MESC OPENING	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 3% Yr TO 1988		
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006								
2007								
2008								
2009								
2010								
2011								
2012	100				100	49		
2013								
2014								
2015		22	91		113	51	26	12
2016		22	91		113	49	26	11
2017		22	91		113	48	26	11
2018		22	91		113	47	26	11
2019		22	91		113	45	26	10
2020		22	91		113	44	26	10
2021		22	91		113	43	26	10
2022		22	91		113	41	26	10
2023				5	5	2		
TOTAL	100	176	728	5	1,009	419	208	85
DISC TOTAL	49	72	296	2	419			
UNIT COST (per kgU)	.58	.85	3.50	.02	4.95			
% OF TOTAL DISC COST	12%	17%	71%	0%	100%			

TABLE E-15
INCREMENTAL LIFE CYCLE COST OF FWMs FACILITIES RESULTING FROM RECEIPT OF 564 MTL
AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT MRS FACILITY
(MESCS OPENED IN HOT CELL FACILITIES -- VERTICAL CONCRETE CASKS USED FOR STORAGE)

COSTS (\$000, 1988)										QUANTITIES (MTU)	
YEAR	CAPITAL COSTS			OPERATING COSTS				TOTAL COSTS	DISC. @ 3% Yr TC 1988	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3% Yr TO 1988
	HOT CELL FACILITIES	STORAGE PADS	MRS CASKS	HOT CELL FACILITIES	STORAGE AREA	MESC DISPOSAL	DECOMM COSTS				
1998	1,030							1,030	766		
1999	1,030							1,030	744		
2000	1,030							1,030	722		
2001	1,030							1,030	701		
2002	1,030							1,030	681		
2003				175				175	112		
2004				175				175	109		
2005				175				175	106		
2006				175				175	103		
2007				175				175	100		
2008				175				175	97		
2009				175				175	94		
2010				175				175	91		
2011				175				175	89		
2012				175				175	86		
2013				175				175	84		
2014				175				175	81		
2015				175				175	79		
2016				175				175	76		
2017				175				175	74		
2018				175				175	72		
2019				175				175	70		
2020		35	-320	175	2			-108	-42	188	73
2021		35	-320	175	2			-108	-41	188	71
2022		35	-320	175	2			-108	-40	188	69
2023				175				175	62		
2024				175				175	60		
2025				175				175	59		
2026				175				175	57		
2027				293	6	1,472		1,771	559		
2028				175			-43	132	40		
2029				175				175	52		
2030				175				175	51		
2031				175				175	49		
2032				175				175	48		
2033							1,030	1,030	272		
TOTAL	5,150	105	-960	5,368	12	1,472	987	12,134	6,326	564	213
DISC TOTAL	3,615	40	-362	2,305	4	465	259	6,326			
UNIT COST (per kgU)	17.00	.19	-1.70	10.84	.02	2.19	1.22	29.74			
% OF TOTAL DISC COST	57%	1%	-6%	36%	0%	7%	4%	100%			

TABLE E-16
 INCREMENTAL LIFE CYCLE COST OF PWS FACILITIES RESULTING FROM RECEIPT OF 940 HTL
 AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT MRS FACILITY
 (MESCS OPENED IN HOT CELL FACILITIES -- VERTICAL CONCRETE CASKS USED FOR STORAGE)

COSTS (\$000, 1988)										QUANTITIES (MTU)	
CAPITAL COSTS				OPERATING COSTS				TOTAL COSTS		ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
HOT CELL FACILITIES	STORAGE PADS	MRS CASKS	HOT CELL FACILITIES	STORAGE AREA	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 3%/Yr TC 1988			
1998	1,030						1,030	766			
1999	1,030						1,030	744			
2000	1,030						1,030	722			
2001	1,030						1,030	701			
2002	1,030						1,030	681			
2003				175			175	112			
2004				175			175	109			
2005				175			175	106			
2006				175			175	103			
2007				175			175	100			
2008				175			175	97			
2009				175			175	94			
2010				175			175	91			
2011				175			175	89			
2012				175			175	86			
2013				175			175	84			
2014				175			175	81			
2015				175			175	79			
2016				175			175	76			
2017				175			175	74			
2018		33	-320	175	2		-110	-45	188	77	
2019		33	-320	175	2		-110	-44	188	75	
2020		33	-320	175	2		-110	-43	188	73	
2021		33	-320	175	2		-110	-41	188	71	
2022		33	-320	175	2		-110	-40	188	69	
2023				175			175	62			
2024				175			175	60			
2025				175			175	59			
2026				175			175	57			
2027				372	10	2,453	2,835	895			
2028				175		-72	163	32			
2029				175			175	52			
2030				175			175	51			
2031				175			175	49			
2032				175			175	48			
2033						1,030	1,030	272			
TOTAL	5,150	165	-1,600	5,447	20	2,453	958	12,593	6,419	940	365
DISC TOTAL	3,615	64	-622	2,330	7	775	250	6,419			
UNIT COST (per kgU)	9.90	.18	-1.70	6.38	.02	2.12	.69	17.57			
% OF TOTAL DISC COST	56%	1%	-10%	36%	0%	12%	4%	190%			

TABLE E-17
 INCREMENTAL LIFE CYCLE COST OF FWMs FACILITIES RESULTING FROM RECEIPT OF 1504 MTU
 AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT MRS FACILITY
 (MESCS OPENED IN HOT CELL FACILITIES -- VERTICAL CONCRETE CASKS USED FOR STORAGE)

COSTS (\$000, 1988)										QUANTITIES (MTU)	
CAPITAL COSTS			OPERATING COSTS					TOTAL COSTS		ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
YEAR	HOT CELL FACILITIES	STORAGE PADS	MRS CASKS	HOT CELL FACILITIES	STORAGE AREA	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 3%/Yr TC 1988		
1998	1,030							1,030	766		
1999	1,030							1,030	744		
2000	1,030							1,030	722		
2001	1,030							1,030	701		
2002	1,030							1,030	681		
2003				175				175	112		
2004				175				175	109		
2005				175				175	106		
2006				175				175	103		
2007				175				175	100		
2008				175				175	97		
2009				175				175	94		
2010				175				175	91		
2011				175				175	89		
2012				175				175	86		
2013				175				175	84		
2014				175				175	81		
2015		32	-320	175	2			-111	-50	188	85
2016		32	-320	175	2			-111	-49	188	82
2017		32	-320	175	2			-111	-47	188	80
2018		32	-320	175	2			-111	-46	188	77
2019		32	-320	175	2			-111	-44	188	75
2020		32	-320	175	2			-111	-43	188	73
2021		32	-320	175	2			-111	-42	188	71
2022		32	-320	175	2			-111	-41	188	69
2023				175				175	62		
2024				175				175	60		
2025				175				175	59		
2026				175				175	57		
2027				491	16	3,925		4,432	1,399		
2028				175			-115	60	18		
2029				175				175	52		
2030				175				175	51		
2031				175				175	49		
2032				175				175	48		
2033							1,030	1,030	272		
TOTAL	5,150	256	-2,560	5,566	32	3,925	915	13,284	6,533	1,504	612
DISC TOTAL	3,615	104	-1,042	2,367	12	1,239	237	6,533			
UNIT COST (per kgU)	5.91	.17	-1.70	3.87	.02	2.03	.39	10.68			
% OF TOTAL DISC COST	55%	2%	-16%	36%	0%	19%	4%	100%			

TABLE E-18
 INCREMENTAL LIFE CYCLE COST OF PWR FACILITIES RESULTING FROM RECEIPT OF 1880 MTU
 AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT MRS FACILITY
 (MESCS OPENED IN HOT CELL FACILITIES - VERTICAL CONCRETE CASKS USED FOR STORAGE)

COSTS (\$000, 1988)										QUANTITIES (MTU)	
YEAR	CAPITAL COSTS			OPERATING COSTS				TOTAL COSTS	DISC. @ 3%/Yr TO 1988	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
	HOT CELL FACILITIES	STORAGE PADS	MRS CASKS	HOT CELL FACILITIES	STORAGE AREA	MESC DISPOSAL	DECOMM COSTS				
1998	1,030							1,030	766		
1999	1,030							1,030	744		
2000	1,030							1,030	722		
2001	1,030							1,030	701		
2002	1,030							1,030	681		
2003				175				175	112		
2004				175				175	109		
2005				175				175	106		
2006				175				175	103		
2007				175				175	100		
2008				175				175	97		
2009				175				175	94		
2010				175				175	91		
2011				175				175	89		
2012				175				175	86		
2013		31	-320	175	2			-112	-53	188	90
2014		31	-320	175	2			-112	-52	188	87
2015		31	-320	175	2			-112	-50	188	85
2016		31	-320	175	2			-112	-49	188	82
2017		31	-320	175	2			-112	-48	188	80
2018		31	-320	175	2			-112	-46	188	77
2019		31	-320	175	2			-112	-45	188	75
2020		31	-320	175	2			-112	-43	188	73
2021		31	-320	175	2			-112	-42	188	71
2022		31	-320	175	2			-112	-41	188	69
2023				175				175	62		
2024				175				175	60		
2025				175				175	59		
2026				175				175	57		
2027				570	20	4,907		5,497	1,736		
2028				175			-145	30	9		
2029				175				175	52		
2030				175				175	51		
2031				175				175	49		
2032				175				175	48		
2033							1,030	1,030	272		
TOTAL	5,150	310	-3,200	5,645	40	4,907	885	13,737	6,587	1,880	789
DISC TOTAL	3,615	130	-1,343	2,392	15	1,549	228	6,587			
UNIT COST (per kgU)	4.58	.16	-1.70	3.03	.02	1.96	.29	8.35			
% OF TOTAL DISC COST	55%	2%	-20%	36%	0%	24%	3%	100%			

TABLE E-19
INCREMENTAL LIFE CYCLE COST OF FWMs FACILITIES RESULTING FROM RECEIPT OF 534 MTU
AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT REPOSITORY
(MESCS OPENED IN HOT CELL FACILITIES)

COSTS (\$000, 1988)							QUANTITIES (MTU)	
CAPITAL COSTS		OPERATING COSTS			TOTAL COSTS		ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
HOT CELL YEAR FACILITIES		HOT CELL FACILITIES	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 3%/Yr TC 1988		
1998	1,030				1,030	766		
1999	1,030				1,030	744		
2000	1,030				1,030	722		
2001	1,030				1,030	701		
2002	1,030				1,030	681		
2003		175			175	112		
2004		175			175	109		
2005		175			175	106		
2006		175			175	103		
2007		175			175	100		
2008		175			175	97		
2009		175			175	94		
2010		175			175	91		
2011		175			175	89		
2012		175			175	86		
2013		175			175	84		
2014		175			175	81		
2015		175			175	79		
2016		175			175	76		
2017		175			175	74		
2018		175			175	72		
2019		175			175	70		
2020		212	465		677	263	178	69
2021		212	465		677	255	178	67
2022		212	465		677	248	178	65
2023		175			175	62		
2024		175			175	60		
2025		175			175	59		
2026		175			175	57		
2027		175			175	55		
2028		175			175	54		
2029		175			175	52		
2030		175			175	51		
2031		175			175	49		
2032		175			175	48		
2033				1,030	1,030	272		
TOTAL	5,150	5,361	1,395	1,030	12,936	6,723	534	201
DISC TOTAL	3,615	2,310	526	272	6,723			
UNIT COST (per kgU)	17.95	11.47	2.61	1.35	33.38			
% OF TOTAL DISC COST	54%	34%	8%	4%	100%			

TABLE E-20
INCREMENTAL LIFE CYCLE COST OF FWMs FACILITIES RESULTING FROM RECEIPT OF 890 MTU
AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT REPOSITORY
(MESCS OPENED IN HOT CELL FACILITIES)

COSTS (\$000, 1988)							QUANTITIES (MTU)	
CAPITAL COSTS			OPERATING COSTS			TOTAL COSTS	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
HOT CELL YEAR FACILITIES			HOT CELL FACILITIES	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS		
						DISC. @ 3%/Yr TC 1988		
1998	1,030					1,030	766	
1999	1,030					1,030	744	
2000	1,030					1,030	722	
2001	1,030					1,030	701	
2002	1,030					1,030	681	
2003			175			175	112	
2004			175			175	109	
2005			175			175	106	
2006			175			175	103	
2007			175			175	100	
2008			175			175	97	
2009			175			175	94	
2010			175			175	91	
2011			175			175	89	
2012			175			175	86	
2013			175			175	84	
2014			175			175	81	
2015			175			175	79	
2016			175			175	76	
2017			175			175	74	
2018			212	465		677	279	178
2019			212	465		677	271	178
2020			212	465		677	263	178
2021			212	465		677	255	178
2022			212	465		677	248	178
2023			175			175	62	
2024			175			175	60	
2025			175			175	59	
2026			175			175	57	
2027			175			175	55	
2028			175			175	54	
2029			175			175	52	
2030			175			175	51	
2031			175			175	49	
2032			175			175	48	
2033					1,030	1,030	272	
TOTAL	5,150		5,435	2,325	1,030	13,940	7,131	890
DISC TOTAL	3,615		2,340	904	272	7,131		346
UNIT COST (per kgU)	10.45		6.76	2.61	.79	20.61		
% OF TOTAL DISC COST	51%		33%	13%	4%	100%		

TABLE E-21
INCREMENTAL LIFE CYCLE COST OF FWMs FACILITIES RESULTING FROM RECEIPT OF 1424 MTU
AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT REPOSITORY
(MESCS OPENED IN HOT CELL FACILITIES)

COSTS (\$000, 1988)							QUANTITIES (MTU)	
CAPITAL COSTS			OPERATING COSTS			TOTAL COSTS	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3% Yr TO 1988
YEAR	HOT CELL FACILITIES		HOT CELL FACILITIES	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS		
						DISC. @ 3% Yr TO 1988		
1998	1,030					1,030		
1999	1,030					1,030		
2000	1,030					1,030		
2001	1,030					1,030		
2002	1,030					1,030		
2003			175			175		
2004			175			175		
2005			175			175		
2006			175			175		
2007			175			175		
2008			175			175		
2009			175			175		
2010			175			175		
2011			175			175		
2012			175			175		
2013			175			175		
2014			175			175		
2015			212	465		677	178	80
2016			212	465		677	178	78
2017			212	465		677	178	76
2018			212	465		677	178	73
2019			212	465		677	178	71
2020			212	465		677	178	69
2021			212	465		677	178	67
2022			212	465		677	178	65
2023			175			175		
2024			175			175		
2025			175			175		
2026			175			175		
2027			175			175		
2028			175			175		
2029			175			175		
2030			175			175		
2031			175			175		
2032			175			175		
2033					1,030	1,030		
TOTAL	5,150		5,546	3,720	1,030	15,446	7,789	579
DISC TOTAL	3,615		2,388	1,514	272	7,789		
UNIT COST (per kgU)	6.24		4.12	2.61	.47	13.44		
% OF TOTAL DISC COST	46%		31%	19%	3%	10%		

TABLE E-22
INCREMENTAL LIFE CYCLE COST OF FWM FACILITIES RESULTING FROM RECEIPT OF 1700 MTU
AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT REPOSITORY
(MESCS OPENED IN HOT CELL FACILITIES)

COSTS (\$000, 1988)							QUANTITIES (MTU)	
CAPITAL COSTS			OPERATING COSTS			TOTAL COSTS	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
YEAR	HOT CELL FACILITIES	POT CELL FACILITIES	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 3%/Yr TC 1988		
1998	1,030				1,030	766		
1999	1,030				1,030	744		
2000	1,030				1,030	722		
2001	1,030				1,030	701		
2002	1,030				1,030	681		
2003		175			175	112		
2004		175			175	109		
2005		175			175	106		
2006		175			175	103		
2007		175			175	100		
2008		175			175	97		
2009		175			175	94		
2010		175			175	91		
2011		175			175	89		
2012		175			175	86		
2013		212	465		677	323	178	85
2014		212	465		677	314	178	83
2015		212	465		677	305	178	80
2016		212	465		677	296	178	78
2017		212	465		677	287	178	76
2018		212	465		677	279	178	73
2019		212	465		677	271	178	71
2020		212	465		677	263	178	69
2021		212	465		677	255	178	67
2022		212	465		677	248	178	65
2023		175			175	62		
2024		175			175	60		
2025		175			175	59		
2026		175			175	57		
2027		175			175	55		
2028		175			175	54		
2029		175			175	52		
2030		175			175	51		
2031		175			175	49		
2032		175			175	48		
2033				1,030	1,030	272		
TOTAL	5,150	5,620	4,650	1,030	16,450	8,262	1,780	747
DISC TOTAL	3,615	2,423	1,951	272	8,262			
UNIT COST (per kgU)	4.84	3.24	2.61	.36	11.06			
% OF TOTAL DISC COST	44%	29%	24%	3%	100%			

TABLE E-23
 INCREMENTAL LIFE CYCLE COST OF PWR FACILITIES RESULTING FROM RECEIPT OF 58 MTU
 AS PWR ASSEMBLIES IN 7 PWR ASSEMBLY MESCS AT MRS FACILITY
 (MESCS OPENED IN HOT CELL FACILITIES -- VERTICAL CONCRETE CASKS USED FOR STORAGE)

COSTS (\$000, 1988)										QUANTITIES (MTU)	
CAPITAL COSTS					OPERATING COSTS			TOTAL COSTS		ANNUAL QUAN., RECEIVED	QUAN DISC @ 3%/Yr TO 1988
YEAR	HOT CELL FACILITIES	STORAGE PADS	MRS CASKS	HOT CELL FACILITIES	STORAGE AREA	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 3%/Yr TC 1988		
1998	114							114	85		
1999	114							114	82		
2000	114							114	80		
2001	114							114	78		
2002	114							114	75		
2003				19				19	12		
2004				19				19	12		
2005				19				19	11		
2006				19				19	11		
2007				19				19	11		
2008				19				19	11		
2009				19				19	10		
2010				19				19	10		
2011				19				19	10		
2012				19				19	9		
2013				19				19	9		
2014				19				19	9		
2015				19				19	9		
2016				19				19	8		
2017				19				19	8		
2018				19				19	8		
2019				19				19	8		
2020				19				19	7		
2021				19				19	7		
2022		32	414	19	2			467	171	58	21
2023				19				19	7		
2024				19				19	7		
2025				19				19	6		
2026				19				19	6		
2027				58	2	202		262	83		
2028				19			22	41	13		
2029				19				19	6		
2030				19				19	5		
2031				19				19	5		
2032				19				19	5		
2033							114	114	30		
TOTAL	570	32	414	609	4	202	136	1,967	924	58	21
DISC TOTAL	400	12	152	259	1	64	37	924			
UNIT COST (per kgU)	18.85	.55	7.14	12.18	.06	3.00	1.74	43.52			
% OF TOTAL DISC COST	43%	1%	16%	28%	0%	7%	4%	100%			

TABLE E-24
 INCREMENTAL LIFE CYCLE COST OF FWM FACILITIES RESULTING FROM RECEIPT OF 116 MTU
 AS PWR ASSEMBLIES IN 7 PWR ASSEMBLY WESCS AT MRS FACILITY
 (WESCS OPENED IN HOT CELL FACILITIES -- VERTICAL CONCRETE CASKS USED FOR STORAGE)

COSTS (\$000, 1988)										QUANTITIES (MTU)	
CAPITAL COSTS				OPERATING COSTS				TOTAL COSTS		ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
YEAR	HOT CELL FACILITIES	STORAGE PADS	MRS CASKS	HOT CELL FACILITIES	STORAGE AREA	WESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 3%/Yr TC 1988		
1998	114							114	85		
1999	114							114	82		
2000	114							114	80		
2001	114							114	78		
2002	114							114	75		
2003				19				19	12		
2004				19				19	12		
2005				19				19	11		
2006				19				19	11		
2007				19				19	11		
2008				19				19	11		
2009				19				19	10		
2010				19				19	10		
2011				19				19	10		
2012				19				19	9		
2013				19				19	9		
2014				19				19	9		
2015				19				19	9		
2016				19				19	8		
2017				19				19	8		
2018				19				19	8		
2019				19				19	8		
2020				19				19	7		
2021		25	414	19	2			460	173	58	22
2022		25	414	19	2			460	168	58	21
2023				19				19	7		
2024				19				19	7		
2025				19				19	6		
2026				19				19	6		
2027				97	4	405		506	160		
2028				19			44	63	19		
2029				19				19	6		
2030				19				19	5		
2031				19				19	5		
2032				19				19	5		
2033							114	114	30		
TOTAL	570	50	828	648	8	405	158	2,667	1,171	116	43
DISC TOTAL	400	19	308	271	3	128	44	1,171			
UNIT COST (per kgU)	9.28	.43	7.14	6.28	.06	2.97	1.01	27.18			
% OF TOTAL DISC COST	34%	2%	26%	23%	0%	11%	4%	100%			

TABLE E-25
 INCREMENTAL LIFE CYCLE COST OF FWMs FACILITIES RESULTING FROM RECEIPT OF 232 MTU
 AS PWR ASSEMBLIES IN 7 PWR ASSEMBLY MESCS AT MRS FACILITY
 (MESCS OPENED IN HOT CELL FACILITIES -- VERTICAL CONCRETE CASKS USED FOR STORAGE)

COSTS (\$000, 1988)										QUANTITIES (MTU)	
CAPITAL COSTS			OPERATING COSTS					TOTAL COSTS		ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
YEAR	HOT CELL FACILITIES	STORAGE PADS	MRS CASKS	HOT CELL FACILITIES	STORAGE AREA	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 3%/Yr TC 1988		
1998	114							114	85		
1999	114							114	82		
2000	114							114	80		
2001	114							114	78		
2002	114							114	75		
2003				19				19	12		
2004				19				19	12		
2005				19				19	11		
2006				19				19	11		
2007				19				19	11		
2008				19				19	11		
2009				19				19	10		
2010				19				19	10		
2011				19				19	10		
2012				19				19	9		
2013				19				19	9		
2014				19				19	9		
2015				19				19	9		
2016				19				19	8		
2017				19				19	8		
2018				19				19	8		
2019		21	414	19	2			456	182	58	23
2020		21	414	19	2			456	177	58	23
2021		21	414	19	2			456	172	58	22
2022		21	414	19	2			456	167	58	21
2023				19				19	7		
2024				19				19	7		
2025				19				19	6		
2026				19				19	6		
2027				174	8	810		992	313		
2028				19			87	106	32		
2029				19				19	6		
2030				19				19	5		
2031				19				19	5		
2032				19				19	5		
2033							114	114	30		
TOTAL	570	84	1,656	725	16	810	201	4,062	1,680	232	89
DISC TOTAL	400	32	634	295	6	256	57	1,680			
UNIT COST (per kgU)	4.50	.36	7.14	3.32	.06	2.88	.64	18.91			
% OF TOTAL DISC COST	24%	2%	38%	18%	0%	15%	3%	100%			

TABLE E-26
INCREMENTAL LIFE CYCLE COST OF FWMs FACILITIES RESULTING FROM RECEIPT OF 52 MTU
AS PWR ASSEMBLIES IN 7 PWR ASSEMBLY MESCS AT REPOSITORY
(MESCS OPENED IN HOT CELL FACILITIES)

COSTS (\$000, 1988)							QUANTITIES (MTU)	
YEAR	CAPITAL COSTS		OPERATING COSTS			TOTAL COSTS	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1998
	HOT CELL FACILITIES	HOT CELL FACILITIES	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 3%/Yr TC 1988		
1998	114				114	85		
1999	114				114	82		
2000	114				114	80		
2001	114				114	78		
2002	114				114	75		
2003		19			19	12		
2004		19			19	12		
2005		19			19	11		
2006		19			19	11		
2007		19			19	11		
2008		19			19	11		
2009		19			19	10		
2010		19			19	10		
2011		19			19	10		
2012		19			19	9		
2013		19			19	9		
2014		19			19	9		
2015		19			19	9		
2016		19			19	8		
2017		19			19	8		
2018		19			19	8		
2019		19			19	8		
2020		19			19	7		
2021		36	91		127	48	26	10
2022		36	91		127	46	26	10
2023		19			19	7		
2024		19			19	7		
2025		19			19	6		
2026		19			19	6		
2027		19			19	6		
2028		19			19	6		
2029		19			19	6		
2030		19			19	5		
2031		19			19	5		
2032		19			19	5		
2033					114	30		
TOTAL	570	604	182	114	1,470	757	52	19
DISC TOTAL	400	259	68	30	757			
UNIT COST (per MtU)	20.71	13.40	3.50	1.56	39.17			
% OF TOTAL DISC COST	53%	34%	9%	4%	100%			

TABLE E-27
 INCREMENTAL LIFE CYCLE COST OF FWMs FACILITIES RESULTING FROM RECEIPT OF 104 MTU
 AS PWR ASSEMBLIES IN 7 PWR ASSEMBLY MESCS AT REPOSITORY
 (MESCS OPENED IN HOT CELL FACILITIES)

COSTS (\$000, 1988)							QUANTITIES (MTU)	
CAPITAL COSTS			OPERATING COSTS			TOTAL COSTS	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
HOT CELL YEAR FACILITIES			HOT CELL FACILITIES	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS DISC. @ 3%/Yr TC 1988		
1998	114					114		
1999	114					114		
2000	114					114		
2001	114					114		
2002	114					114		
2003			19			19		
2004			19			19		
2005			19			19		
2006			19			19		
2007			19			19		
2008			19			19		
2009			19			19		
2010			19			19		
2011			19			19		
2012			19			19		
2013			19			19		
2014			19			19		
2015			19			19		
2016			19			19		
2017			19			19		
2018			19			19		
2019			36	91		127	26	10
2020			36	91		127	26	10
2021			36	91		127	26	10
2022			36	91		127	26	10
2023			19			19		
2024			19			19		
2025			19			19		
2026			19			19		
2027			19			19		
2028			19			19		
2029			19			19		
2030			19			19		
2031			19			19		
2032			19			19		
2033					114	114		
TOTAL	570		638	364	114	1,686	104	40
DISC TOTAL	400		272	139	30	842		
UNIT COST (per kgU)	10.05		6.84	3.50	.76	21.14		
% OF TOTAL DISC COST	48%		32%	17%	4%	100%		

TABLE E-28
INCREMENTAL LIFE CYCLE COST OF PWR FACILITIES RESULTING FROM RECEIPT OF 200 MTU
AS PWR ASSEMBLIES IN 7 PWR ASSEMBLY MESCS AT REPOSITORY
(MESCS OPENED IN HOT CELL FACILITIES)

COSTS (\$000, 1988)							QUANTITIES (MTU)	
CAPITAL COSTS		OPERATING COSTS			TOTAL COSTS			
HOT CELL YEAR FACILITIES		HOT CELL FACILITIES	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 3%/Yr TC 1988	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
1998	114				114	85		
1999	114				114	82		
2000	114				114	80		
2001	114				114	78		
2002	114				114	75		
2003		19			19	12		
2004		19			19	12		
2005		19			19	11		
2006		19			19	11		
2007		19			19	11		
2008		19			19	11		
2009		19			19	10		
2010		19			19	10		
2011		19			19	10		
2012		19			19	9		
2013		19			19	9		
2014		19			19	9		
2015		36	91		127	57	26	12
2016		36	91		127	56	26	11
2017		36	91		127	54	26	11
2018		36	91		127	52	26	11
2019		36	91		127	51	26	10
2020		36	91		127	49	26	10
2021		36	91		127	48	26	10
2022		36	91		127	46	26	10
2023		19			19	7		
2024		19			19	7		
2025		19			19	6		
2026		19			19	6		
2027		19			19	6		
2028		19			19	6		
2029		19			19	6		
2030		19			19	5		
2031		19			19	5		
2032		19			19	5		
2033				114	114	30		
TOTAL	570	706	728	114	2,118	1,028	208	85
DISC TOTAL	400	302	296	30	1,028			
UNIT COST (per kgU)	4.73	3.56	3.50	.36	.215			
% OF TOTAL DISC COST	39%	29%	29%	3%	100%			

TABLE E-29
INCREMENTAL LIFE CYCLE COST OF PWR FACILITIES RESULTING FROM RECEIPT OF 564 MTU
AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT MRS FACILITY
(MESCS OPENED IN HOT CELL FACILITIES -- MSM USED FOR STORAGE)

YEAR	COSTS (\$000, 1988)										QUANTITIES (MTU)	
	CAPITAL COSTS					OPERATING COSTS				TOTAL COSTS	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
	HOT CELL FACILITIES	MSM LOADING EQUIP	MSM	TRANSFER CASE	HOT CELL FACILITIES	STORAGE AREA	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 3%/Yr TO 1988		
1998	1,030								1,030	766		
1999	1,030								1,030	744		
2000	1,030								1,030	722		
2001	1,030								1,030	701		
2002	1,030								1,030	681		
2003					175				175	112		
2004					175				175	109		
2005					175				175	106		
2006					175				175	103		
2007					175				175	100		
2008					175				175	97		
2009					175				175	94		
2010					175				175	91		
2011					175				175	89		
2012					175				175	86		
2013					175				175	84		
2014					175				175	81		
2015					175				175	79		
2016					175				175	76		
2017					175				175	74		
2018					175				175	72		
2019		684			175				859	344		
2020			-2,801		175				-2,626	-1,020	188	73
2021			-2,801		175				-2,626	-990	188	71
2022			-2,801		175				-2,626	-961	188	69
2023					175				175	62		
2024					175				175	60		
2025					175				175	59		
2026				1,000	175				1,175	382		
2027					293	6	1,472		1,771	559		
2028					175			-334	-161	-49		
2029					175				175	52		
2030					175				175	51		
2031					175				175	49		
2032					175				175	48		
2033								1,030	1,030	272		
TOTAL	5,150	684	-8,403	1,000	5,368	6	1,472	694	5,971	3,986	564	213
DISC TOTAL	3,615	274	-3,169	325	2,305	2	465	169	3,986			
UNIT COST (per kgU)	17.00	1.29	-14.90	1.53	10.84	.01	2.19	.80	18.74			
% OF TOTAL DISC COST	91%	7%	-80%	8%	58%	0%	12%	4%	100%			

TABLE E-30
INCREMENTAL LIFE CYCLE COST OF FOMS FACILITIES RESULTING FROM RECEIPT OF 940 MTU
AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT MRS FACILITY
(MESCS OPENED IN HOT CELL FACILITIES -- HSM USED FOR STORAGE)

COSTS (\$000, 1988)											QUANTITIES (MTU)	
YEAR	CAPITAL COSTS				OPERATING COSTS				TOTAL COSTS		ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
	HOT CELL FACILITIES	HSM LOADING EQUIP	HSM	TRANSFER CASK	HOT CELL FACILITIES	STORAGE AREA	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 3%/Yr TO 1988		
1998	1,030								1,030	766		
1999	1,030								1,030	744		
2000	1,030								1,030	722		
2001	1,030								1,030	701		
2002	1,030								1,030	681		
2003					175				175	112		
2004					175				175	109		
2005					175				175	106		
2006					175				175	103		
2007					175				175	100		
2008					175				175	97		
2009					175				175	94		
2010					175				175	91		
2011					175				175	89		
2012					175				175	86		
2013					175				175	84		
2014					175				175	81		
2015					175				175	79		
2016					175				175	76		
2017		684			175				859	365		
2018			-2,801		175				-2,626	-1,082	188	77
2019			-2,801		175				-2,626	-1,050	188	75
2020			-2,801		175				-2,626	-1,020	188	73
2021			-2,801		175				-2,626	-990	188	71
2022			-2,801		175				-2,626	-961	188	69
2023					175				175	62		
2024					175				175	60		
2025					175				175	59		
2026				1,000	175				1,175	382		
2027					372	10	2,453		2,835	895		
2028					175			-615	-441	-135		
2029					175				175	52		
2030					175				175	51		
2031					175				175	49		
2032					175				175	48		
2033								1,030	1,030	272		
TOTAL	5,150	684	-14,005	1,000	5,447	10	2,453	414	1,153	1,978	940	365
DISC TOTAL	3,615	290	-5,443	325	2,330	3	775	84	1,978			
UNIT COST (per kgU)	9.90	.79	-14.90	.89	6.38	.01	2.12	.23	5.42			
% OF TOTAL DISC COST	183%	15%	-275%	16%	118%	0%	39%	4%	100%			

TABLE E-31
 INCREMENTAL LIFE CYCLE COST OF FOMS FACILITIES RESULTING FROM RECEIPT OF 1504 MTU
 AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT MRS FACILITY
 (MESCS OPENED IN HOT CELL FACILITIES -- HSM USED FOR STORAGE)

YEAR	COSTS (\$000, 1988)										QUANTITIES (MTU)	
	CAPITAL COSTS				OPERATING COSTS				TOTAL COSTS		ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
	HOT CELL FACILITIES	HSM LOADING EQUIP	HSM	TRANSFER CASK	HOT CELL FACILITIES	STORAGE AREA	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 3%/Yr TO 1988		
	YEAR FACILITIES	YEAR EQUIP	YEAR	YEAR	YEAR FACILITIES	YEAR AREA	YEAR DISPOSAL	YEAR COSTS	YEAR COSTS	YEAR TO 1988		
1998	1,030								1,030	766		
1999	1,030								1,030	744		
2000	1,030								1,030	722		
2001	1,030								1,030	701		
2002	1,030								1,030	681		
2003					175				175	112		
2004					175				175	109		
2005					175				175	106		
2006					175				175	103		
2007					175				175	100		
2008					175				175	97		
2009					175				175	94		
2010					175				175	91		
2011					175				175	89		
2012					175				175	86		
2013					175				175	84		
2014		684			175				859	398		
2015			-2,801		175				-2,626	-1,182	188	85
2016			-2,801		175				-2,626	-1,148	188	82
2017			-2,801		175				-2,626	-1,114	188	80
2018			-2,801		175				-2,626	-1,082	188	77
2019			-2,801		175				-2,626	-1,050	188	75
2020			-2,801		175				-2,626	-1,020	188	73
2021			-2,801		175				-2,626	-990	188	71
2022			-2,801		175				-2,626	-961	188	69
2023					175				175	62		
2024					175				175	60		
2025					175				175	59		
2026				1,000	175				1,175	382		
2027					491	16	3,925		4,432	1,399		
2028					175			-1,036	-861	-264		
2029					175				175	52		
2030					175				175	51		
2031					175				175	49		
2032					175				175	48		
2033								1,030	1,030	272		
TOTAL	5,150	684	-22,408	1,000	5,566	16	3,925	-6	-6,073	-1,293	1,504	612
DISC TOTAL	3,615	317	-9,117	325	2,367	5	1,239	-45	-1,293			
UNIT COST (per kgU)	5.91	.52	-14.90	.53	3.87	.01	2.03	-.07	-2.11			
% OF TOTAL DISC COST	-280%	-25%	705%	-25%	-183%	0%	-96%	3%	100%			

TABLE E-32
INCREMENTAL LIFE CYCLE COST OF FWMs FACILITIES RESULTING FROM RECEIPT OF 1880 MTU
AS FWR ASSEMBLIES IN 24 FWR ASSEMBLY MESCS AT MRS FACILITY
(MESCS OPENED IN HOT CELL FACILITIES -- MSM USED FOR STORAGE)

COSTS (\$000, 1980)											QUANTITIES (MTU)	
CAPITAL COSTS					OPERATING COSTS				TOTAL COSTS		ANNUAL QUAN. RECEIVED	QUAN DISC @ 32/Yr TO 1980
YEAR	HOT CELL FACILITIES	MSM LOADING EQUIP	MSM	TRANSFER CASK	HOT CELL FACILITIES	STORAGE AREA	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 32/Yr TO 1980		
1998	1,030								1,030	766		
1999	1,030								1,030	744		
2000	1,030								1,030	722		
2001	1,030								1,030	701		
2002	1,030								1,030	681		
2003					175				175	112		
2004					175				175	109		
2005					175				175	106		
2006					175				175	103		
2007					175				175	100		
2008					175				175	97		
2009					175				175	94		
2010					175				175	91		
2011					175				175	89		
2012		684			175				859	423		
2013			-2,801		175				-2,626	-1,254	188	90
2014			-2,801		175				-2,626	-1,218	188	87
2015			-2,801		175				-2,626	-1,182	188	85
2016			-2,801		175				-2,626	-1,148	188	82
2017			-2,801		175				-2,626	-1,114	188	80
2018			-2,801		175				-2,626	-1,082	188	77
2019			-2,801		175				-2,626	-1,050	188	75
2020			-2,801		175				-2,626	-1,020	188	73
2021			-2,801		175				-2,626	-990	188	71
2022			-2,801		175				-2,626	-961	188	69
2023					175				175	62		
2024					175				175	60		
2025					175				175	59		
2026				1,000	175				1,175	382		
2027					570	20	4,907		5,497	1,736		
2028					175			-1,317	-1,142	-350		
2029					175				175	52		
2030					175				175	51		
2031					175				175	49		
2032					175				175	48		
2033								1,030	1,030	272		
TOTAL	5,150	684	-28,010	1,000	5,645	20	4,907	-287	-10,891	-3,660	1,880	789
DISC TOTAL	3,615	336	-11,754	325	2,392	6	1,549	-131	-3,660			
UNIT COST (per kgU)	4.58	.43	-14.90	.41	3.03	.01	1.96	-.17	-4.64			
% OF TOTAL DISC COST	-99%	-9%	321%	-9%	-65%	0%	-42%	4%	100%			

TABLE E-33
 INCREMENTAL LIFE CYCLE COST OF PWRMS FACILITIES RESULTING FROM RECEIPT OF 58 MTU
 AS PWR ASSEMBLIES IN 7 PWR ASSEMBLY MESCS AT MRS FACILITY
 (MESCS OPENED IN HOT CELL FACILITIES -- HSM USED FOR STORAGE)

COSTS (\$000, 1988)											QUANTITIES (MTU)	
CAPITAL COSTS					OPERATING COSTS				TOTAL COSTS		ANNUAL QUAN. RECEIVED	QUAN DISC @ 3% Yr TO 1988
YEAR	HOT CELL FACILITIES	HSM LOADING EQUIP	HSM	TRANSFER CASK	HOT CELL FACILITIES	STORAGE AREA	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 3%/Yr TO 1988		
1998		114							114	85		
1999		114							114	82		
2000		114							114	80		
2001		114							114	78		
2002		114							114	75		
2003					19				19	12		
2004					19				19	12		
2005					19				19	11		
2006					19				19	11		
2007					19				19	11		
2008					19				19	11		
2009					19				19	10		
2010					19				19	10		
2011					19				19	10		
2012					19				19	9		
2013					19				19	9		
2014					19				19	9		
2015					19				19	9		
2016					19				19	8		
2017					19				19	8		
2018					19				19	8		
2019		76			19				95	38		
2020					19				19	7		
2021					19				19	7		
2022			-252		19				-233	-85	58	21
2023					19				19	7		
2024					19				19	7		
2025					19				19	6		
2026				1,000	19				1,019	331		
2027					58	2	202		262	83		
2028					19			41	60	18		
2029					19				19	6		
2030					19				19	5		
2031					19				19	5		
2032					19				19	5		
2033								114	114	38		
TOTAL	570	76	-252	1,000	609	2	202	155	2,362	1,029	58	21
DISC TOTAL	400	30	-92	325	259	1	64	43	1,029			
UNIT COST (per kgU)	18.85	1.43	-4.34	15.32	12.18	.03	3.00	2.01	48.48			
% OF TOTAL DISC COST	39%	3%	-9%	32%	25%	0%	6%	4%	100%			

TABLE E-34
 INCREMENTAL LIFE CYCLE COST OF FOMS FACILITIES RESULTING FROM RECEIPT OF 116 MTU
 AS PWR ASSEMBLIES IN 7 PWR ASSEMBLY MESCS AT MRS FACILITY
 (MESCS OPENED IN HOT CELL FACILITIES -- HSM USED FOR STORAGE)

COSTS (\$000, 1988)											QUANTITIES (MTU)	
YEAR	CAPITAL COSTS				OPERATING COSTS				TOTAL COSTS	DISC. @ 3%/Yr TO 1988	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
	HOT CELL FACILITIES	HSM LOADING EQUIP	HSM	TRANSFER CASK	HOT CELL FACILITIES	STORAGE AREA	MESC DISPOSAL	DECOMM COSTS				
1998		114							114	85		
1999		114							114	82		
2000		114							114	80		
2001		114							114	78		
2002		114							114	75		
2003					19				19	12		
2004					19				19	12		
2005					19				19	11		
2006					19				19	11		
2007					19				19	11		
2008					19				19	11		
2009					19				19	10		
2010					19				19	10		
2011					19				19	10		
2012					19				19	9		
2013					19				19	9		
2014					19				19	9		
2015					19				19	9		
2016					19				19	8		
2017		76			19				95	40		
2018					19				19	8		
2019					19				19	8		
2020					19				19	7		
2021			-252		19				-233	-88	58	22
2022			-252		19				-233	-85	58	21
2023					19				19	7		
2024					19				19	7		
2025					19				19	6		
2026				1,000	19				1,019	331		
2027					97	4	405		506	160		
2028					19			29	48	15		
2029					19				19	6		
2030					19				19	5		
2031					19				19	5		
2032					19				19	5		
2033								114	114	30		
TOTAL	570	76	-504	1,000	648	4	405	143	2,342	1,009	116	43
DISC TOTAL	400	32	-187	325	271	1	128	39	1,009			
UNIT COST (per kgU)	9.28	.75	-4.34	7.55	6.28	.03	2.97	.91	23.42			
% OF TOTAL DISC COST	40%	3%	-19%	32%	27%	0%	13%	4%	100%			

TABLE E-35
 INCREMENTAL LIFE CYCLE COST OF PWS FACILITIES RESULTING FROM RECEIPT OF 232 MTU
 AS PWR ASSEMBLIES IN 7 PWR ASSEMBLY MESCS AT MRS FACILITY
 (MESCS OPENED IN HOT CELL FACILITIES -- HSM USED FOR STORAGE)

COSTS (\$000, 1988)											QUANTITIES (MTU)	
CAPITAL COSTS					OPERATING COSTS				TOTAL COSTS		ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/YR TO 1988
YEAR	HOT CELL FACILITIES	HSM LOADING EQUIP	HSM	TRANSFER CASK	HOT CELL FACILITIES	STORAGE AREA	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC, @ 3% Yr TO 1988		
1998	114								114	85		
1999	114								114	82		
2000	114								114	80		
2001	114								114	78		
2002	114								114	75		
2003					19				19	12		
2004					19				19	12		
2005					19				19	11		
2006					19				19	11		
2007					19				19	11		
2008					19				19	11		
2009					19				19	10		
2010					19				19	10		
2011					19				19	10		
2012		76			19				95	47		
2013					19				19	9		
2014					19				19	9		
2015					19				19	9		
2016					19				19	8		
2017					19				19	8		
2018					19				19	8		
2019			-252		19				-233	-93	58	23
2020			-252		19				-233	-90	58	23
2021			-252		19				-233	-88	58	22
2022			-252		19				-233	-85	58	21
2023					19				19	7		
2024					19				19	7		
2025					19				19	6		
2026				1,000	19				1,019	331		
2027					174	8	810		992	313		
2028					19			4	23	7		
2029					19				19	6		
2030					19				19	5		
2031					19				19	5		
2032					19				19	5		
2033								114	114	30		
TOTAL	570	76	-1,008	1,000	725	8	810	118	2,299	962	232	89
DISC TOTAL	400	37	-386	325	295	3	256	31	962			
UNIT COST (per kgU)	4.50	.42	-4.34	3.66	3.32	.03	2.88	.35	10.83			
% OF TOTAL DISC COST	42%	4%	-40%	34%	31%	0%	27%	3%	100%			

TABLE E-36
 INCREMENTAL LIFE CYCLE COST OF PWR FACILITIES RESULTING FROM RECEIPT OF 564 MTU
 AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT MRS FACILITY
 (MESCS OPENED OUTSIDE OF HOT CELL FACILITIES AFTER STORAGE -- HSM USED FOR STORAGE)

YEAR	COSTS (\$000, 1988)										QUANTITIES (MTU)	
	CAPITAL COSTS				OPERATING COSTS				TOTAL COSTS		ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1989
	MESC OPENING EQUIP	TRANSFER CASK	HSM LOADING EQUIP	HSM	MESC OPENING	STORAGE AREA	MESC DISPOSAL	DECOMF COSTS	TOTAL COSTS	DISC. @ 3%/Yr TO 1988		
1998												
1999												
2000												
2001												
2002												
2003												
2004												
2005												
2006												
2007												
2008												
2009												
2010												
2011												
2012												
2013												
2014												
2015												
2016												
2017												
2018												
2019			684						684	274		
2020				-2,801					-2,801	-1,088	188	73
2021				-2,801					-2,801	-1,056	188	71
2022				-2,801					-2,801	-1,025	188	49
2023												
2024												
2025												
2026	399	1,000							1,399	455		
2027					186	6	1,472		1,664	525		
2028								-316	-316	-97		
2029												
2030												
2031												
2032												
2033												
TOTAL	399	1,000	684	-8,403	186	6	1,472	-316	-4,972	-2,012	564	213
DISC TOTAL	130	325	274	-3,169	59	2	465	-77	-2,012			
UNIT COST (per kgJ)	.61	1.53	1.29	-14.90	.28	.01	2.19	-.46	-9.46			
% OF TOTAL DISC COST	-6%	-16%	-14%	158%	-3%	0%	-23%	5%	100%			

TABLE E-37
 INCREMENTAL LIFE CYCLE COST OF FWH FACILITIES RESULTING FROM RECEIPT OF 940 MTU
 AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT MFS FACILITY
 (MESCS OPENED OUTSIDE OF HOT CELL FACILITIES AFTER STORAGE -- HSM USED FOR STORAGE)

YEAR	COSTS (\$000, 1988)										QUANTITIES (MTU)	
	CAPITAL COSTS					OPERATING COSTS				TOTAL COSTS	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1989
	MESC OPENING EQUIP	TRANSFER CASE	HSM LOADING EQUIP	HSM	MESC OPENING	STORAGE AREA	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 3%/Yr TO 1988		
1998												
1999												
2000												
2001												
2002												
2003												
2004												
2005												
2006												
2007												
2008												
2009												
2010												
2011												
2012												
2013												
2014												
2015												
2016												
2017			684						684	290		
2018				-2,801					-2,801	-1,154	188	77
2019				-2,801					-2,801	-1,120	188	75
2020				-2,801					-2,801	-1,088	188	73
2021				-2,801					-2,801	-1,056	188	71
2022				-2,801					-2,801	-1,025	188	69
2023												
2024												
2025												
2026	399	1,000							1,399	455		
2027					310	10	2,453		2,773	876		
2028								-596	-596	-183		
2029												
2030												
2031												
2032												
2033												
TOTAL	399	1,000	684	-14,005	310	10	2,453	-596	-9,745	-4,005	940	365
DISC TOTAL	130	325	290	-5,443	98	3	775	-193	-4,005			
UNIT COST (per kgJ)	.36	.89	.79	-14.90	.27	.01	2.12	-.50	-10.96			
% OF TOTAL DISC COST	3%	8%	7%	136%	2%	0%	19%	5%	100%			

TABLE E-38
 INCREMENTAL LIFE CYCLE COST OF FWM FACILITIES RESULTING FROM RECEIPT OF 1504 MTU
 AS FWR ASSEMBLIES IN 24 FWR ASSEMBLY MESCS AT MRS FACILITY
 (MESCS OPENED OUTSIDE OF HOT CELL FACILITIES AFTER STORAGE -- HSM USED FOR STORAGE)

YEAR	COSTS (\$000, 1988)										QUANTITIES (MTU)	
	CAPITAL COSTS				OPERATING COSTS				TOTAL COSTS		ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
	MESC OPENING EQUIP	TRANSFER CASK	HSM LOADING EQUIP	HSM	MESC OPENING	STORAGE AREA	MESC DISPOSAL	DECOMM COSTS	TOTAL COSTS	DISC. @ 3%/Yr TO 1988		
1998												
1999												
2000												
2001												
2002												
2003												
2004												
2005												
2006												
2007												
2008												
2009												
2010												
2011												
2012												
2013												
2014			684						684	317		
2015				-2,801					-2,801	-1,261	188	85
2016				-2,801					-2,801	-1,224	188	92
2017				-2,801					-2,801	-1,189	188	80
2018				-2,801					-2,801	-1,154	188	77
2019				-2,801					-2,801	-1,120	188	75
2020				-2,801					-2,801	-1,088	188	73
2021				-2,801					-2,801	-1,056	188	71
2022				-2,801					-2,801	-1,025	188	69
2023												
2024												
2025												
2026	399	1,000							1,399	455		
2027					496	16	3,925		4,437	1,401		
2028								-1,016	-1,016	-311		
2029												
2030												
2031												
2032												
2033												
TOTAL	399	1,000	684	-22,408	496	16	3,925	-1,016	-16,904	-7,256	1,504	612
DISC TOTAL	130	325	317	-9,117	157	5	1,239	-311	-7,256			
UNIT COST (per kgJ)	.21	.53	.52	-14.90	.26	.01	2.03	-.51	-11.86			
% OF TOTAL DISC COST	-2%	-4%	-4%	126%	-2%	0%	-17%	4%	100%			

TABLE E-39
 INCREMENTAL LIFE CYCLE COST OF FWR FACILITIES RESULTING FROM RECEIPT OF 1880 MTJ
 AS PWR ASSEMBLIES IN 24 PWR ASSEMBLY MESCS AT MRS FACILITY
 (MESCS OPENED OUTSIDE OF HOT CELL FACILITIES AFTER STORAGE -- HSM USED FOR STORAGE)

YEAR	COSTS (\$000, 1988)										QUANTITIES (MTU)		
	CAPITAL COSTS					OPERATING COSTS				TOTAL COSTS	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988	
	MESC OPENING EQUIP	TRANSFER CASK	HSM LOADING EQUIP	HSM	MESC OPENING	STORAGE AREA	MESC DISPOSAL	DECOMP COSTS	TOTAL COSTS	DISC. @ 3%/Yr TO 1988			
1998													
1999													
2000													
2001													
2002													
2003													
2004													
2005													
2006													
2007													
2008													
2009													
2010													
2011													
2012				684						684	336		
2013					-2,801					-2,801	-1,338	188	90
2014					-2,801					-2,801	-1,299	188	97
2015					-2,801					-2,801	-1,261	188	85
2016					-2,801					-2,801	-1,224	188	92
2017					-2,801					-2,801	-1,189	188	80
2018					-2,801					-2,801	-1,154	188	77
2019					-2,801					-2,801	-1,120	188	75
2020					-2,801					-2,801	-1,088	188	73
2021					-2,801					-2,801	-1,056	188	71
2022					-2,801					-2,801	-1,025	188	69
2023													
2024													
2025													
2026	399	1,000								1,399	455		
2027						620	20	4,907		5,547	1,751		
2028									-1,297	-1,297	-398		
2029													
2030													
2031													
2032													
2033													
TOTAL	399	1,000	684	-28,010	620	20	4,907	-1,297	-21,677	-9,608		1,880	789
DISC TOTAL	130	325	336	-11,754	196	6	1,549	-378	-9,608				
UNIT COST (per kgU)	.16	.41	.43	-14.90	.25	.01	1.96	-.50	-12.18				
% OF TOTAL DISC COST	-1%	-3%	-4%	122%	-2%	0%	-16%	4%	100%				

TABLE E-40
 INCREMENTAL LIFE CYCLE COST OF PWR FACILITIES RESULTING FROM RECEIPT OF 58 MTU
 AS PWR ASSEMBLIES IN 7 PWR ASSEMBLY MESCS AT MRS FACILITY
 (MESCS OPENED OUTSIDE OF HOT CELL FACILITIES AFTER STORAGE -- HSM USED FOR STORAGE)

YEAR	COSTS (\$000, 1988)										QUANTITIES (MTU)	
	CAPITAL COSTS				OPERATING COSTS				TOTAL COSTS		ANNUAL QUAN. RECEIVED	QUAN. DISC @ 3%/Yr TO 1989
	MESC OPENING EQUIP	TRANSFER CASK	HSM LOADING EQUIP	HSM	MESC OPENING	STORAGE AREA	MESC DISPOSAL	DECOMP COSTS	TOTAL COSTS	DISC. @ 3%/Yr TO 1988		
1998												
1999												
2000												
2001												
2002												
2003												
2004												
2005												
2006												
2007												
2008												
2009												
2010												
2011												
2012												
2013												
2014												
2015												
2016												
2017												
2018												
2019			76						76	30		
2020												
2021												
2022				-252					-252	-92	58	21
2023												
2024												
2025												
2026	100	1,000							1,100	358		
2027					50	2	202		254	80		
2028								46	46	14		
2029												
2030												
2031												
2032												
2033												
TOTAL	100	1,000	76	-252	50	2	202	46	1,224	390	58	21
DISC TOTAL	33	325	30	-92	16	1	64	14	390			
UNIT COST (per kgJ)	1.53	15.32	1.43	-4.34	.74	.03	3.00	.46	18.38			
% OF TOTAL DISC COST	8%	83%	8%	-24%	4%	0%	16%	4%	100%			

TABLE E-41
 INCREMENTAL LIFE CYCLE COST OF PWR FACILITIES RESULTING FROM RECEIPT OF 116 NTU
 AS PWR ASSEMBLIES IN 7 PWR ASSEMBLY MESCS AT MRS FACILITY
 (MESCS OPENED OUTSIDE OF HOT CELL FACILITIES AFTER STORAGE -- HSM USED FOR STORAGE)

YEAR	COSTS (\$000, 1988)										QUANTITIES (NTU)	
	CAPITAL COSTS				OPERATING COSTS				TOTAL COSTS		ANNUAL QUAN. RECEIVED	PLAN DISC @ 3%/Yr TO 1989
	MESC OPENING EQUIP	TRANSFER CASK	HSM LOADING EQUIP	HSM	MESC OPENING	STORAGE AREA	MESC DISPOSAL	DECOMP COSTS	TOTAL COSTS	DISC. @ 3%/Yr TO 1988		
1998												
1999												
2000												
2001												
2002												
2003												
2004												
2005												
2006												
2007												
2008												
2009												
2010												
2011												
2012												
2013												
2014												
2015												
2016												
2017			76							76	32	
2018												
2019												
2020												
2021					-252					-252	-95	58
2022					-252					-252	-92	58
2023												22
2024												21
2025												
2026	100	1,000								1,100	358	
2027						100	4	405		509	161	
2028									34	34	10	
2029												
2030												
2031												
2032												
2033												
TOTAL	100	1,000	76	-504		100	4	405	34	1,215	374	116
DISC TOTAL	33	325	32	-187		32	1	128	10	374		43
UNIT COST (per kgU)	.75	7.55	.75	-4.34		.73	.03	2.97	.24	8.68		
% OF TOTAL DISC COST	9%	87%	9%	-50%		8%	0%	34%	3%	100%		

TABLE E-42
 INCREMENTAL LIFE CYCLE COST OF FOMS FACILITIES RESULTING FROM RECEIPT OF 232 MTU
 AS PWR ASSEMBLIES IN 7 PWR ASSEMBLY MESCS AT MRS FACILITY
 (MESCS OPENED OUTSIDE OF HOT CELL FACILITIES AFTER STORAGE -- HSM USED FOR STORAGE)

YEAR	COSTS (\$000, 1988)										QUANTITIES (MTU)	
	CAPITAL COSTS					OPERATING COSTS				TOTAL COSTS	ANNUAL QUAN. RECEIVED	QUAN DISC @ 3%/Yr TO 1988
	MESC OPENING EQUIP	TRANSFER CASK	HSM LOADING EQUIP	HSM	MESC OPENING	STORAGE AREA	MESC DISPOSAL	DECOMP COSTS	TOTAL COSTS	DISC. @ 3%/Yr TO 1988		
1998												
1999												
2000												
2001												
2002												
2003												
2004												
2005												
2006												
2007												
2008												
2009												
2010												
2011												
2012				76					76	37		
2013												
2014												
2015												
2016												
2017												
2018												
2019					-252				-252	-101	58	23
2020					-252				-252	-98	58	23
2021					-252				-252	-95	58	22
2022					-252				-252	-92	58	21
2023												
2024												
2025												
2026	100	1,000							1,100	358		
2027					200	8	810		1,018	321		
2028								9	9	3		
2029												
2030												
2031												
2032												
2033												
TOTAL	100	1,000	76	-1,008	200	8	810	9	1,195	333	232	89
DISC TOTAL	33	325	37	-386	63	3	256	3	333			
UNIT COST (per kgJ)	.37	3.66	.42	-4.34	.71	.03	2.88	.03	3.75			
% OF TOTAL DISC COST	10%	98%	11%	-116%	19%	1%	77%	1%	100%			

Year	Costs Incurred		Value of Service	
	Total Annual Costs	Discounted @ 3%/Yr To 1989	Total Annual Costs ^a	Discounted @ 3%/Yr To 1989
1989	\$100.0	\$100.0		
1990	5.0	4.9	\$ 10.0C	\$ 9.7C
1991	5.0	4.7	10.0C	9.4C
1992	5.0	4.6	10.0C	9.2C
1993	5.0	4.4	10.0C	8.9C
1994	5.0	4.3	10.0C	8.6C
1995	5.0	4.2	10.0C	8.4C
1996	5.0	4.1	10.0C	8.1C
1997	5.0	3.9	10.0C	7.9C
1998	5.0	3.8	10.0C	7.7C
1999	5.0	3.7	10.0C	7.4C
Total	<u>\$150.0</u>	<u>\$142.7</u>	<u>\$100.0C</u>	<u>\$ 85.3C</u>

$$C, \text{Levelized Unit Cost} = \frac{\$142.7}{85.3} = \$1.6723$$

^a Number of units times the levelized unit cost (C).

This levelized unit cost of \$1.6723/unit is the unit cost that when escalated at the inflation rate and applied to the specific quantities involved, will provide enough money to pay all costs that are incurred, inflated as appropriate, plus imputed interest on the difference between the costs incurred and the payments made (or benefits accrued). This is demonstrated in the following table which shows the cash flows involved for two different combinations of inflation rates and money values, with the ratios between the two being held constant at 1.03.

	<u>Inflated Cost</u>	<u>Value of Service^a</u>	<u>Amount Cost Is In Excess Of Value Received</u>	<u>Imputed Interest On Excess At Indicated Value Of Money</u>
<u>No Inflation; Value of Money 3%</u>				
1989	\$100.0		\$100.0	\$ 3.0
1990	5.0	\$ 16.7	91.3	2.7
1991	5.0	16.7	82.3	2.5
1992	5.0	16.7	73.1	2.2
1993	5.0	16.7	63.6	1.9
1994	5.0	16.7	53.8	1.6
1995	5.0	16.7	43.7	1.3
1996	5.0	16.7	33.3	1.0
1997	5.0	16.7	22.6	0.7
1998	5.0	16.7	11.6	0.4
1999	5.0	16.7	.3	
Total	<u>\$150.0</u>	<u>\$167.0</u>		<u>\$ 17.3</u>
<u>6.8%/Yr. Inflation; Value of Money 10%</u>				
1989	100.0		100.0	10.0
1990	5.3	17.9	97.4	9.7
1991	5.7	19.1	93.7	9.4
1992	6.1	20.4	88.8	8.9
1993	6.5	21.8	82.4	8.2
1994	6.9	23.2	74.3	7.4
1995	7.4	24.8	64.3	6.4
1996	7.9	26.5	52.1	5.2
1997	8.5	28.3	37.5	3.8
1998	9.0	30.2	20.1	2.0
1999	9.7	32.3	-.5	
Total	<u>\$173.0</u>	<u>\$244.5</u>		<u>\$ 71.0</u>

^a Number of units times the levelized unit costs, escalated to the time service is performed at the indicated inflation rate.

From the foregoing it can be seen that the value of service exactly (except for rounding) offsets the inflated costs plus the imputed interest on costs unrecovered by service value. This demonstrates the suitability of this method of determination of levelized unit cost. It also illustrates the significance of the levelized unit cost under two typical ways of doing long-

term cost evaluations: the first way, with zero inflation, is frequently called the "constant dollar" evaluation; the second way, with actual inflation (and actual interest) is frequently called the "actual dollar" evaluation. In the "constant dollar" evaluation, the unit cost is the "constant-dollar" unit cost that is recovered (or accrued) for all units of the product, at all times. In the "actual dollar" evaluation, the unit cost is the unit cost at time zero, and the actual unit cost collected (or accrued) in subsequent years is this time-zero unit cost, multiplied by the escalation factor appropriate to the time of production.

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