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Comparative Economics for DUCRETE Spent Fuel Storage Cask Handling, Transportation, and Capital Requirements

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**F. P. Powell
Sierra Nuclear Corporation
Roswell, Georgia**

Published April 1995

**Idaho National Engineering Laboratory
Environmental and Life Sciences Products Department
Lockheed Idaho Technologies Company
Idaho Falls, Idaho 83415**

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Comparative Economics for DUCRETE Spent Fuel Storage Cask Handling, Transportation, and Capital Requirements

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Prepared by:

F. P. Powell
Sierra Nuclear Corporation

April 26, 1995
Date

Reviewed and Approved by:

William J. Quapp, Project Manager
Depleted Uranium Recycle Project

May 18, 1995
Date

ABSTRACT

This report summarizes the economic differences between a DUCRETE spent nuclear fuel storage cask and a conventional concrete storage cask in the areas of handling, transportation, and capital requirements. The DUCRETE spent fuel cask is under evaluation as a new technology that could substantially reduce the overall costs of spent fuel and depleted uranium disposal. DUCRETE incorporates depleted uranium in a Portland cement mixture and functions as the cask's primary radiation barrier. The cask system design includes insertion of the U.S. Department of Energy (DOE) Multi-Purpose Canister (MPC) inside the DUCRETE cask. The economic comparison is from the time a cask is loaded in a spent fuel pool until it is placed in the repository and includes the utility and overall U.S. system perspectives.

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ACRONYMS

DOE	U.S. Department of Energy
DTC	DOE transportation cask
DU	depleted uranium
INEL	Idaho National Engineering Laboratory
ISFSI	independent spent fuel storage installation
LLW	low level waste
MGDS	mined geologic disposal system
MPC	multi-purpose canister
MRS	monitored retrievable storage
MSB	multi-assembly sealed basket
MTC	MPC transfer cask
OCRWM	Office of Civilian Radioactive Waste Management
OP	overpack
SNC	Sierra Nuclear Corporation
TOP	transportation overpack
TVSC	transportable spent fuel storage cask
VSC	ventilated storage cask

Comparative Economics for DUCRETE Spent Fuel Storage Cask Handling, Transportation, and Capital Requirements

1. INTRODUCTION

1.1 Background

Spent nuclear fuel storage requirements are projected to exceed most U.S. utilities' spent fuel pool capacities, so some form of interim storage or permanent disposal is needed. In 1982, the U.S. Department of Energy (DOE) was directed by Congress to provide a permanent disposal facility (Nuclear Waste Policy Act). In 1987, Congress passed the Nuclear Waste Policy Amendments Act, which authorized DOE to provide an interim storage facility preceding the availability of a final repository. The DOE Office of Civilian Radioactive Waste Management (OCRWM) developed two conceptual facilities as a result of this legislation. The first facility scheduled for construction and use is the monitored retrievable storage (MRS) facility for the interim storage of spent fuel; the second is the mined geologic disposal system (MGDS), which will function as a permanent repository. While these facilities are scheduled for operation in 1998 and 2010, respectively, there is now debate on whether or not the MRS will ever be built. There is also serious question concerning the ability to meet the announced schedule of the MGDS. As a result, U.S. utilities are proceeding with their own plans for spent fuel interim storage. The most likely avenue is the construction and operation of Independent Spent Fuel Storage Installations (ISFSI) at the reactor sites.

The primary vehicle for interim storage of spent fuel is dry storage casks. This technology involves two basic types of shielding materials, concrete and metal compounds. A new cask technology under development is based on DUCRETE, which uses depleted uranium oxide as the aggregate in a Portland cement mixture. The result is an ultra high density concrete that serves as the primary shielding barrier instead of concrete or metal.

Depleted uranium (DU) used in spent fuel shielding and other applications (armor piercing shells, etc.) has consumed only a very small portion of the DU inventory. Depleted uranium is a low-level waste (LLW) that will have to be disposed of in a LLW facility unless an alternative use is

found. Currently, the DOE has about 400,000 metric tons of depleted uranium, and disposal cost estimates range from \$4.00 to \$15.00/kg. Using depleted uranium in a DUCRETE cask that is eventually placed in the MGDS will avoid the need to dispose of the depleted uranium as LLW. The current design for the DUCRETE cask uses about 40 metric tons of depleted uranium per cask. Placing all of the U.S. spent fuel (about 86,000 metric tons) in DUCRETE casks would require about 9,500 casks and use most of the current DOE depleted uranium inventory.

1.2 General Assumptions and Methodology

The general assumptions and methodology used in this report are discussed in the following paragraphs. In the more detailed sections of this report, additional assumptions are identified for individual casks, specific handling operations, case development, etc.

Under the DOE OCRWM, a safe, environmentally sound, standardized approach for the handling, storage, transportation, and disposal of spent nuclear fuel was to be designed. To facilitate this, the Multi-Purpose Canister (MPC) was developed to handle the vast majority of spent fuel. The MPC is a metal canister that will be loaded in a spent fuel pool and then welded closed. Subsequent movement of the spent fuel will be accomplished via the MPC as opposed to handling individual assemblies. In this report, MPC interim storage is assumed to occur at the reactor site (ISFSI) in a storage cask. For final disposal, the MPC will be shipped to the MGDS with final disposition in either a DUCRETE cask or a stainless steel disposal overpack. The Sierra Nuclear Corporation (SNC) Multi-assembly Sealed Basket (MSB), a good example of the MPC concept, is shown in Figure 1.

This report assumes the use of an MPC in all cask types under discussion and a capacity of 9.1 MTU per cask. The MPC includes a stainless steel fuel basket with fixed neutron poisons as well as the shield and structural lids. Cask handling operations are defined as beginning with loading of the MPC in a reactor spent fuel pool and ending with final disposition at the repository. The intermediate step of interim storage is assumed to occur at an ISFSI.

Depending upon the type of dry storage cask system selected, different costs will be incurred. This report focuses on the differences in cost for three types of cask systems: 1) a conventional concrete storage cask; 2) a DUCRETE storage cask; and 3) a DUCRETE storage cask that is transportable. Metal storage and dual purpose casks were not considered in this evaluation due to their

Figure 1. Sierra Nuclear multi-assembly sealed basket.

high capital cost (approximately three times that of a conventional concrete system); however, the handling characteristics of metal casks will be very similar to those of DUCRETE casks.

The areas of evaluation are capital costs, cask handling operations, labor requirements and costs, dose accumulation and costs, and transportation costs pertinent to each cask system. Capital cost information has been obtained from conceptual studies performed by the Idaho National Engineering Laboratory (INEL) and SNC. Capital costs include all costs necessary for a given component, from production through delivery, and are representative of the total cost the end user will incur unless otherwise noted. All capital and other cost data are presented in constant dollars. Handling times, dose rates, and personnel requirements are from a variety of sources, including actual operating experience and estimates, industry publications, safety analyses, and topical reports. Handling operations are considered in two primary time frames: 1) from loading of the MPC in the spent fuel pool through interim storage at the ISFSI; and 2) after at least twenty years of storage at the ISFSI, transport to and final placement of the MPCs in the repository. After comparison of the individual cask systems, their individual characteristics are applied and compared from an average utility perspective and then on a total U.S. system basis.

2. CASK SYSTEM ECONOMICS

This section describes the three types of spent fuel storage cask systems considered (conventional concrete, DUCRETE, and transportable DUCRETE) and their economic characteristics. Capital costs include the major components required for a given cask system and unique support equipment, such as transfer casks, required for broad-scale use in the time frames considered. Cask handling operations and their respective costs are from the time the MPC is loaded in the spent fuel pool through final placement at the repository. Transportation costs are also identified for each type of cask.

2.1 Sierra Nuclear Ventilated Concrete Storage Cask

The conventional concrete cask system considered in this report is the SNC Ventilated Storage Cask (VSC); the basic VSC design is common to all casks in this study. The system is designed to store fuel for at least fifty years. Spent fuel is loaded, stored, and cooled in the vertical position. The VSC has four basic components: a 29-inch thick outer shell constructed of reinforced concrete, a 1.75-inch inner carbon steel liner, ventilation duct work that allows the decay heat to be removed by natural circulation, and a 3/4-inch steel lid. The SNC VSC-24, shown in Figure 2, holds 24 PWR spent fuel assemblies in the MSB. In this report, the SNC MSB is considered to function as a MPC.^a The MPC will be stored in the central cavity of the VSC. Downstream, after ISFSI storage, an MPC coming from storage in a VSC will require additional components, such as a transportation cask and a final disposal overpack at the repository.

One of the primary differences between casks in this report is the requirement for a transfer cask (MTC) for handling the MPC. Since the MPC has no shielding capability, if it cannot be placed into the storage cask before being loaded with spent fuel, a method of moving a loaded MPC from the pool to the cask is required. For the SNC VSC this is accomplished with a transfer cask, illustrated in Figure 3.

a. The primary differences between the MPC and the MSB are that the MSB is fabricated with carbon steel and contains no neutron absorbers.

Figure 2. SNC VSC and MSB.

SK030

Figure 3. MPC transfer cask.

2.1.1 Capital Costs

The MPC, which is used in all the cask systems considered, will eventually be supplied to the utilities by DOE. This report assumes DOE bears this cost, estimated at \$250,000 each, for all cask systems under evaluation. (Currently, utilities would bear the cost of the MSB as part of a storage cask system.) The VSC materials, without an MPC/MSB, cost about \$200,000 (not including engineering, design, project management, etc.). One MTC is required for each reactor site; it costs approximately \$750,000. The costs of additional components required after ISFSI storage, such as a transportation cask and a final disposal overpack, are included in a subsequent section of this study; the ISFSI is not included as a component in economic comparisons.

2.1.2 Cask Handling Operations

There is reasonable experience with conventional concrete cask handling operations from the time spent fuel assemblies are loaded into the MPC in the spent fuel pool through storage cask placement at the ISFSI. Although operations to unload the MPC from the storage cask at the ISFSI through shipment off-site have not occurred yet, they should parallel similar operations and tasks that have been performed in the cask loading cycle. A simplified pictorial sequence of the operations involved with MPC loading through shipment off-site is shown in Figures 4a through 4d. The operations, and their economic impact, that are or can be expected to be performed from the time fuel is loaded in the utility pool until the time of shipment off-site are shown in Table 1. The primary MPC movements occur at two times, 1) from the time of MPC loading in the spent fuel pool to placement at the ISFSI, and 2) approximately 20 plus years later, at the time the MPC is removed from the VSC and loaded into a DOE transportation cask (DTC) for shipment to the repository. Six different major operations are identified for the utility during these two times that include a variety of tasks applicable to each operation.

This section also projects the tasks required for DOE at the MGDS. Certain tasks in this area are difficult to quantify absent hard information on the subject. The MPC coming from the SNC VSC will require some form of disposal overpack and remote operations. The cost of these remote operations was conservatively estimated in Table 1 at 3 times the labor cost associated with the comparable but not remote Steps 7.6 - 7.10 of Table 2. This increased the handling cost of the MPC coming from a SNC VSC by about \$4,000 per cask. An additional cost penalty may be built into the off-loading and loading sequence identified in Table 1 Steps 7.3 - 7.4, handling of the overpack. This

1. The empty MPC is lowered into the MTC.

2. The MPC/MTC is lowered into the spent fuel pool.

3. Fuel loading

a. Loading the MPC.

4. The shield lid is placed on the MPC

MPC Shield Lid

Figure 4. Sequence of the operations in MPC loading through shipment off-site.

5. The MPC\WTC is removed from the spent fuel pool.

Loaded MTC/MPC

6. The MPC\WTC is lowered into the decon area.

Drain, Dry, Inert MPC,
Weld Shield and Structural Lids.

7. The MTC is placed on VSC. The MTC bottom doors open allowing the transfer of the MPC into the VSC.

VSC

8. The VSC is closed.

9. The loaded VSC ready for ISFSI placement.

Figure 4b. MPC closure and transfer.

10. The loaded VSC is then transported to the ISFSI site.

11. The ISFSI site

Figure 4c. ISFSI placement.

10. MPC is raised from the VSC into the MTC.

11. The MPC is then lowered into the DOE transportation cask.

12. The DOE transportation cask is then transported by rail to the final repository.

Figure 4d. Off-site shipment.

Table 1. Handling Operations and Tasks for a SNC VSC

	<u>Manhours</u>	<u>Labor Cost, \$</u>	<u>Dose mrem</u>	<u>Dose Cost, \$</u>	<u>Total Cost, \$</u>
Loading & Storage					
<u>1. Fuel Loading</u>					
1.1 Lift and lower MTC with MPC into pool	16	800	33	330	1130
1.2 Load MPC with spent fuel assemblies	16	640	12	120	760
1.3 Lift and place shield lid on MPC	24	1195	30	300	1495
1.4 Lift MTC with MPC and wash exterior	<u>24</u>	<u>1195</u>	<u>40</u>	<u>400</u>	<u>1595</u>
Sub-Totals	80	3,830	115	1,150	4,980
<u>2. MPC Closure</u>					
2.1 Weld MPC shield lid and inspect	72	3520	125	1250	4770
2.2 Decon MTC	6	290	20	200	490
2.3 Weld structural lid and inspect	60	2990	64	640	3630
2.4 Drain MPC	8	408	0	0	408
2.5 Vacuum dry MPC	20	990	5	50	1040
2.6 Backfill with helium	0.3	12	0	0	12
2.7 Weld valve covers and inspect	<u>16</u>	<u>800</u>	<u>21</u>	<u>210</u>	<u>1010</u>
Sub-Totals	182	9,010	235	2,350	11,360
<u>3. MPC Transfer to VSC</u>					
3.1 Lift MTC above VSC	10	500	5	50	550
3.2 Install MTC hydraulics	4	200	2	20	220
3.3 Open MTC bottom doors	2	91	10	100	191
3.4 Lower MPC into VSC	6	295	42	420	715
3.5 Remove MTC from VSC	6	300	6	60	360
3.6 Place shield ring in VSC	<u>2</u>	<u>98</u>	<u>40</u>	<u>400</u>	<u>498</u>
Sub-Totals	30	1,484	105	1,050	2,534
<u>4. VSC Storage</u>					
4.1 Tow VSC to ISFSI	12	610	36	360	970
4.2 Place VSC on ISFSI	<u>36</u>	<u>1830</u>	<u>18</u>	<u>180</u>	<u>2010</u>
Sub-Totals	48	2,440	54	540	2,980
Loading & Storage Totals	<u>340</u>	<u>16,764</u>	<u>509</u>	<u>5,090</u>	<u>21,854</u>

Table 1. Continued

	<u>Manhours</u>	<u>Labor Cost, \$</u>	<u>Dose mrem</u>	<u>Dose Cost, \$</u>	<u>Total Cost, \$</u>
Shipment Off-Site					
<u>5. Load DTC</u>					
5.1 Unload DTC from rail car	16	789	4	40	829
5.2 Move DTC to ISFSI	8	394	2	20	414
5.3 Prepare DTC for MPC	9	444	12	120	564
5.4 Place MTC on VSC	9	444	10	100	544
5.5 Raise MPC from VSC into MTC	3	148	10	100	248
5.6 Place MTC on DTC	6	296	10	100	396
5.7 Lower MPC into DTC	3	148	17	170	318
5.8 Install DTC lid	<u>9</u>	<u>444</u>	<u>16</u>	<u>160</u>	<u>604</u>
Sub-Totals	63	3,106	81	810	3,916
<u>6. Prepare and Ship DTC to MGDS</u>					
6.1 Move DTC from ISFSI	12	592	7	70	662
6.2 Place DTC on rail car	16	789	6	60	849
6.3 Install tie downs, impact limiters, barrier	16	789	14	140	929
6.4 Ship off-site	2	99	0	0	99
6.5 Move VSC from ISFSI & dismantle	12	592	0	0	592
6.6 Place VSC on rail car or truck	16	789	0	0	789
6.7 Ship off-site	<u>2</u>	<u>99</u>	<u>0</u>	<u>0</u>	<u>99</u>
Sub-Totals	76	3,747	27	270	4,017
Shipment Off-Site Totals	<u>139</u>	<u>6,853</u>	<u>108</u>	<u>1,080</u>	<u>7,933</u>
UTILITY TOTALS	<u>479</u>	<u>23,617</u>	<u>617</u>	<u>6,170</u>	<u>29,787</u>
<u>7. Unload DTC at MGDS</u>					
7.1 Remove barrier, impact limiters, tie downs	16	789	14	140	929
7.2 Unload DTC from rail car	16	789	4	40	829
7.3 Unload disposal overpack	16	789	0	0	789
7.4 Move disposal overpack to hot cell	16	789	0	0	789
7.5 Move DTC to hot cell, open lid	16	789	20	200	989
7.6 Place MTC on DTC	6	887	9	90	977
7.7 Lift MPC from DTC	4	592	3	30	622
7.8 Place MTC on disposal overpack	9	1,331	9	90	1,421
7.9 Lower MPC into disposal overpack	3	444	17	170	614
7.10 Final placement of disposal overpack	<u>16</u>	<u>2,366</u>	<u>8</u>	<u>80</u>	<u>2,446</u>
DOE TOTALS	<u>118</u>	<u>9,564</u>	<u>84</u>	<u>840</u>	<u>10,404</u>
UTILITY & DOE TOTALS	<u>597</u>	<u>33,181</u>	<u>701</u>	<u>7,010</u>	<u>40,191</u>

report assumed those steps to be comparable to the steps associated with moving an empty storage cask from a rail car to the unloading area at the MGDS. If the estimates for Steps 7.3 - 7.4 in Table 1 are cut by 2/3, the impact on handling costs is a reduction of about \$1,000 per cask. Thus, in total, the current projections could result in an additional cost of approximately \$5,000 per cask for the remote operations. The remote operations necessary to achieve the repository goals of 100 year retrievability and maintainability are likely to be more costly than projected here. This point was included in the SNC VSC evaluation since remote operations and disposal overpacks are not required for MPCs coming from DUCRETE casks.

2.1.3 Labor Requirements and Costs

The labor requirements of a VSC loading cycle include maintenance, operations, health physics, and engineering or supervision personnel. The labor hours and costs presented in Table 1 are totals of all personnel involved in a particular task or operation. The data presented for Fuel Loading through VSC Storage are derived from SNC operating experience at the Palisades Nuclear Plant (presented in Appendix A). These values are representative of the nth loading cycle as opposed to the first. Labor rates are as follows: Maintenance, \$50/hour; Operations, \$40/hour; Health Physics, \$40/hour; and Engineering or Supervision, \$60/hour.

The labor data for Off-Site Shipment are estimates based on operating experience. A standard labor rate for these operations was assumed to be \$49.30/hour based on the average labor rate calculated for Loading and Storage. After the MPC is removed and shipped, the VSC will undergo some form of handling. This report assumes these costs will be equivalent to loading the VSC on a rail car for shipment off-site, although the actual steps may entail other activities such as break-up and removal to a local landfill. This step was included to provide a consistent comparison base with the other two types of casks in this study. Although not included in this study, a benefit may be derived from an empty VSC by using it as a storage container for Greater Than Class C waste from reactor decommissioning activities.

2.1.4 Dose Accumulation and Costs

Dose accumulations and costs, also presented in Table 1, are from SNC operating experience. These data represent the nth loading, not the first--after several loading cycles, exposures have a tendency to trend lower (see Appendix A), as the personnel involved gain experience and decrease the

time required for specific operations and tasks. After 20 years of storage, operational exposures reflect reduced dose rates (about 60%) as a result of the fuel having less neutron and gamma source strength.¹ The data for Shipment Off-Site after ISFSI storage are estimates based on operating experience. The dose cost rate is assumed at \$10,000 per man REM (\$10/millirem-man).

2.1.5 Transportation Costs

In this study, transportation costs are assumed to not be incurred for at least twenty years. When incurred, however, they are assumed to be similar to the costs of spent fuel shipments made today. Transportation costs, as defined here, are those costs that are attributable to rail shipment, i.e., the MPC has already been removed from the VSC and loaded into a DTC. To determine a reasonable base for estimating shipment costs, the Millstone reactor was chosen as a hypothetical point of origination. Yucca mountain was chosen as the hypothetical destination point. Based on these points, an "incremental" transportation cost of \$30,000 can be expected for each DTC shipped. In addition, a special train cost of \$30,000 is assumed as a "fixed" cost per shipment.^b These costs are applicable to all casks in this study unless otherwise noted.

2.2 DUCRETE Ventilated Storage Cask

The DUCRETE ventilated storage cask under design² and development emulates the basic design of the Sierra Nuclear ventilated storage cask system, see Figure 5. Like the SNC VSC, the DUCRETE VSC is a vertically loaded, dry spent fuel storage system. The DUCRETE VSC has four basic components: a 12-inch-thick reinforced DUCRETE radiation barrier encased with inner and outer stainless steel shells, ventilation duct work, and a 3/4-inch stainless steel lid. Thus the major differences between the DUCRETE VSC and the SNC VSC are that 1) the shielding material is DUCRETE instead of concrete and, 2) the DUCRETE is completely encased in 1/2 inch thick inner and outer stainless steels shells whereas the SNC VSC has an inner carbon steel liner and no exterior liner. The use of DUCRETE rather than concrete results in the DUCRETE VSC weighing about 40 tons less than the SNC VSC and being about 2.5 feet smaller in diameter, see Figure 6. Operationally, these differences offer improved handling characteristics. A MTC is not required for loading of spent fuel assemblies: the MPC is placed inside the DUCRETE VSC and is then loaded in the spent fuel pool.

b. Science Applications International Corporation, Telephone conversations with Mr. Larry Denise and Mr. Steve Schmid.

Figure 5. DUCRETE ventilated storage cask.

However, as with the SNC VSC system, the DUCRETE VSC will require a transfer cask for moving the MPC to a DOE transportation cask for shipment from the ISFSI to the MGDS.

Experience with the SNC VSC has been extrapolated and applied where judged appropriate to determine the economics of the DUCRETE casks. The basic components and costs are identified in the following sections.

2.2.1 Capital Costs

As noted above, the MPC is by definition a generic component of the spent fuel storage systems presented here and is assumed to be provided by DOE. The DUCRETE VSC has an estimated materials cost of about \$220,000 (not including licensing, design, engineering, project management, etc.). It is assumed that the depleted uranium will be supplied at no cost in oxide form as an aggregate suitable for mixing with Portland cement. (Conversion to a stable oxide will be required for the depleted uranium either for disposal as a LLW or for use in a DUCRETE cask.) In the event the depleted uranium requires further transformation into an acceptable aggregate, an additional cost of up to \$200,000 per cask has been projected by INEL. Without this additional cost for aggregate production, the DUCRETE VSC is projected to cost about 10% more than a SNC VSC due to the anticipated higher construction costs and the stainless steel inner and outer shells.

Figure 6. Cross section of DUCRETE VSC (top) and standard VSC (bottom).

The above costs are exclusive of any credits that can be applied for the avoidance of LLW disposal costs for the depleted uranium. A credit is included in the overall system comparison.

While a transfer cask is required at the time of shipment from the ISFSI to the MGDS, a separate cask is not required for each ISFSI. This report assumes DOE will provide the MTC at the time of shipment to the repository. A DOE transportation cask will also be required for the

downstream operations. However, the MPC from a DUCRETE VSC will not require a disposal overpack or remote operations for final placement in the repository.

2.2.2 Cask Handling Operations

There is no experience in DUCRETE VSC handling operations. However, many of the same operations used in loading the SNC VSC will also be performed in loading a DUCRETE VSC. There is one major exception: the DUCRETE VSC containing the MPC can be placed directly in the spent fuel pool for loading of spent fuel assemblies. This will eliminate the need for a reactor site MPC transfer cask and its associated costs.

The MPC is assumed to remain in the DUCRETE storage cask at the ISFSI for at least twenty years prior to off-site shipment. After storage, the MPC would be transferred from the DUCRETE VSC to a DOE transportation cask and shipped to the repository. The DUCRETE VSC is assumed to be shipped, empty, to the repository as well. Upon arrival at the MGDS, the MPC would again be placed in DUCRETE VSC, which becomes the final overpack. Thus, unlike the SNC VSC, contact handling as opposed to remote operations can be used with the DUCRETE VSC. This feature eliminates the costs of the overpack and remote operations. Table 2 shows the handling operations expected for a DUCRETE VSC.

2.2.3 Labor Requirements and Costs

The labor requirements for a DUCRETE VSC loading cycle and off-site shipment include the same personnel as for the SNC VSC. The differences in labor costs will be attributable to the different operations and tasks required. These values are estimated in Table 2.

2.2.4 Dose Accumulation and Costs

The DUCRETE VSC dose accumulations and costs, also presented in Table 2, are the same as for the SNC VSC unless the individual operation and tasks are different (see 2.2.2 Cask Handling Operations).

Table 2. Handling Operations and Tasks for a DUCRETE VSC

	<u>Manhours</u>	<u>Labor Cost, \$</u>	<u>Dose mrem</u>	<u>Dose Cost, \$</u>	<u>Total Cost, \$</u>
Loading & Storage					
<u>1. Fuel Loading</u>					
1.1 Place Cask with MPC into pool	16	800	33	330	1130
1.2 Load MPC with spent fuel assemblies	16	640	12	120	760
1.3 Lift and place shield lid on MPC	24	1195	30	300	1495
1.4 Lift Cask with MPC and wash exterior	<u>24</u>	<u>1195</u>	<u>40</u>	<u>400</u>	<u>1595</u>
Sub-Totals	80	3,830	115	1,150	4,980
<u>2. MPC Closure</u>					
2.1 Weld MPC shield lid and inspect	72	3520	125	1250	4770
2.2 Decon DUCRETE VSC	6	290	20	200	490
2.3 Weld structural lid and inspect	60	2990	64	640	3630
2.4 Drain MPC	8	408	0	0	408
2.5 Vacuum dry MPC	20	990	5	50	1040
2.6 Backfill with helium	0.3	12	0	0	12
2.7 Weld valve covers and inspect	<u>16</u>	<u>800</u>	<u>21</u>	<u>210</u>	<u>1010</u>
Sub-Totals	182	9,010	235	2,350	11,360
<u>3. MPC Transfer to Storage Cask</u> (Not Required for DUCRETE Storage Casks)					
<u>4. DUCRETE VSC Storage</u>					
4.1 Tow DUCRETE VSC to ISFSI	12	610	36	360	970
4.2 Place DUCRETE VSC on ISFSI	<u>36</u>	<u>1830</u>	<u>18</u>	<u>180</u>	<u>2010</u>
Sub-Totals	48	2440	54	540	2980
Loading & Storage Totals	<u>310</u>	<u>15,280</u>	<u>404</u>	<u>4,040</u>	<u>19,320</u>
Shipment Off-Site					
<u>5. Load DTC</u>					
5.1 Unload DTC from rail car	16	789	4	40	829
5.2 Move DTC to ISFSI	8	394	2	20	414
5.3 Prepare DTC for MPC	9	444	12	120	564
5.4 Place MTC on DUCRETE VSC	9	444	10	100	544
5.5 Raise MPC from Cask into MTC	3	148	10	100	248
5.6 Place MTC on DTC	6	296	10	100	396
5.7 Lower MPC into DTC	3	148	17	170	318
5.8 Install DTC lid	<u>9</u>	<u>444</u>	<u>16</u>	<u>160</u>	<u>604</u>
Sub-Totals	63	3,106	81	810	3,916

Table 2. Continued

	<u>Manhours</u>	<u>Labor Cost, \$</u>	<u>Dose mrem</u>	<u>Dose Cost, \$</u>	<u>Total Cost, \$</u>
Shipment Off-Site (continued)					
6. Prepare and Ship DTC & DUCRETE VSC to MGDS					
6.1 Move DTC from ISFSI	12	592	7	70	662
6.2 Place DTC on rail car	16	789	6	60	849
6.3 Install tie downs, impact limiters, barrier	16	789	14	140	929
6.4 Move DUCRETE VSC from ISFSI	12	592	0	0	592
6.5 Place DUCRETE VSC on rail car	16	789	0	0	789
6.6 Ship off-site	<u>2</u>	<u>99</u>	<u>0</u>	<u>0</u>	<u>99</u>
Sub-Totals	74	3,648	27	270	3,918
Shipment Off-Site Totals	<u>137</u>	<u>6,754</u>	<u>108</u>	<u>1,080</u>	<u>7,834</u>
UTILITY TOTALS	<u>447</u>	<u>22,034</u>	<u>512</u>	<u>5,120</u>	<u>27,154</u>
7. Unload DTC at MGDS					
7.1 Remove barrier, impact limiters, tie downs	16	789	14	140	929
7.2 Unload DTC from rail car	16	789	4	40	829
7.3 Unload DUCRETE VSC from rail car	16	789	0	0	789
7.4 Move DUCRETE VSC to unload area	16	789	0	0	789
7.5 Move DTC to unload area, open lid	16	789	20	200	989
7.6 Place MTC on DTC	6	296	9	90	386
7.7 Lift MPC from DTC	4	197	3	30	227
7.8 Place MTC on DUCRETE VSC	9	444	9	90	534
7.9 Lower MPC into DUCRETE VSC	3	148	17	170	318
7.10 Lower DUCRETE VSC in final spot	<u>16</u>	<u>789</u>	<u>8</u>	<u>80</u>	<u>869</u>
DOE TOTALS	<u>118</u>	<u>5,817</u>	<u>84</u>	<u>840</u>	<u>6,657</u>
UTILITY & DOE TOTALS	<u>565</u>	<u>27,852</u>	<u>596</u>	<u>5,960</u>	<u>33,812</u>

2.2.5 Transportation Costs

Transportation costs for a DUCRETE VSC will be identical to those for a SNC VSC with one exception--the DUCRETE VSC system will bear an additional cost of \$3,000 per cask for shipping the empty DUCRETE VSC to the MGDS. Standard "Plate B" cars are assumed for cask transport. This step is not projected for the SNC VSC. In an effort to keep the evaluation completely comparative, consideration was given to allowing some cost credit for shipping the empty disposal overpack that would be required for the MPC coming from a SNC VSC. This consideration has merit but was discounted for conservatism.

2.3 DUCRETE Transportable VSC

The DUCRETE transportable spent fuel storage cask (DUCRETE TVSC) under design² and development takes the DUCRETE VSC to the next conceptual level. Like the SNC VSC and the DUCRETE VSC, the DUCRETE TVSC loads and stores the MPC in a vertical position. The DUCRETE and DUCRETE transportable storage casks are identical except that heat transfer fins have been placed in the transportable cask walls. The DUCRETE VSC is then made transportable by the addition of a simple transportation overpack (TOP). The current TOP design is a stainless steel cylinder that will provide the structural strength necessary to meet NRC transportation requirements. The DUCRETE TVSC will be loaded into the TOP from a vertical position, placed on a rail car, and shipped to the repository for final placement. In the DUCRETE TVSC, the MPC always remains inside the cask. As a result, transfer casks will not be required for MPC loading of assemblies in the spent fuel pool, or for preparing the MPC for shipment to the repository and final placement.

2.3.1 Capital Costs

The MPC, as previously noted, is assumed to be supplied by DOE. The DUCRETE TVSC is expected to cost about \$80,000 more than the DUCRETE VSC because of higher manufacturing costs due to the addition of heat transfer fins; this results in a total material cost of about \$300,000 per cask (does not include licensing, design, engineering, project management, etc.). These costs include the same basic components and factors outlined in Section 2.2.1; one additional step will be the removal of re-bar if heat fins are added. Transfer casks, transportation casks, and a disposal overpacks are not required in this system. However, a transportation overpack is required; it is assumed to be provided by DOE. This cost and its impact are addressed in the overall system economics.

2.3.2 Cask Handling Operations

The differences in cask handling operations between the DUCRETE TVSC and the DUCRETE VSC occur after twenty plus years of storage at the ISFSI. The DUCRETE TVSC will not require the transfer operations associated with unloading the MPC from the DUCRETE storage cask for placement in a transportation cask, nor will it require separate tasks for moving an empty storage cask off site. The transportation overpack will be loaded with the DUCRETE TVSC, as opposed to the transportation cask being loaded with a MPC as with the DUCRETE VSC. Table 3 shows the expected DUCRETE TVSC handling operations.

2.3.3 Labor Requirements and Costs

The labor requirements and costs involved with a DUCRETE TVSC are identical to those of the DUCRETE VSC for fuel loading and ISFSI storage. The labor requirements differ, as discussed in Section 2.3.2, for the tasks required for off-site shipment after ISFSI storage. The estimated labor costs are shown in Table 3.

2.3.4 Dose Accumulation and Costs

The DUCRETE TVSC dose accumulations and costs, also presented in Table 3, reflect the same relation to those of the DUCRETE VSC as discussed in Section 2.3.3.

2.3.5 Transportation Costs

Transportation costs for a DUCRETE TVSC are assumed to be identical to the costs identified for the SNC VSC.

Table 3. Handling Operations and Tasks for a DUCRETE TVSC

	<u>Manhours</u>	<u>Labor Cost, \$</u>	<u>Dose mrem</u>	<u>Dose Cost, \$</u>	<u>Total Cost, \$</u>
Loading & Storage					
<u>1. Fuel Loading</u>					
1.1 Place Cask with MPC into pool	16	800	33	330	1130
1.2 Load MPC with spent fuel assemblies	16	640	12	120	760
1.3 Lift and place shield lid on MPC	24	1195	30	300	1495
1.4 Lift Cask with MPC and wash exterior	<u>24</u>	<u>1195</u>	<u>40</u>	<u>400</u>	<u>1595</u>
Sub-Totals	80	3,830	115	1,150	4,980
<u>2. MPC Closure</u>					
2.1 Weld MPC shield lid and inspect	72	3520	125	1250	4770
2.2 Decon DUCRETE TVSC	6	290	20	200	490
2.3 Weld structural lid and inspect	60	2990	64	640	3630
2.4 Drain MPC	8	408	0	0	408
2.5 Vacuum dry MPC	20	990	5	50	1040
2.6 Backfill with helium	.3	12	0	0	12
2.7 Weld valve covers and inspect	<u>16</u>	<u>800</u>	<u>21</u>	<u>210</u>	<u>1010</u>
Sub-Totals	182	9,010	235	2,350	11,360
<u>3. MPC Transfer to Storage Cask</u> (Not Required for DUCRETE Storage Casks)					
<u>4. DUCRETE SC Storage</u>					
4.1 Tow DUCRETE TVSC ISFSI	12	610	36	360	970
4.2 Place DUCRETE TVSC on ISFSI	<u>36</u>	<u>1830</u>	<u>18</u>	<u>180</u>	<u>2010</u>
Sub-Totals	48	2440	54	540	2980
Loading & Storage Totals	<u>310</u>	<u>5,280</u>	<u>404</u>	<u>4,040</u>	<u>19,320</u>
Shipment Off-Site					
<u>5. Load Transportation Overpack</u>					
5.1 Unload TOP from rail car	16	789	4	40	829
5.2 Move TOP to ISFSI	8	394	2	20	414
5.3 Prepare TOP for DUCRETE SC	9	444	12	120	564
5.4 N/A ^a	0	0	0	0	0
5.5 Raise DUCRETE SC	3	148	10	100	248
5.6 N/A	0	0	0	0	0
5.7 Lower DUCRETE SC into TOP	3	148	17	170	318
5.8 Install TOP lid	<u>9</u>	<u>444</u>	<u>16</u>	<u>160</u>	<u>604</u>
Sub-Totals	48	2,366	61	610	2,976

Table 3. Continued

	<u>Manhours</u>	<u>Labor Cost, \$</u>	<u>Dose mrem</u>	<u>Dose Cost, \$</u>	<u>Total Cost, \$</u>
Shipment Off-Site (continued)					
<u>6. Prepare and Ship DUCRETE TVSC in TOP to MGDS</u>					
6.1 Move TOP from ISFSI	12	592	7	70	662
6.2 Place TOP on rail car	16	789	6	60	849
6.3 Install tie downs, impact limiters, barrier	16	789	14	140	929
6.4 N/A	0	0	0	0	0
6.5 N/A	0	0	0	0	0
6.6 Ship off-site	<u>2</u>	<u>99</u>	<u>0</u>	<u>0</u>	<u>99</u>
Sub-Totals	46	2,268	27	270	2,538
Shipment Off-Site Totals	<u>94</u>	<u>4,634</u>	<u>88</u>	<u>880</u>	<u>5,514</u>
UTILITY TOTALS	<u>404</u>	<u>19,914</u>	<u>492</u>	<u>4,920</u>	<u>24,834</u>
<u>7. Unload TOP at MGDS</u>					
7.1 Remove barrier, impact limiters, tie downs	16	789	14	140	929
7.2 Unload TOP from rail car	16	789	4	40	829
7.3 Move TOP to unload area, open lid	16	789	20	200	989
7.4 N/A	0	0	0	0	0
7.5 Lift DUCRETE VSC from TOP	4	197	3	30	227
7.6 N/A	0	0	0	0	0
7.7 N/A	0	0	0	0	0
7.8 Final Placement - DUCRETE TVSC	<u>16</u>	<u>789</u>	<u>8</u>	<u>80</u>	<u>869</u>
DOE TOTALS	<u>68</u>	<u>3,352</u>	<u>49</u>	<u>490</u>	<u>3,842</u>
UTILITY & DOE TOTALS	<u>472</u>	<u>23,267</u>	<u>541</u>	<u>5,410</u>	<u>28,677</u>

a. Not applicable for the DUCRETE TVSC.

3. CASK COMPARISONS

For a cask comparison to be meaningful it is important to note how the major players will be impacted and how a given cask's economic characteristics will look on a broad scale. Models were developed to show how an average utility could compare the cask systems evaluated here and how the overall system would be impacted by any given cask's full implementation.

3.1 Utility Perspective

The MGDS was assumed to be operational by 2010.³ In this case, total utility on-site dry storage requirements peak about the year 2012 when the cumulative shipments to the MGDS exceed new storage demand.⁴ The dry storage requirement is projected at 14,095 MTU in 2012.⁴ Based on 109 operating reactors, a storage demand of about 127 MTU per reactor can be calculated. At 9.1 MTU per MPC, this translates into about 14 casks per reactor.

This report assumes a continuation of the current system in which the utilities pay for their individual on-site storage needs; DOE is assumed to provide the MPC and bear the costs of off-site transportation and the handling and components that may be required at the MGDS.

For each cask system, total handling and shipping costs are combined with capital component costs to determine the total cask system cost for reactor sites with one, two, or three reactors (see Tables 4, 5, and 6). Each cask system's total costs are then summarized and presented for comparison in Table 7. The cost per cask and cost per MTU of spent fuel stored are also shown in these tables.

As can be seen from Table 7, a DUCRETE VSC is competitive with a conventional concrete cask. This comparison is exclusive of any credits that DOE could apply to the cost of the cask for the avoidance of depleted uranium disposal costs.

3.2 Total System Perspective

To illustrate a total system perspective for the three types of spent fuel storage casks under evaluation, three different cases were developed. These cases are for storage demands of
1) 14,095 MTU in 2012, discussed above; 2) 21,730 MTU in 2020 with no MRS or MGDS; and
3) 86,179 MTU in 2040 with no MRS or MGDS. The case analyses include capital cost components,

Table 4. Utility Costs for a SNC Ventilated Storage Cask

Component	Component Cost, \$	Reactor Sites ^a		
		One Reactor (14 Casks), \$	Two Reactors (28 Casks), \$	Three Reactors (42 Casks), \$
MPC with Lids	250,000	n/a	n/a	n/a
VSC	200,000	2,800,000	5,600,000	8,400,000
MPC Transfer Cask	750,000	<u>750,000</u>	<u>750,000</u>	<u>750,000</u>
Total Capital Cost per Site		3,550,000	6,350,000	9,150,000
Loading and Storage Handling	21,854	305,956	611,912	917,868
Shipment Off-site Handling	<u>7,933</u>	<u>111,058</u>	<u>222,116</u>	<u>333,173</u>
Total Handling Costs	29,787	417,014	834,028	1,251,041
UTILITY TOTAL COST		<u>3,967,014</u>	<u>7,184,028</u>	<u>10,401,041</u>
Utility cost/MTU ^b		31,138	28,195	27,214
Utility cost/cask		283,358	256,572	247,644

a. Assumption of 14 casks for a one reactor site, 28 casks for a two reactor site, and 42 casks for a three reactor site is based on Table 4.2a of Reference 4 and calculated as follows:

Year 2012 MTU=14,095, which at 9.1 MTU/MPC yields 1549 casks. There are 109 operating reactors, or approximately 14 casks per reactor.

b. Utility total cost ÷ (number of casks x 9.1 MTU/cask).

Table 5. Utility Costs for a DUCRETE VSC

Component	Component Cost, \$	Reactor Sites ^a		
		One Reactor (14 Casks), \$	Two Reactors (28 Casks), \$	Three Reactors (42 Casks), \$
MPC with Lids	250,000	n/a	n/a	n/a
DUCRETE Storage Cask	220,000	3,080,000	6,160,000	9,240,000
MPC Transfer Cask	0	0	0	0
Total Capital Cost per Site		3,080,000	6,160,000	9,240,000
Loading and Storage Handling	19,320	270,480	540,960	811,440
Shipment Off-site Handling	7,834	109,677	219,355	329,032
Total Handling Costs	27,154	380,157	760,315	1,140,472
UTILITY TOTAL COST		<u>3,460,157</u>	<u>6,920,315</u>	<u>10,380,472</u>
Utility cost/MTU		27,160	27,160	27,160
Utility cost/cask		247,154	247,154	247,154

a. Same assumptions as Table 4.

Table 6. Utility Costs for a DUCRETE TVSC

Component	Component Cost, \$	Reactor Sites ^a		
		One Reactor (14 Casks), \$	Two Reactors (28 Casks), \$	Three Reactors (42 Casks), \$
MPC with Lids	250,000	n/a	n/a	n/a
DUCRETE Storage Cask	300,000	4,200,000	8,400,000	12,600,000
MPC Transfer Cask	0	0	0	0
Total Capital Cost per Site		4,200,000	8,400,000	12,600,000
Loading and Storage Handling	19,320	270,480	540,960	811,440
Shipment Off-site Handling	5,514	77,199	154,398	231,596
Total Handling Costs	24,834	347,679	695,358	1,043,036
UTILITY TOTAL COST		<u>4,547,679</u>	<u>9,095,358</u>	<u>13,643,036</u>
Utility cost/MTU		35,696	35,696	35,696
Utility cost/cask		324,834	324,834	324,834

a. Same assumptions as Table 4.

Table 7. Utility Cask Comparison Summary

	VSC System, \$	DUCRETE VSC, \$	DUCRETE TVSC, \$
<u>One Reactor Site</u>			
Total Costs for 14 Casks	3,967,014	3,460,157	4,547,679
Total Capital Costs	3,550,000	3,080,000	4,200,000
Total Handling Costs	417,014	380,157	347,679
Total Cost per Cask	283,358	247,154	324,834
Total Cost per MTU	31,138	27,160	35,696
<u>Two Reactor Site</u>			
Total Costs for 28 Casks	7,184,028	6,920,315	9,095,358
Total Capital Costs	6,350,000	6,160,000	8,400,000
Total Handling Costs	834,028	760,315	695,358
Total Cost per Cask	256,572	247,154	324,834
Total Cost per MTU	28,195	27,160	35,696
<u>Three Reactor Site</u>			
Total Costs for 42 Casks	10,401,041	10,380,472	13,643,036
Total Capital Costs	9,150,000	9,240,000	12,600,000
Total Handling Costs	1,251,041	1,140,472	1,043,036
Total Cost per Cask	247,644	247,154	324,834
Total Cost per MTU	27,214	17,160	35,696

handling costs, and transportation costs attributable to each cask system. The following section presents capital cost components that have unique application to the total system. Each case is then described and presented.

3.2.1 Cost Components Unique to Total System

The cost components discussed in this section generally have been identified in the previous sections of this report as they apply to a given cask system. However, there are several areas that require further discussion to develop a complete system perspective.

3.2.1.1 Transportation Casks or Overpacks

A DOE transportation cask is required for the SNC and DUCRETE storage casks. This report uses a capital cost for one DTC of \$2,000,000.⁵ It is projected that a total of twenty DTCs will be required once the MGDS becomes fully operational. Assuming one day to load each cask times five DTCs per train shipment, seven days to ship, two days to unload, and four days to ship the DTCs to another site yields an eighteen day load and unload cycle for the DTCs, or 20 cycles (MPCs) per DTC per year. The MGDS is projected to accept spent fuel at a rate of 3,000 MTU per year when fully operational.³ With a 9.1 MTU/MPC capacity, approximately 329 MPCs could be shipped each year, which would require 17 DOE transportation casks. This report assumes that twenty DTCs will be acquired; the three additional casks allow for maintenance, repair, or other downtime. Twenty DTCs were used for all three demand cases.

As previously discussed, DUCRETE TVSCs will not require a DTC but will require a transportation overpack. The TOP, which is currently being designed, is a simple stainless steel overpack that the loaded DUCRETE TVSC will be placed into at the time of shipment from the ISFSI. The cost of this component has been estimated at \$1,000,000. For total system case analysis, the same number of TOPs as DTCs would be required, namely 20.

3.2.1.2 Rail Transportation Costs

For a total system perspective, rail transportation costs are calculated by dividing the number of MPCs or storage casks required by the number of casks per train (5), and multiplying by the cost per rail shipment previously identified for each cask type. For example, in Case I, the number of

shipments will be 310 ($14,095 \text{ MTU} \div 9.1 \text{ MTU/cask} \div 5 \text{ casks/train}$). The cost per shipment is \$30,000/cask, times five casks per train, plus a special train charge of \$30,000/train, which equals \$180,000. This cost is applicable to the SNC VSC and DUCRETE TVSC systems; the DUCRETE VSC system will require an incremental charge of \$3,000/empty cask shipped, for a total cost per shipment of \$195,000.

3.2.1.3 MPC Transfer Casks

The SNC and DUCRETE VSCs require transfer casks to move the MPCs from the storage casks in the ISFSI to the transport casks. From a system perspective, this report assumes that DOE will provide one MTC per train to unload MPCs. Thus, these two systems will require about five MTCs (includes one spare) for each demand case at a cost of \$750,000 per cask as identified in Section 2.1.

The SNC VSC system also requires a MTC for loading fuel into the MPC. As discussed in Section 2.1, it is assumed that one transfer cask will be required for each reactor site requiring spent fuel storage. For Cases I and II, the number of sites requiring MTCs is 22 and 36, respectively.⁴ For Case III, the total number of sites is 72.⁶ These values are added to the requirements for shipping mentioned above to determine the total number of MTCs required for any given storage cask in any given case.

3.2.1.4 Final Disposal Overpacks

Final disposal overpacks are required for MPCs coming from the SNC VSCs. (The DUCRETE storage casks serve as the final disposal overpack for their MPCs. This avoids the disposal cost associated with the depleted uranium contained in the cask walls.) The overpack is projected to cost approximately \$50,000, and to require remote handling. The number of overpacks needed is directly related to the spent fuel storage demand for a given case.

3.2.1.5 Depleted Uranium Cost Credits

If the depleted uranium is not built into storage casks or used in some other way, the material will have to be buried as LLW. The burial cost credit has been conservatively estimated at \$2.00/kg

based on current disposal rates. A DUCRETE cask is projected to contain about 40,000 kg of DU, which will result in a \$80,000/DUCRETE storage cask credit.

3.2.2 Case Development

For Case I, the MGDS was assumed to be operational by 2010, with peak utility on-site dry storage requirements of 14,095 MTU in 2012.⁴ The number of casks required, based on 9.1 MTU/MPC, is 1,549 casks.^c

In Cases II and III, it was assumed that there is no MRS or MGDS. For Case II, all fuel in excess of pool capacity is placed at the ISFSI. Case II was selected to be the demand in the year 2020, assuming a 40 year plant life and no new orders. The storage requirement in 2020 is 21,730 MTU,⁴ or 2,388 casks. The Case III demand is for the year 2040, also under a 40 year plant life and no new orders. At this point, all fuel is discharged from the reactor fuel pools and placed in an ISFSI. The storage requirement is 86,179 MTU,⁴ or 9,470 casks.

The models developed for these cases calculate a total cost for each component, a function of the component cost and quantity. These costs are summed by major category and then on a total system basis. The total system presentation is not intended to distinguish which entity will bear what cost, although many of the assumptions and data are built on the premise of who will bear the responsibility. The intent here is to present a total system cost for each cask system.

Tables 8, 9, and 10 show the results of the case analyses for the SNC VSC, DUCRETE VSC, and DUCRETE TVSC systems, respectively. Table 11 presents a comparison of all of these casks from a total system perspective.

c. In this report, MTIHM in the DOE/EIA data is assumed to be equal to MTU.

Table 8. SNC VSC Total System Costs

Case I - 2012 Cask Demand

<u>Component</u>	<u>Component Cost</u>	<u>Component Quantity</u>	<u>14,095 MTU Total Cost</u>
MPC & Lids	250,000	1,549	387,250,000
SNC VSC	200,000	1,549	309,800,000
MPC Transfer Cask	750,000	27	20,250,000
DOE Transportation Cask	2,000,000	20	40,000,000
Final Disposal Over-Pack	50,000	1,549	77,450,000
DU Disposal Credit (\$2/kg)	<u>n/a</u>	<u>1,549</u>	<u>0</u>
Total Capital Cost			834,750,000
Pool to ISFSI Handling	21,854	1,549	33,851,846
ISFSI to Off-site Handling	<u>7,933</u>	<u>1,549</u>	<u>12,287,752</u>
Total Utility Handling	29,787		46,139,598
DOE Handling at MGDS	<u>10,404</u>	<u>1,549</u>	<u>16,116,106</u>
TOTAL HANDLING			<u>62,255,704</u>
Rail Transportation Costs	180,000	310	55,764,000
TOTAL COST			<u>952,769,704</u>

Case II - 2020 Cask Demand

<u>Component</u>	<u>Component Cost</u>	<u>Component Quantity</u>	<u>21,730 MTU Total Cost</u>
MPC & Lids	250,000	2,388	597,000,000
SNC VSC	200,000	2,388	477,600,000
MPC Transfer Cask	750,000	41	30,750,000
DOE Transportation Cask	2,000,000	20	40,000,000
Final Disposal Over-Pack	50,000	2,388	119,400,000
DU Disposal Credit (\$2/kg)	<u>n/a</u>	<u>2,388</u>	<u>0</u>
Total Capital Cost			1,264,750,000
Pool to ISFSI Handling	21,854	2,388	52,187,352
ISFSI to Off-site Handling	<u>7,933</u>	<u>2,388</u>	<u>18,943,288</u>
Total Utility Handling	29,787		71,130,640
DOE Handling at MGDS	<u>10,404</u>	<u>2,388</u>	<u>24,845,230</u>
TOTAL HANDLING			<u>95,975,869</u>
Rail Transportation Costs	180,000	478	85,968,000
TOTAL COST			<u>1,446,693,869</u>

Table 8. Continued

Case III - 2040 Cask Demand

<u>Component</u>	<u>Component Cost</u>	<u>Component Quantity</u>	<u>86,179 MTU Total Cost</u>
MPC & Lids	250,000	9,470	2,367,500,000
SNC VSC	200,000	9,470	1,894,000,000
MPC Transfer Cask	750,000	77	57,750,000
DOE Transportation Cask	2,000,000	20	40,000,000
Final Disposal Over-Pack	50,000	9,470	473,500,000
DU Disposal Credit (\$2/kg)	<u>n/a</u>	<u>9,470</u>	<u>0</u>
Total Capital Cost			4,832,750,000
Pool to ISFSI Handling	21,854	9,470	206,957,380
ISFSI to Off-site Handling	<u>7,933</u>	<u>9,470</u>	<u>75,122,669</u>
Total Utility Handling	29,787		282,080,049
DOE Handling at MGDS	<u>10,404</u>	<u>9,470</u>	<u>98,527,774</u>
TOTAL HANDLING			<u>380,607,823</u>
Rail Transportation Costs	180,000	1,894	340,920,000
TOTAL COST			<u>5,554,277,823</u>

Table 9. DUCRETE VSC Total System Costs

Case I - 2012 Cask Demand

<u>Component</u>	<u>Component Cost</u>	<u>Component Quantity</u>	<u>14,095 MTU Total Cost</u>
MPC & Lids	250,000	1,549	387,250,000
DUCRETE VSC	220,000	1,549	340,780,000
MPC Transfer Cask	750,000	5	3,750,000
DOE Transportation Cask	2,000,000	20	40,000,000
Final Disposal Over-Pack	n/a	0	0
DU Disposal Credit (\$2/kg)	<u>(80,000)</u>	<u>1,549</u>	<u>(123,920,000)</u>
Total Capital Cost			647,860,000
Pool to ISFSI Handling	19,320	1,549	29,926,680
ISFSI to Off-site Handling	<u>7,834</u>	<u>1,549</u>	<u>12,135,021</u>
Total Utility Handling	27,154		42,061,701
DOE Handling at MGDS	<u>6,657</u>	<u>1,549</u>	<u>10,312,313</u>
TOTAL HANDLING			<u>52,374,014</u>
Rail Transportation Costs	195,000	310	60,411,000
TOTAL COST			<u>760,645,013</u>

Case II - 2020 Cask Demand

<u>Component</u>	<u>Component Cost</u>	<u>Component Quantity</u>	<u>21,730 MTU Total Cost</u>
MPC & Lids	250,000	2,388	597,000,000
DUCRETE VSC	220,000	2,388	525,360,000
MPC Transfer Cask	750,000	5	3,750,000
DOE Transportation Cask	2,000,000	20	40,000,000
Final Disposal Over-Pack	n/a	0	0
DU Disposal Credit (\$2/kg)	<u>(80,000)</u>	<u>2,388</u>	<u>(191,040,000)</u>
Total Capital Cost			975,070,000
Pool to ISFSI Handling	19,320	2,388	46,136,160
ISFSI to Off-site Handling	<u>7,834</u>	<u>2,388</u>	<u>18,707,831</u>
Total Utility Handling	27,154		64,843,991
DOE Handling at MGDS	<u>6,657</u>	<u>2,388</u>	<u>15,897,871</u>
TOTAL HANDLING			<u>80,741,862</u>
Rail Transportation Costs	195,000	478	93,132,000
TOTAL COST			<u>1,148,943,862</u>

Table 9. Continued

Case III - 2040 Cask Demand

<u>Component</u>	<u>Component Cost</u>	<u>Component Quantity</u>	<u>86,179 MTU Total Cost</u>
MPC & Lids	250,000	9,470	2,367,500,000
DUCRETE VSC	220,000	9,470	2,083,400,000
MPC Transfer Cask	750,000	5	3,750,000
DOE Transportation Cask	2,000,000	20	40,000,000
Final Disposal Over-Pack	n/a	0	0
DU Disposal Credit (\$2/kg)	<u>(80,000)</u>	<u>9,470</u>	<u>(757,600,000)</u>
Total Capital Cost			3,737,050,000
Pool to ISFSI Handling	19,320	9,470	182,960,400
ISFSI to Off-site Handling	<u>7,834</u>	<u>9,470</u>	<u>74,188,927</u>
Total Utility Handling	27,154		257,149,327
DOE Handling at MGDS	<u>6,657</u>	<u>9,470</u>	<u>63,045,578</u>
TOTAL HANDLING			<u>320,194,905</u>
Rail Transportation Costs	195,000	1,894	369,330,000
TOTAL COST			<u>4,426,574,905</u>

Table 10. DUCRETE TVSC Total System Costs

Case I - 2012 Cask Demand

<u>Component</u>	<u>Component Cost</u>	<u>Component Quantity</u>	<u>14,095 MTU Total Cost</u>
MPC & Lids	250,000	1,549	387,250,000
DUCRETE TVSC	300,000	1,549	464,700,000
MPC Transfer Cask	n/a	0	0
DOE Transportation Cask	1,000,000	20	20,000,000
Final Disposal Over-Pack	n/a	1,549	0
DU Disposal Credit (\$2/kg)	<u>(80,000)</u>	<u>1,549</u>	<u>(123,920,000)</u>
Total Capital Cost			748,030,000
Pool to ISFSI Handling	19,320	1,549	29,926,680
ISFSI to Off-site Handling	<u>5,514</u>	<u>1,549</u>	<u>8,541,496</u>
Total Utility Handling	24,834		38,468,176
DOE Handling at MGDS	<u>3,842</u>	<u>1,549</u>	<u>5,951,878</u>
TOTAL HANDLING			<u>44,420,053</u>
Rail Transportation Costs	180,000	310	55,764,000
TOTAL COST			<u>848,214,053</u>

Case II - 2020 Cask Demand

<u>Component</u>	<u>Component Cost</u>	<u>Component Quantity</u>	<u>21,730 MTU Total Cost</u>
MPC & Lids	250,000	2,388	597,000,000
DUCRETE TVSC	300,000	2,388	716,400,000
MPC Transfer Cask	n/a	0	0
DOE Transportation Cask	1,000,000	20	20,000,000
Final Disposal Over-Pack	n/a	2,388	0
DU Disposal Credit (\$2/kg)	<u>(80,000)</u>	<u>2,388</u>	<u>(191,040,000)</u>
Total Capital Cost			1,142,360,000
Pool to ISFSI Handling	19,320	2,388	46,136,160
ISFSI to Off-site Handling	<u>5,514</u>	<u>2,388</u>	<u>13,167,910</u>
Total Utility Handling	24,834		59,304,070
DOE Handling at MGDS	<u>3,842</u>	<u>2,388</u>	<u>9,175,651</u>
TOTAL HANDLING			<u>68,479,721</u>
Rail Transportation Costs	180,000	478	85,968,000
TOTAL COST			<u>1,296,807,721</u>

Table 10. Continued

Case III - 2040 Cask Demand

<u>Component</u>	<u>Component Cost</u>	<u>Component Quantity</u>	<u>86,179 MTU Total Cost</u>
MPC & Lids	250,000	9,470	2,367,500,000
DUCRETE TVSC	300,000	9,470	2,841,000,000
MPC Transfer Cask	n/a	0	0
DOE Transportation Cask	1,000,000	20	20,000,000
Final Disposal Over-Pack	n/a	9,470	0
DU Disposal Credit (\$2/kg)	<u>(80,000)</u>	<u>9,470</u>	<u>(757,600,000)</u>
Total Capital Cost			4,470,900,000
Pool to ISFSI Handling	19,320	9,470	182,960,400
ISFSI to Off-site Handling	<u>5,514</u>	<u>9,470</u>	<u>52,219,474</u>
Total Utility Handling	24,834		235,179,874
DOE Handling at MGDS	<u>3,842</u>	<u>9,470</u>	<u>36,387,528</u>
TOTAL HANDLING			<u>271,567,402</u>
Rail Transportation Costs	180,000	1,894	340,920,000
TOTAL COST			<u>5,083,387,402</u>

Table 11. Total System Cask Comparisons

Case I - 2012 Storage Demand - 14,095 MTU

<u>Component</u>	<u>SNC VSC</u>	<u>DUCRETE VSC</u>	<u>DUCRETE TVSC</u>
MPC & Lids	387,250,000	387,250,000	387,250,000
Storage Cask	309,800,000	340,780,000	464,700,000
MPC Transfer Cask	20,250,000	3,750,000	0
Transportation OP or Cask	40,000,000	40,000,000	20,000,000
Final Disposal Over-Pack	77,450,000	0	0
DU Disposal Credit (\$2/kg)	0	(123,920,000)	(123,920,000)
Total Capital Cost	834,750,000	647,860,000	748,030,000
Pool to ISFSI Handling	33,851,846	29,926,680	29,926,680
ISFSI to Off-site Handling	12,287,752	12,135,021	8,541,496
Total Utility Handling	46,139,598	42,061,701	38,468,176
DOE Handling at MGDS	16,116,106	10,312,313	5,951,878
TOTAL HANDLING	62,255,704	52,374,014	44,420,053
Rail Transportation Costs	55,764,000	60,411,000	55,764,000
TOTAL COST	952,769,704	760,645,013	848,214,053

Case II - 2020 Storage Demand - 21,730 MTU

<u>Component</u>	<u>SNC VSC</u>	<u>DUCRETE VSC</u>	<u>DUCRETE TVSC</u>
MPC & Lids	597,000,000	597,000,000	597,000,000
Storage Cask VSC	477,600,000	525,360,000	716,400,000
MPC Transfer Cask	30,750,000	30,750,000	0
Transportation OP or Cask	40,000,000	40,000,000	20,000,000
Final Disposal Over-Pack	119,400,000	0	0
DU Disposal Credit (\$2/kg)	0	(191,040,000)	(191,040,000)
Total Capital Cost	1,264,750,000	975,070,000	1,142,360,000
Pool to ISFSI Handling	52,187,352	46,136,160	46,136,160
ISFSI to Off-site Handling	18,943,288	18,707,831	13,167,910
Total Utility Handling	71,130,640	64,843,991	59,304,070
DOE Handling at MGDS	24,845,230	15,897,871	9,175,651
TOTAL HANDLING	95,975,869	80,741,862	68,479,721
Rail Transportation Costs	85,968,000	93,132,000	85,968,000
TOTAL COST	1,446,693,869	1,148,943,862	1,296,807,721

Table 11. Continued

Case III - 2040 Storage Demand - 86,179 MTU

<u>Component</u>	<u>SNC VSC</u>	<u>DUCRETE VSC</u>	<u>DUCRETE TVSC</u>
MPC & Lids	2,367,500,000	2,367,500,000	2,367,500,000
Storage Cask VSC	1,894,000,000	2,083,400,000	2,841,000,000
MPC Transfer Cask	57,750,000	3,750,000	0
Transportation OP or Cask	40,000,000	40,000,000	20,000,000
Final Disposal Over-Pack	473,500,000	0	0
DU Disposal Credit (\$2/kg)	0	(757,600,000)	(757,600,000)
Total Capital Cost	4,832,750,000	3,737,050,000	4,470,900,000
Pool to ISFSI Handling	206,957,380	182,960,400	182,960,400
ISFSI to Off-site Handling	75,122,669	74,188,927	52,219,474
Total Utility Handling	282,080,049	257,149,327	235,179,874
DOE Handling at MGDS	98,527,774	63,045,578	36,387,528
TOTAL HANDLING	<u>380,607,823</u>	<u>320,194,905</u>	<u>271,567,402</u>
Rail Transportation Costs	340,920,000	369,330,000	340,920,000
TOTAL COST	<u>5,554,277,823</u>	<u>4,426,574,905</u>	<u>5,083,387,402</u>

4. CONCLUSIONS

This report evaluated the expected capital, handling, and transportation costs for a conventional concrete storage cask (SNC VSC), a DUCRETE VSC, and a DUCRETE transportable VSC from the perspectives of an average utility and the overall system. The handling and transportation cost differences between the various cask systems are relatively insignificant compared to the capital cost differentials. Within the overall system, for example, the capital cost difference between the SNC VSC and the DUCRETE VSC in Case II is about \$290 million while the handling cost differential is about \$9 million. The transportation costs are almost identical for all three systems. Clearly, the initial capital components required for a given cask system, in addition to other major costs required or omitted downstream as a byproduct of a given cask system, will drive the overall economics.

Under the assumption that the depleted uranium aggregate for the DUCRETE storage cask walls is provided without cost, the analysis shows the DUCRETE VSC to be competitive from the utility viewpoint. In the majority of utility cases, the DUCRETE VSC displayed the lowest total capital costs of any of the systems--the small additional cost of the storage cask is offset by the cost saving of not requiring a transfer cask. This savings diminishes for sites with a large requirement for storage casks as the incremental costs accumulate. However, in all of the cases presented, the total utility costs favored the DUCRETE VSC. The analysis shows that a DUCRETE VSC can be competitive with a conventional concrete cask even without a cost credit from the savings DOE would realize for avoiding DU disposal costs.

With DU disposal cost credits, the capital costs and total costs for the DUCRETE transportable VSC are lower than those of the conventional concrete cask. Absent disposal credits, the cask is not as attractive. Expectations of high manufacturing costs to place heat transfer fins in the DUCRETE cask walls under the current preliminary design penalize this system. However, a more economic design may become possible with further exploration.

The analysis shows the DUCRETE VSC to have a real economic advantage to the utility and for the overall system. There is uncertainty in the cost of producing a depleted uranium aggregate that is acceptable for the DUCRETE mixture, as well as in what the costs might be under other final disposal options for the depleted uranium. However, because the depleted uranium aggregate is about three times denser than oxide powder, the costs of making the aggregate may be more than offset by

the savings in disposal cost due to reduced volume. Furthermore, the aggregate's cost may be born by the agency responsible for UF_6 disposal.

Another area that needs quantification is the cost of remote handling at the repository for MPCs coming from conventional concrete cask systems. MPCs coming from the DUCRETE systems will not require remote handling, and this should offer real long-term advantages for retrievableness and maintainability at the repository. Over a hundred year period, savings from contact versus remote handling could easily amount to tens to hundreds of millions of dollars.

In summary, the economic advantage of the DUCRETE VSC is very noticeable from an overall system point of view, especially when credit is included for DOE avoidance of depleted uranium disposal costs. From a utility perspective, the difference is more narrow and is a function of how many storage casks are required. The utility viewpoint in this evaluation does not recognize any benefit from DOE avoiding the deleted uranium disposal costs. DOE could subsidize the DUCRETE cask with the savings realized from avoidance of DU disposal costs; the DOE alternative is to pay for the DU disposal.

5. REFERENCES

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5. Electric Power Research Institute, *Comparative System Economics of Concrete Casks for Spent-Fuel Storage*, EPRI TR-102415, June 1993.
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Appendix A

Sierra Nuclear Corporation VSC-24 Loading Cycle Experience and Palisades Occupational Exposure Trend

SNC VSC LOADING CYCLE OPERATIONS, LABOR REQUIREMENTS & COST and DOSE ACCUMULATION & COST

		Maintenance Personnel (\$50/hr)				Engineering Personnel (\$60/hr)				Health Physics Personnel (\$40/hr)				Operations Personnel (\$40/hr)				Total Task Dose (mrem)	Total Dose Dollars	Total Man Hours	Total Labor Cost	Total Task Cost																		
Task/Op.	Total Time	No.	Hours	mrem	Labor (\$)	No.	Hours	mrem	Labor (\$)	No.	Hours	mrem	Labor (\$)	No.	Hours	mrem	Labor (\$)																							
Prepare VSC																																								
Check and clean MSB	8	4	19.5	0	975	1	0.5	0	30	0	0	0	0	0	0	0	0	0	0	20	1005	1005																		
Check and clean VCC	4	4	11.5	0	575	1	0.5	0	30	0	0	0	0	0	0	0	0	0	12	605	605																			
Check and clean MTC	4	4	11	4	550	1	0.5	0	30	1	0.5	0	20	0	0	0	0	4	40	12	600	640																		
Place MSB in MTC	1	4	5.5	2	275	1	0.25	0	15	1	0.25	0	10	0	0	0	0	2	20	6	300	320																		
Install MTC/MSB shims	1	4	3.5	2	175	1	0.25	0	15	1	0.25	0	10	0	0	0	0	2	20	4	200	220																		
Fill MSB with water	3	2	3.75	1	188	0	0	0	0	1	0.25	0	10	2	4	1	160	2	20	8	358	378																		
Totals	21	22	54.75	9	2738	5	2	0	120	4	1.25	0	50	2	4	1	160	10	100	62	3068	3168																		
Load Fuel																																								
Move MTC into pool	2	8	15	31	750	1	0.5	1	30	1	0.5	1	20	0	0	0	0	33	330	16	800	1130																		
Load fuel into MSB	8	0	0	0	0	0	0	0	0	1	2	2	80	2	14	10	560	12	120	16	640	760																		
Place shield lid on MSB	3	8	22.5	27	1125	1	0.5	1	30	2	1	2	40	0	0	0	0	30	300	24	1195	1495																		
Lift MTC from pool	3	8	22.5	37	1125	1	0.5	1	30	2	1	2	40	0	0	0	0	40	400	24	1195	1595																		
Totals	16	24	60	95	3000	3	1.5	3	90	6	4.5	7	180	2	14	10	560	115	1150	80	3830	4980																		
MSB Closure																																								
Weld shield lid/inspect	12	6	60	115	3000	2	2	2	120	2	10	8	400	0	0	0	0	125	1250	72	3520	4770																		
Washdown MTC	2	3	5	18	250	0	0	0	0	1	1	2	40	0	0	0	0	20	200	6	290	490																		
Weld/inspect MSB lid	12	6	57	60	2850	2	1	2	60	1	2	2	80	0	0	0	0	64	640	60	2990	3630																		
Drain MSB	4	2	6.75	0	338	1	1	0	60	2	0.25	0	10	0	0	0	0	0	0	8	408	408																		
Vacuum dry MSB	20	1	18	4	900	1	0.5	0	30	1	1.5	1	60	0	0	0	0	5	50	20	990	1040																		
Backfill MSB with helium	0.25	1	0.08	0	4	1	0.08	0	5	1	0.08	0	3	0	0	0	0	0	0	0.24	12	12																		
Weld/test valve covers	4	4	14	20	700	2	1	0	60	1	1	1	40	0	0	0	0	21	210	16	800	1010																		
Totals	54.25	23	160.83	217	8042	9	5.58	4	335	9	15.83	14	633	0	0	0	0	235	2350	182.24	9010	11360																		
MSB Transfer to VCC																																								
Lift MTC above VCC	1	10	9	5	450	1	0.5	0	30	1	0.5	0	20	0	0	0	0	5	50	10	500	550																		
Install hydraulics to MTC	1	4	4	2	200	0	0	0	0	0	0	0	0	0	0	0	0	2	20	4	200	220																		
Open MTC botm doors	0.5	4	1.1	10	55	0	0	0	0	3	0.9	0	36	0	0	0	0	10	100	2	91	191																		
Lower MSB into VCC	1	6	5	42	250	1	0.25	0	15	3	0.75	0	30	0	0	0	0	42	420	6	295	715																		
Remove MTC	1	6	5.5	6	275	1	0.25	0	15	1	0.25	0	10	0	0	0	0	6	60	6	300	360																		
Place shield ring in VCC	0.5	4	1.6	40	80	1	0.1	0	6	3	0.3	0	12	0	0	0	0	40	400	2	98	498																		
Totals	5	34	26.2	105	1310	4	1.1	0	66	11	2.7	0	108	0	0	0	0	105	1050	30	1484	2534																		
VSC Storage																																								
Tow trailer to ISFSI	1	12	11	36	550	1	1	0	60	0	0	0	0	0	0	0	0	36	360	12	610	970																		
Move VCC off trailer	3	12	33	18	1650	1	3	0	180	0	0	0	0	0	0	0	0	18	180	36	1830	2010																		
Totals	4	24	44	54	2200	2	4	0	240	0	0	0	0	0	0	0	0	54	540	48	2440	2980																		
Total System	100	127	346	480	17289	23	14	7	851	30	24	21	971	4	18	11	720	519	5190	402	19831	25021