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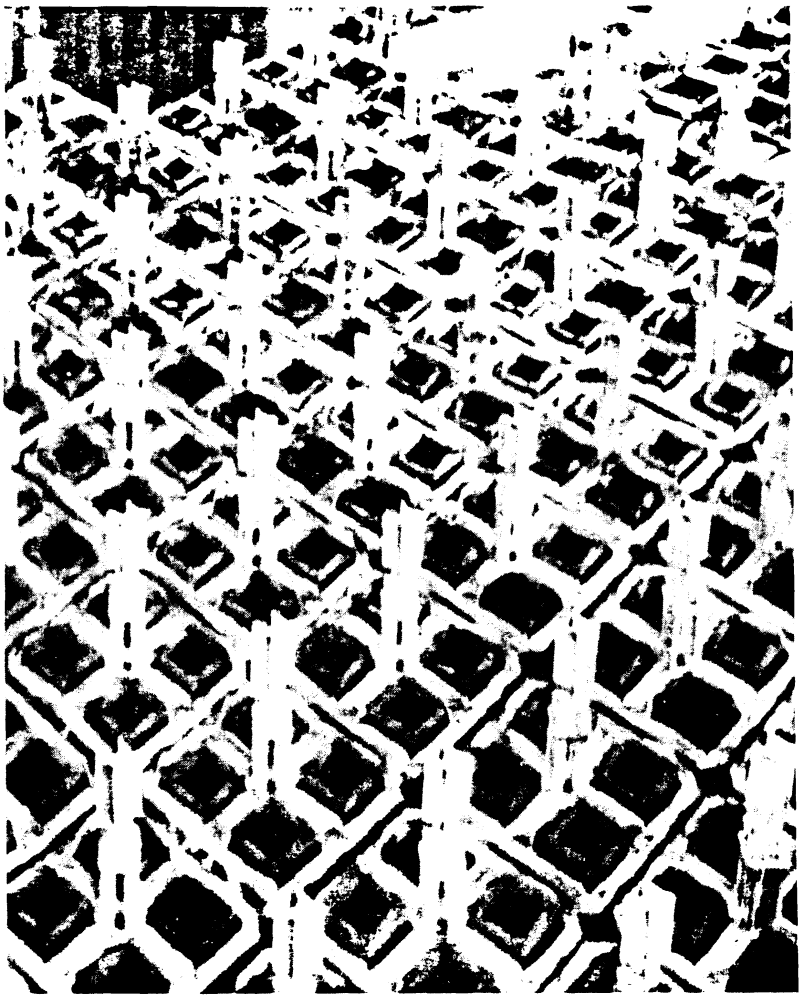
Economics of At-Reactor Spent Fuel Storage Alternatives

April 1983



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ECONOMICS OF AT-REACTOR SPENT FUEL STORAGE ALTERNATIVES

E. T. Merrill
J. F. Fletcher

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Richland, Washington 99352

CONTENTS

ACKNOWLEDGMENTS v

SUMMARY vii

1.0 INTRODUCTION 1.1

2.0 ANALYTICAL METHOD 2.1

2.1 USE OF COST TABLES 2.2

3.0 EXAMPLE CALCULATION AND ANALYSIS 3.1

3.1 CASE DESCRIPTION 3.1

3.2 CALCULATION METHOD AND CONSIDERATIONS 3.2

3.3 RESULTS OF CALCULATIONS 3.4

4.0 REFERENCES 4.1

APPENDIX A.1

FIGURES

2.1 Spent Fuel Storage Decision Matrix 2.8

3.1 Life Cycle Cost Comparisons for Spent Fuel Storage Options 3.8

3.2 Unit Cost Comparisons for Spent Fuel Storage Options . . . 3.9

TABLES

1 Cost Comparison for Storage Options viii

2 Unit Cost Comparison for Storage Options ix

2.1 Reracking Costs 2.11

2.2 New Water Basin Costs 2.12

2.3 Storage Cask Costs 2.13

2.4 Drywell Storage Costs 2.14

2.5 Storage Costs in Silos 2.15

2.6 Storage Costs in an Air-Cooled Vault 2.16

2.7 In-Pool Canning Costs 2.17

2.8 Canning in Separate Facility Costs 2.18

2.9 In-Pool Consolidation and Canning Costs 2.19

2.10 Consolidation and Canning in Separate Facility Costs . . . 2.20

3.1 Storage Cost Summary 3.3

3.2 Fuel Canning and Consolidation Cost Summary 3.5

3.3 Cost Comparison for Storage Options 3.6

3.4 Unit Cost Comparison for Storage Options 3.7

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Additionally, E. R. Johnson of E. R. Johnson Associates, Inc. provided significant assistance in interpreting engineering and economic parameters from his reports (Johnson [1981]; Johnson [1982]) for application to this evaluation.

SUMMARY

This report presents estimates of costs that would be incurred by a utility providing enhanced storage capability for spent light water reactor (LWR) fuel. The cost data are arranged to assist in estimating and evaluating costs for specific storage situations.

Estimated storage costs are provided in a series of tables providing cost factors or arrays for each alternative method of storage considered, and the additional costs involved in various options of pre-storage preparation of the fuel. Cost data are provided for (1) storage enhancement within an existing storage pool, by reracking and/or consolidation of fuel; (2) construction and use of an additional, separate water basin for storage; and (3) utilization of dry storage options (metal casks, drywells, concrete silos, or storage vaults). In addition, costs are given for canning of integral assemblies and for consolidation and canning of fuel. In each case, the storage facilities are assumed to be located at an existing reactor site. If a separate site were to be utilized for storage, appropriate site development and maintenance costs would need to be added.

The basic cost tables are tied together by a "decision tree" logic diagram designed to simulate the decision steps a utility planner might take in selecting from alternative storage technologies to best meet the requirements of his situation.

Using the decision tree and its associated tables, example calculations were made to show the life cycle storage costs for a hypothetical case assuming a pressurized water reactor (PWR) site. The reactor was assumed to discharge 40 assemblies (18.4 MTU) of spent fuel each year; costs were estimated for storage periods of one, five, and 15 years respectively.

Discounted life cycle storage costs in thousands of dollars and unit costs in dollars per kilogram of initial uranium content ($/kgU) are shown in Tables 1 and 2 for this hypothetical site.

Cost for spent fuel storage are dependent upon conditions at each reactor site and the most economical method is not expected to be the same at all

TABLE 1. Cost Comparison for Storage Options

Discounted Costs in Thousands of Dollars (Based on a Typical PWR)

Case	1 Year	5 Years	15 Years
In-pool consolidation only	2,013	2,996	NF[a]
Rerack	5,306	5,712	6,851
Casks - as discharged	3,832	8,325	17,311
- In-pool consolidation	4,866	8,019	14,960
- Separate consolidation		24,367	34,475
Drywells - as discharged	6,566	10,092	17,699
- In-pool consolidation	8,240	11,030	17,045
- In-pool canning	7,381	11,908	21,408
- Separate consolidation		27,320	36,438
- Separate canning		28,634	41,084
Silos - In-pool consolidation		14,938	21,844
- In-pool canning		16,133	26,744
- Separate consolidation		25,105	33,923
- Separate canning		26,533	38,612
Vault - as discharged			46,200
- In-pool consolidation			38,918
- In-pool canning			48,623
- Separate consolidation			58,311
- Separate canning			67,861
Water Basin - as discharged			67,473

(a) NF = Not feasible (insufficient storage capability).

sites. For the specific example chosen, reracking of the pool with high-density storage racks is seen to be the most economical mode for longer term storage, although if the storage requirement is only for a short time period it could best be met by consolidating the fuel and storing it in the original racks. If the pool were already reracked to the maximum (as is the case at many reactors), or if reracking were infeasible (for example, from structural limitations in the pool), the use of storage casks may be the economically preferable option, followed closely (for longer storage periods)

TABLE 2. Unit Cost Comparison for Storage Options

Unit Costs in Dollars per Kilogram Uranium (Based on a Typical PWR)

Case	1 Year	5 Years	15 Years
In-pool consolidation only	144	46	
Rerack	379	87	41
Casks - as discharged	274	127	104
- In-pool consolidation	348	123	90
- Separate consolidation		373	207
Drywells - as discharged	469	155	106
- In-pool consolidation	589	169	102
- In-pool canning	527	182	128
- Separate consolidation		418	219
- Separate canning		438	247
Silos - In-pool consolidation		229	131
- In-pool canning		247	161
- Separate consolidation		384	204
- Separate canning		406	232
Vault - as discharged			277
- In-pool consolidation			234
- In-pool canning			292
- Separate consolidation			350
- Separate canning			407
Water Basin - as discharged			405

by the use of drywells with consolidation of fuel. In many cases, the choice between casks and drywells is very close; in any case the choice may be decided by non-economic considerations (public perception, etc).

Silos may be a viable option in some cases, particularly where larger quantities of fuel require storage. Storage vaults and the installation of new water basins entail appreciably higher initial costs, and may be applicable only to large-scale storage situations.

1.0 INTRODUCTION

Evaluations and projections for spent fuel storage in the United States clearly indicate that in the near future conventional storage of spent fuel in reactor storage facilities will, for some utilities, fail to meet the storage needs for future discharges of spent fuel. The need for additional storage facilities for spent fuel is now projected to commence as early as 1984, and to continue until a fuel reprocessing industry has been established and/or until geological repositories for spent fuel or nuclear wastes are in service.

If Barnwell nuclear fuel reprocessing plant startup occurs as projected (receiving fuel in 1987, operations in 1989) and additional reprocessing plants are available by the end of the century, the requirements for additional spent fuel storage will be small. In the ideal scenario, where fuel for reprocessing is selected preferentially from utilities or sites most in need of additional storage, national-scale storage requirements would be limited to about 260 metric tons of uranium. The ideal situation likely will not occur, and greater storage requirements are likely to develop.

Delays in initiation of reprocessing, however, could sharply increase the need for spent fuel storage. By 1995, when a federal interim storage system for spent fuel and reprocessing wastes is expected to be in place, nationwide requirements for additional spent fuel storage in the absence of reprocessing are projected to increase to about 5600 metric tons. Storage for an individual site could be as high as 500 metric tons, and requirements for utility combined storage could exceed 700 metric tons.

The federal government recognizes the coming fuel storage problem. The Department of Energy has instituted the Commercial Spent Fuel Management Program, one of whose major goals is to assist utilities in meeting this problem. Nuclear waste bills currently before Congress include provisions for emergency storage of spent fuel. However, this storage will be limited both in quantity and duration of storage, and the utilities will have to meet criteria for accepting spent fuel before they can use government storage facilities.

For many utilities the preferable solution to the spent fuel storage problem may well be the construction and operation of their own facilities to provide the required additional storage. This report provides a brief economic assessment of alternative methods of providing additional storage, and is intended to assist in selecting the storage technology most suited to specific needs. Alternatives for "wet" (underwater) storage of fuel include the reracking (providing new, high-density storage racks) in existing pools, the construction of additional conventional storage pools, and "consolidation" of fuel. Consolidation is accomplished by removing the fuel rods from fuel assemblies and repackaging them in a more densely packed configuration in metal canisters, followed by storage of the consolidated canisters in existing pools.

"Dry" storage technologies involve storage of the fuel in air, either as integral assemblies or consolidated into canisters. Storage technologies considered include the use of large metal storage casks, subterranean drywells, above-ground concrete silos, or air-cooled vaults.

Economic assessments of the alternate technologies are presented as examples for three cases, assuming a hypothetical single-reactor site and varying periods of time over which additional storage might be required.

The methodology for economic assessments and comparisons presented is designed to be flexible and applicable to a broad range of storage requirements that might be experienced by a utility. It is presented as a guide in the selection of storage technologies most suited to specific storage situations.

2.0 ANALYTICAL METHOD

Since the mid-1970s, when it became apparent that existing spent fuel storage capacities at nuclear reactor sites would eventually be insufficient to handle increasing inventories of spent fuel, interest has increased in alternative technologies for providing additional storage capacity and the costs of that added capacity. During the intervening years several publications have dealt with the question of costs of storage alternatives.

In 1981, Clark (1981) provided a detailed comparison of costs for wet storage alternatives, including and correlating the results of several earlier publications on the subject. Also in 1981, E. R. Johnson Associates (JAI) (1981) provided a comparison of cost estimates for dry storage alternatives, reporting on an engineering study addressing the storage costs at the Surry site of the Virginia Electric and Power Company (VEPCO). The estimates provided by Clark and JAI form the primary basis for the present cost comparison. Those cost estimates were adjusted to mid-1982 levels, and modified as appropriate by including the results of recent engineering studies in the PNL Commercial Spent Fuel Management (CSFM) and Monitored Retrievable Storage (MRS) programs.

The data used in providing cost estimates for a specific alternative are provided in a series of tables of cost and cost factors, one for each alternative considered. Entry to these tables is made via a "decision tree". The decision tree and its associated cost tables (Figure 2.1 and Tables 2.1 through 2.10) address the selection logic and associated cost estimation for the storage options considered. The basic storage options include:

- reracking to increase capacity of an existing pool
- construction of a new pool
- dry storage in large storage casks
- dry storage in drywells
- dry storage in concrete silos
- dry storage in air-cooled vaults.

Options considered for preparation of the fuel before storage, in addition to storage "as is" in integral fuel assemblies, include the following:

- canning of fuel assemblies in storage pools
- disassembly, consolidation and canning of fuel in storage pools
- "dry" canning of fuel in a separate facility
- "dry" consolidation and canning in a separate facility.

2.1 USE OF COST TABLES

The decision tree presented in Figure 2.1 represents the decision process a utility planner might go through in selecting an option for spent fuel storage. First he would decide (at least on a trial basis) whether the needed additional storage capacity should be provided at each reactor or at a single site serving all reactors operated by the utility. From this, the total storage capacity and the annual increments of capacity required at the site may be estimated.

As his next step in selection, he would choose one of the available options for storage; costs for these options may be estimated from Tables 2.1 through 2.6. Finally, he would decide on the preparation of the fuel before it is placed in storage. Depending on circumstances, it may be desirable to store the fuel "as is," as integral fuel assemblies; to "can" the assemblies, enclosing them in metal canisters; or to disassemble the fuel rods and consolidate them into metal canisters. Each option may have advantages in particular circumstances. Tables 2.7 through 2.10 present costs for the canning and consolidation options, performed either in a reactor storage pool or in a separate consolidation/canning facility.

Capital costs for the tables were primarily taken from Clark and JAI, with modifications developed by Pacific Northwest Laboratory (PNL) for the Commercial Spent Fuel Management (CSFM) program. Labor costs and other operating costs incurred during fuel handling or the emplacement and removal of stored fuel were derived from the sources mentioned. Costs of maintenance and maintenance supplies during the storage period were taken from PNL as an annual amount equivalent to 1.4% of total capital costs. Labor costs, general supplies, and overhead during the storage period were apportioned according to

the number of fuel assemblies handled, number of canisters handled, number of storage units placed or removed and the number of storage units in inventory. Labor assessments for both handling and storage phases of operation assumed that the activities involved were incremental for the normal operating crew.

Decommissioning costs were taken as 10% of the total capital costs, with cost reductions allowed in some facilities storing canned fuel.

Normally the most economical means of achieving increased spent fuel storage capacity is by installing "high density" racks in an existing storage pool. These racks permit fuel storage in more closely packed configurations, and are usually equipped with neutron poisons and/or flux traps to preclude criticality problems.

Table 2.1 presents typical costs of reracking an existing pool. The capital costs were obtained from Clark, and increased by a factor of 1.059 to convert 1981 dollars to 1982 dollars. The schedule of capital expenditures was derived from similar data presented by JAI. However, the JAI schedule was delayed by one year to reflect completion of reracking in the first year of use rather than in the year prior to use.

The apportioned costs previously discussed were used for operating and decommissioning costs.

Construction of an additional water basin for additional storage is a technically feasible option, but because of the relatively high costs involved it is not expected to be exercised frequently. Selection of a capital-intensive option such as this would normally infer that the storage requirement will be intensive and long-lasting.

Capital costs of the new basin are derived from a formula given by Clark; the schedule of expenditures is as given by JAI (1981). Annual operating costs (6% of capital) are from JAI (1982); Clark estimates 5% of capital as operating costs.

The use of large storage casks for dry storage of spent fuel is one of the more popular options under consideration. The "front end" costs of this option are low, the casks are moderately priced, and the use of casks would lend an air of impermanence to the storage facility.

Costs for this option were taken from JAI, except the cask and storage yard costs developed by PNL for the CSFM program. Initial costs for the storage yard include licensing, site preparation and leveling, and construction of access roads for a rubber-tired transporter. The costs were compiled for a yard capable of holding 1000 casks; cost reductions for smaller yards would be minor and may be masked by site-to-site differences in preparation and leveling costs.

Large metal casks capable of storing 24 PWR or 52 BWR assemblies are estimated at $700,000 each. Concrete storage pads (one per cask) are poured the year before they are placed in service and estimated at $2000 each. Additionally, $2330 per cask is assessed for placement or removal of the cask in or from the field, after JAI. Loading and unloading operations are an estimated $5000 per cask; if the cask is loaded during a canning operation, the $5000 fee is included in the canning fee.

Decommissioning costs are assumed at 10% of capital costs if uncanned fuel has been stored in a cask. However, if canned fuel is stored in the cask, decontamination costs will be minimal and the salvage value of the cask materials covers the decommissioning costs.

The use of drywells may be an attractive option in many instances; front-end costs for this option are moderate, and the drywells are inexpensive to install and use. The drywells are assumed to be designed to hold one PWR or 3 BWR assemblies, either canned or uncanned, or the same numbers of consolidated fuel canisters. Radioactivity-control regulations, however, may preclude the use of uncanned fuel.

Capital costs for the drywell option were taken from JAI, excepting the drywell and storage yard costs developed for the CSFM program by PNL. Costs of preparing a storage yard capable of holding 1000 drywells are estimated at $300,000; licensing costs are an added $1.63 million (assumed to be assigned to costs of the first yard). Transfer equipment required consists of a rubber-tired transporter equipped with a shielded transfer cask designed for top loading and bottom unloading.

The drywells themselves cost $18,000 and are assumed to be emplaced in the year before use. Operating costs are incurred as indicated in the table for loading fuel in the drywell and removing it; storage and surveillance costs are assigned at $185 per year per drywell.

The use of concrete silos may offer an alternative to casks or drywells for storage of spent fuel. The silos (at an estimated $78,000 ea) are intermediate in cost between casks and drywells; storage yard development costs and base pad costs are the same as for casks (excluding license fees). However, since the silo is cooled by an induced flow of air through its structure, the fuel (whether as assemblies or consolidated) must be encapsulated in storage canisters. If a separate "dry" consolidation or canning facility is provided, the canned fuel may be loaded directly into the silo at that facility. Otherwise, special transporters and silo loading structures must be provided, as indicated in the table. Loading and unloading of the silo are relatively complicated operations bearing higher charges than casks.

An air-cooled vault is in essence a structure containing shielded rooms or pits in which spent fuel is stored--in racks or equivalent arrangement--and cooled by induced recirculation of air.

The initial construction costs of a storage vault are significantly higher than those of other dry storage options. For this reason, the vault storage option is best suited to storage of large quantities of fuel and/or to long storage periods. So it may not be as attractive to a utility as other options.

The costs for vault storage were taken from JAI and recast into the format shown in the table. Although provisions are included for estimating the costs of storing uncanned, "as-discharged" fuel, the air-cooling features of the vault likely will require canning of the fuel unless air filtration facilities and perhaps an air discharge stack are added.

For any method of storage chosen, several options are usually available for the form in which the fuel is stored. The simplest option, and on the surface the least expensive, is to store the fuel assemblies in the "as

discharged" condition with no further treatment. Alternatively, the assemblies may be canned (emplaced in sealed canisters) for storage, or they may be disassembled, the fuel rods regrouped in more compact arrays, and the consolidated rods canned. Further, the canning and consolidation may be carried out in a reactor storage pool, if space is available, or in facilities constructed for "dry" consolidation and canning.

Costs for the preparation options are provided in Tables 2.7 through 2.10. The costs listed in these tables were primarily derived from JAI and escalated by 5.9% to convert 1981 dollars to 1982 dollars; canister costs are from an estimate developed for the CSFM program by PNL. The costs of labor and general supplies, given by JAI in case-by-case analyses, are converted in these tables to a "linear equation" form (a constant term plus a term proportional to throughput) for greater ease of use.

Cost estimates available in the literature, including those referenced, are for PWR fuel only. Cost factors for BWRs as given in the tables assume, as an estimation, that preparation and storage costs for PWR and BWR fuels would be approximately equal on an equivalent-weight basis.

The tables allow estimation of costs for any preparation option in combination with any of the storage variants. In using the tables, however, it should be borne in mind that for some of the storage methods available, certain fuel preparation options may be precluded or inappropriate. For example, fuel may be stored "as discharged" in water basins or sealed storage casks. For these cases, canning of the assemblies would have no economic advantage; canning would not be used unless needed to isolate assemblies with leaking or failed fuel rods. On the other hand, if storage is to be in drywells, silos, or vaults, radiological considerations may preclude the use of "as discharged" fuel or contamination control may require that added facilities be provided, at extra cost, if as-discharged fuel is used.

Consolidation of fuel, while it involves added costs, also provides more efficient use of the available storage space. Depending on the situation, overall cost reductions for storage may be realized if consoldiation is used. In addition, cost saving may result after the storage period is past. For

example, fewer shipments are required for transporting consolidated fuel than for the same quantity of fuel in integral assemblies. Thus, savings in post-storage shipping costs may assist in compensating for consolidation costs.

In selecting and sizing any facility for additional storage, possible long-term effects of the selection must be taken into account. Selection of an option (e.g., vaults or water basins) requiring high-volume or long-term storage for economy of costs, for example, can result in unexpected costs if reprocessing should become available before the "breakeven" point in the storage period is reached. Whether full use of the facility is abrogated or the reprocessing option is deferred until after the "breakeven" point is reached, greater costs are likely to be incurred than if an option amenable to modular storage additions had been chosen. On the other hand, unexpected additional delay in reprocessing could require a second vault or water basin, while the modular systems could be expanded for relatively little cost.

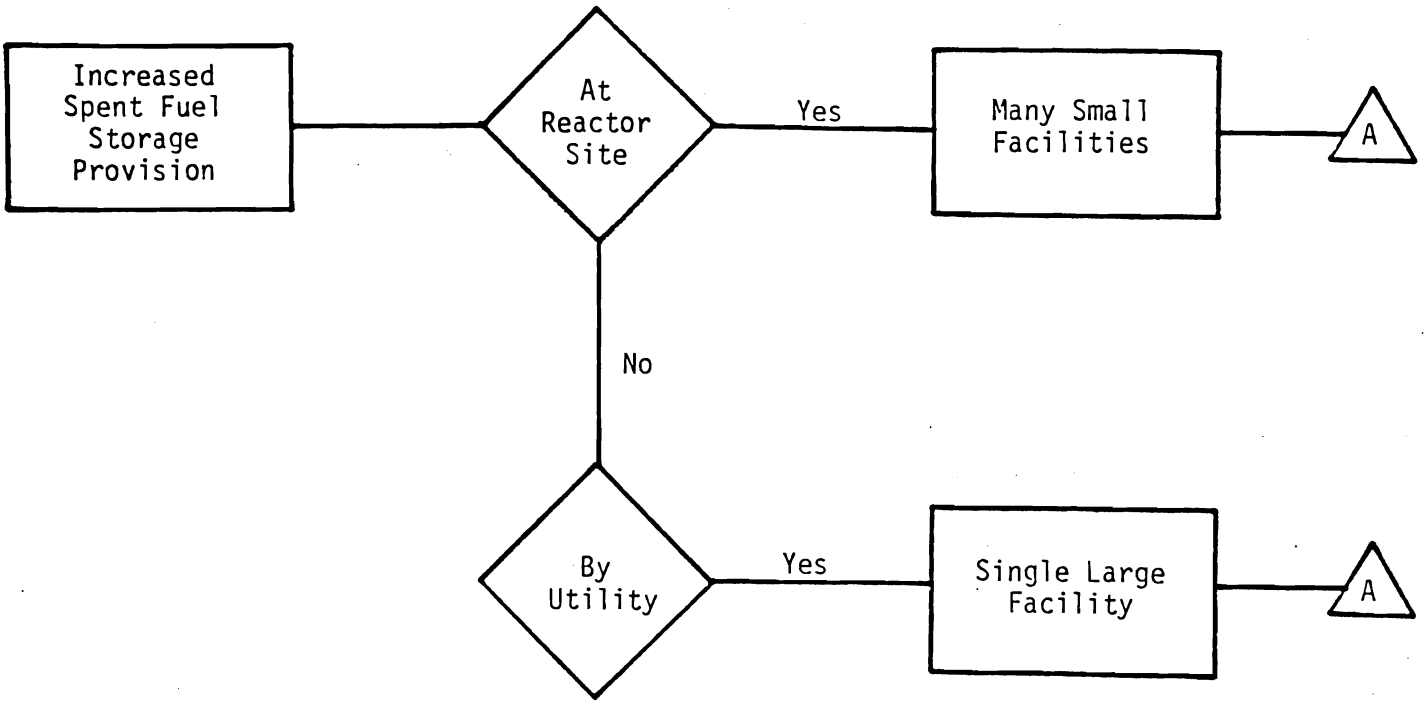

FIGURE 2.1. Spent Fuel Storage Decision Matrix

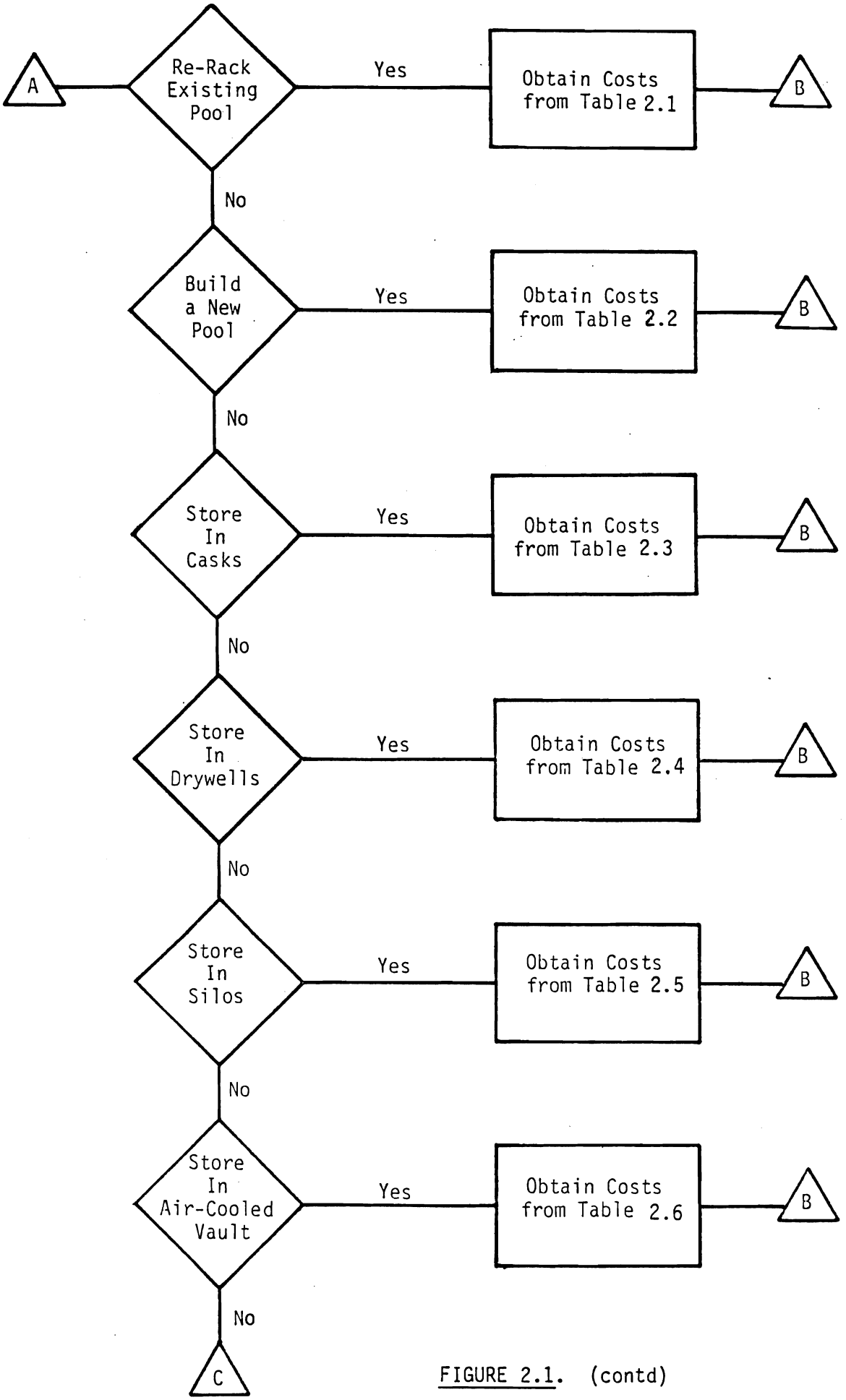

FIGURE 2.1. (contd)

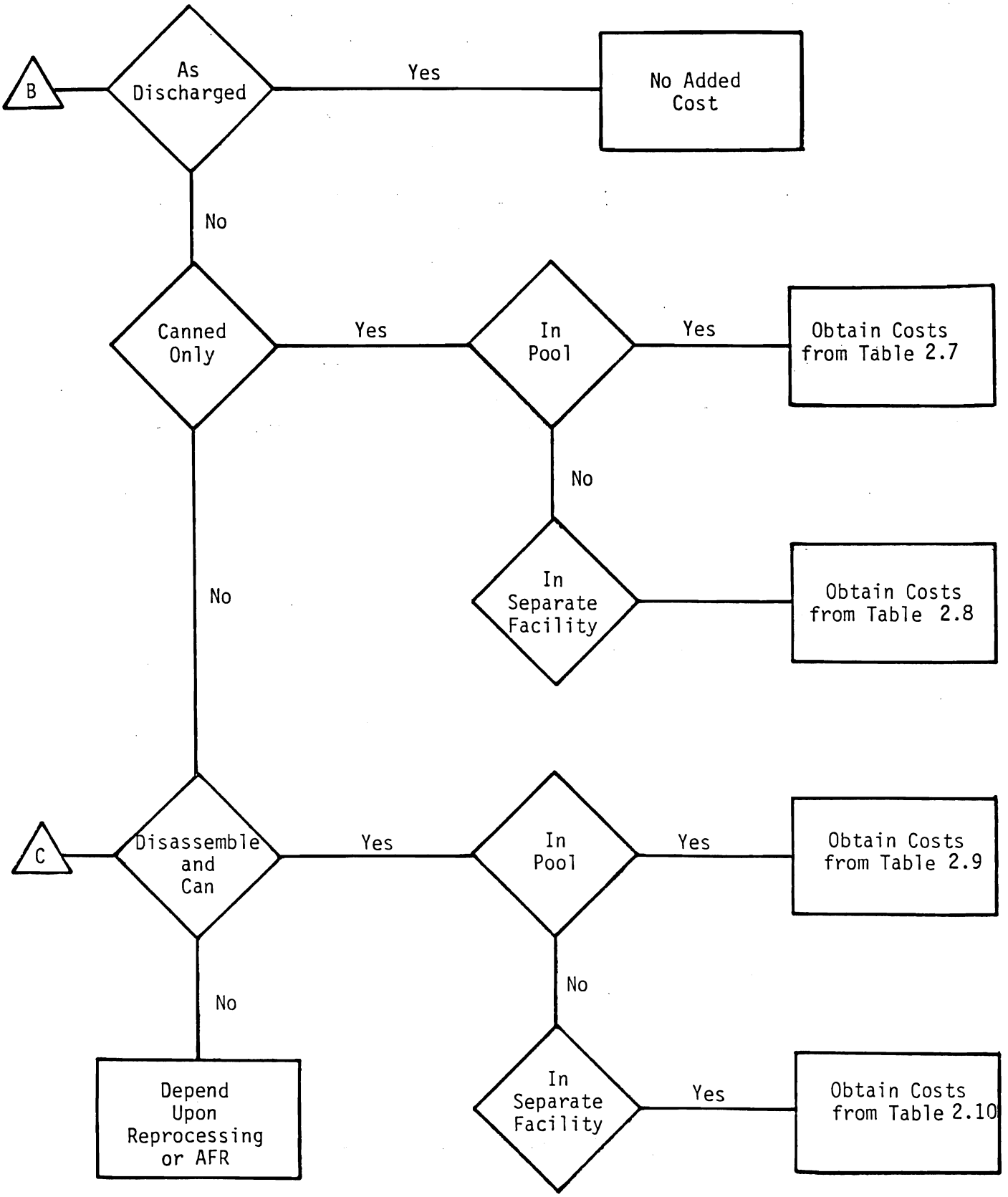

FIGURE 2.1 (contd)

TABLE 2.1. Reracking Costs

Range of application: Reactor Specific

Capital Costs:	PWR	BWR
Assumed pool area	1225 sq ft	1000 sq ft
Assumed initial capacity, assemblies	660	1300
MTU	360	250
Reracked capacity, assemblies	1374	3016
MTU	637	580
Rack Cost	$4,384,000	$4,987,000
Installation and licensing	$1,590,000	$1,590,000
Total Capital Costs	$5,974,000	$6,577,000

Expenditures in year	
-2	20%
-1	20%
0	5%
First year of use	55%

Operating Costs:

Maintenance supplies:	1.4% of capital
Labor and general supplies:	$185 per assembly or canister in inventory
Property tax and insurance:	0.93% of capital
Decommissioning:	10% of capital

NOTE: Placement or removal is not an expense for increased storage in the original pool.

TABLE 2.2. New Water Basin Costs

Range of Application: 500 to 5,000 MTU capacity

Capital Cost in Millions[a]:

$$\left(30 + 30\left(\frac{(S)(C)}{1000}\right)^{0.75}\right)(1.059)$$

where S = storage capacity, Mg U
C = consolidation factor (say, 0.58 if consolidated)

Expenditures in year	-6	6%
	-5	8%
	-4	
	-3	1%
	-2	26%
	-1	43%
	0	16%
First year of use		0%

Transfer Cask:
$1,059,000

Operating Cost:
6% of capital

(a) The sizing formula is from Clark (1981); escalation to mid-1982 dollars involves a factor of 1.059.

TABLE 2.3. Storage Cask Costs

Range of Application: 0 to 12 per year

Capital Costs:

Yard:	$1,270,000 + $2,000 per cask for each increment when built	
Transporter:	$1,520,000	
Expenditures in year:	-3	25%
	-2	6%
	-1	0%
	0	69%
First year of use		0%

Cost of Casks: (year before need) $700,000 (cask holds 24 PWR or 52 BWR assemblies)

Operating Cost:

Maintenance supplies:	1.4% of cumulative investment
Labor and general supplies:	$2,330 per cask placement or removal + $5,000 per cask to load or unload if not inluded in a canning operating + $185 per year for each cask in use.
Property tax and insurance:	0.93% of capital
Decommissioning:	10% of capital if uncanned fuel, none for canned fuel

TABLE 2.4. Drywell Storage Costs

Range of Application: 0 to 300 per year

Capital Costs:

Yard:	$1,930,000 for the first 1000 + $300,000 for each subsequent 1000 drywells	
Transfer equipment:	$4,640,000 (may need more transfer equipment for high removal rates)	
Expenditures in year: (for first increment)	-3	25%
	-2	6%
	-1	0%
	0	69%
First year of use		0%

Cost of Drywells: $18,000

Operating Cost:

Maintenance supplies:	1.4% of investment
Labor and general supplies:	$2,750 per drywell filled + $185 per year for each drywell in use + $780 per drywell emptied
Property tax and insurance:	0.93% of capital
Decommissioning:	10% of capital if uncanned fuel, 2% if canned fuel.

TABLE 2.5. Storage Costs in Silos

Range of Application: 0 to 100

Capital Costs:

Yard:	$1,510,000 loading facility if separate disassembly or canning facility not available + $1,930,000 for the first 1000 silos + $300,000 for each subsequent 1000 silos + $2000/silo
Transporters:	$4,640,000 reactor basin-to-silo transporter if separate canning or disassembly facility not available + $2,280,000 for transporter to move and emplace silos

Expenditures in year:	
-4	18%
-3	11%
-2	0%
-1	25%
0	46%
First year of use	0%

Cost of Silo:		
	Liner	$17,000
	Silo	$61,000
		$78,000 (holds 4 canisters)

Operating Cost:

Maintenance supplies:	1.4% of investment
Labor and general supplies:	$7600 per silo for placement + $1880 per silo for removal (+ $2430 per canister for loading + 1070 per canister for unloading if canned in pool) (+ $1000 to load and unload a transfer cask if not included in a canning operation) + $185 per year per silo in service
Property tax and insurance:	0.93% of capital
Decommissioning:	2% of capital since fuel is canned.

TABLE 2.6. Storage Costs in an Air-Cooled Vault

Range of Application: 0 to 300 assemblies/year

Capital Costs:

Vault and transfer equipment:	$19,900,000 + $30,200/canister of capacity If a high unloading rate is assumed, extra unloading equipment may be required at that time.	
Expenditures in year:	-6	7%
	-5	8%
	-4	0%
	-3	1%
	-2	25%
	-1	38%
	0	21%
First year of use		0%

Operating Cost:

Maintenance supplies:	1.4% of investment
Labor and general supplies:	$4760 per canister placed + $185 per year per canister in inventory + $1270 per canister removed
Property tax and insurance:	0.93% of capital
Decommissioning:	10% of capital if fuel is uncanned, 2% of capital if fuel is canned.

TABLE 2.7. In-Pool Canning Costs

Range of Application: 30 to 300 assemblies/year

Capital Costs: $642,000

Expenditures in year:	-3	19%
	-2	19%
	-1	5%
	0	57%
First year of use		0%

Operating Cost:

Maintenance supplies:	Included in general supplies below
Labor and general supplies:	$5500 per canister + $39,000 + $1800 per canister loaded
Property tax and insurance:	0.93% of capital
Decommissioning:	10% of capital

NOTE: Mild steel cans would dissolve at the reprocessing plant, complicate the process, and increase HLW volume. Stainless steel cans would increase the hulls and hardware volume. The processor would be expected to charge a premium of about the same order as removal of the can or about $1500 each. The can may be an advantage if spent fuel is sent to a disposal site since surface contamination is reduced. A small credit may be expected.

TABLE 2.8. Canning in Separate Facility Costs

Range of Application: 30 to 300 assemblies/year

Capital Costs:

Site preparation	$ 200,000
Structures	5,000,000
Cell Equipment	1,600,000
Transfer Equipment	1,400,000
Subtotal	$ 8,200,000
Installation (35% of equipment)	1,000,000
Subtotal	$ 9,200,000
Engineering	1,400,000
Licensing	1,000,000
License Fee	400,000
Subtotal	$12,000,000
Contingency	3,000,000
TOTAL	$15,000,000 x 1,059 = $15,900,000

Expenditure in year:		
	-6	6%
	-5	11%
	-4	0%
	-3	2%
	-2	26%
	-1	32%
	0	23%
First year of use		0%

(May need additional transfer equipment if removal rate is high)

Operating Cost:

Maintenance supplies: 1.4% of capital

Labor and general supplies: $36,000 + $8150 per canister loaded + $2540 per canister removed + $5500 for canister + $580 per PWR assembly or $290 per BWR assembly if facility and reactor are at different sites

Property tax and insurance: 0.93% of capital

Decommissioning: 10% of capital

NOTE: Same as Table 2.7.

TABLE 2.9. In-Pool Consolidation and Canning Costs

Range of Application: 30 to 300 assemblies/year

Capital Costs: $1,978,000

Expenditures in year:	-3	13%
	-2	10%
	-1	2%
	0	75%
First year of use		0%

Operating Cost:

Maintenance supplies:	Included in general supplies below
Labor and general supplies:	$5500 per canister + $104,000 + $3200 per canister loaded.
Property tax and insurance:	0.93% of capital
Decommissioning:	10% of capital

NOTE: 1) Same as Table 2.7.
2) The number of shipments is reduced by consolidation, resulting in a savings of about $4000 per assembly shipped to a reprocessor, assuming a 500-mile shipment or $13,000 per assembly shipped to a repository, assuming a 2500-mile shipment.

TABLE 2.10. Consolidation and Canning in Separate Facility Costs

Range of Application: 30 to 400 assemblies/year

Capital Costs:

Site preparation	$ 200,000	
Structures	5,000,000	
Cell Equipment	1,900,000	
Transfer Equipment	1,400,000	
Subtotal	$ 8,500,000	
Installation (35% of equipment)	1,100,000	
Subtotal	$ 9,600,000	
Engineering	1,500,000	
Licensing	1,200,000	
License Fee	500,000	
Subtotal	$12,800,000	
Contingency	3,200,000	
TOTAL	$16,000,000	x 1,059 = $16,900,000

Expenditures in year:		
	-6	6%
	-5	11%
	-4	0%
	-3	2%
	-2	26%
	-1	32%
	0	23%
First year of use		0%

Operating Cost:

Maintenance supplies: 1.4% of capital

Labor and general supplies: $61,000 + $14,400 per canister filled + $5500 for canister + $3200 per canister during removal + $580 per PWR assembly or $290 per BWR assembly for shipping if facility and reactor are at different sites.

Property tax and insurance: 0.93% of capital

Decommissioning: 10% of capital

NOTE: 1) Same as Table 2.7.
2) Same as note 2, Table 2.9.

3.0 EXAMPLE CALCULATION AND ANALYSIS

To demonstrate use of the decision tree and its associated tables, example calculations were made of a hypothetical situation and costs for alternative storage modes were compared for that case.

3.1 CASE DESCRIPTION

The example case assumed a utility wishing to provide onsite supplemental storage for a single PWR. This reactor has a spent fuel pool area of 1225 square feet and has non-high density fuel racks with capacity for 660 fuel assemblies, or 306 metric tons contained uranium (MTU). Two hundred fuel positions will remain open to accommodate full core reserve, storage for failed assemblies, and other purposes. The pool contains 460 spent fuel assemblies, and 40 additional assemblies are discharged each year. The utility realizes a return on equity of 6% above inflation, and the interest rate on debt is 2% above inflation. The utility's debt/equity ratio is 1:1 and taxes are levied at an effective 46% rate. Thus, the after-tax weighted cost of capital is 3.5% above inflation. This was used as the discount rate in the example.

With 460 rack positions filled and 200 held in reserve, the spent fuel rack is effectively filled to capacity. Costs of storage using available options are to be compared, assuming the required length of storage is, one,[a] five, and 15 years. Construction of the storage facility is assumed to begin at an appropriate time so that the additional storage is available in the year it is needed. (All cases were normalized for commencement of storage in the year 1990.) Costs are to be calculated as total life-cycle costs, including decommissioning costs, and as unit costs in dollars per kilogram of uranium in the fuel. For the case assuming one year of storage, the storage facility is assumed to be emptied and decommissioned in the second year. For

(a) Storage for a one-year period is not a realistic case. However, costs were calculated for this case for use in interpolation and in graphic displays of data.

the five-year storage case the unloading takes place in the sixth year and decommissioning in the seventh; and in the 15-year case the facility is unloaded in the 16th and 17th years and decommissioned in the 18th.

3.2 CALCULATION METHOD AND CONSIDERATIONS

Calculations for each storage option were performed using the decision tree and its associated tables, as described previously in this report. Tracing through the decision tree defined the tables providing the requisite cost factors both for the specific storage option and for the fuel preparation steps chosen for use with that option. These cost factors were then used to calculate detailed annual cash flows and discounted costs for each year in which construction, operation, or decommissioning activities were assumed to be underway. The appendix to this report contains cash flow tables for each storage mode and fuel preparation method considered in the example exercise. The discounted cost totals from the cash flow tables were transferred to Tables 3.1 and 3.2.

Table 3.1 summarizes the costs for the various storage modes, including the cost variations occasioned by the fuel preparation assumed. Table 3.2 is a similar summary for the costs of options for fuel preparation.

The cost data in Tables 3.1 and 3.2 were combined to provide the costs given in Table 3.3. These are the total discounted costs for each option considered in the exercise. Table 3.4 shows the corresponding unit costs in dollars per kilogram uranium. Figures 3.1 and 3.2 give graphic depiction of this data.

In performing the calculations and assembling the tables of results, considerations of costs or logistics obviated inclusion of some combinations of options. For example, if added storage capability is pursued by using in-pool consolidation of fuel assemblies followed by storage in the existing racks, only eight years' additional storage may be gained in the specific example considered; hence no costs were calculated for the 15-year storage case. On the other hand, if the pool were reracked with high-density racks, a full 15 years' storage could be attained without consolidation; hence the

TABLE 3.1. Storage Cost Summary

Case		Discounted Costs in Thousands Capital	Operating	Total
Rerack Reactor Pool	15 yr	4,961	1,890	6,851
	5 yr	5,091	621	5,712
	1 yr	5,147	159	5,306
New Water Basin	15 yr	40,625	26,848	67,473
Cask Storage (as discharged)	15 yr	14,162	3,149	17,311
	5 yr	7,468	857	8,325
	1 yr	3,675	157	3,832
Cask Storage (consolidated fuel)	15 yr	8,842	2,057	10,889
	5 yr	4,842	584	5,426
	1 yr	2,815	115	2,930
Cask Unloading (add for in-pool consolidation)	15 yr		33	33
	5 yr		16	16
	1 yr		4	4
Drywell Storage (unconsolidated fuel)	15 yr	12,347	4,723	17,070
	5 yr	8,225	1,597	9,822
	1 yr	6,127	380	6,507
Transfer Cask Loading (add for fuel as discharged)	15 yr		362	362
	5 yr		142	142
	1 yr		30	30
Transfer Cask Unloading (add for in-pool canned and as discharged fuel)	15 yr		267	267
	5 yr		128	128
	1 yr		29	29
Drywell Storage (consolidated fuel)	15 yr	9,442	3,420	12,862
	5 yr	7,133	1,246	8,379
	1 yr	5,968	323	6,291
Transfer Cask Unloading (add for in-pool consolidated fuel)	15 yr		155	155
	5 yr		74	74
	1 yr		17	17
Silo Storage (unconsolidated fuel)	15 yr	11,096	3,502	14,598
	5 yr	6,602	1,119	7,721
	1 yr	4,329	246	4,575
Silo Loading Facility (add for in-pool canned fuel)	15 yr	5,115	2,960	8,075
	5 yr	5,139	1,315	6,454
	1 yr	5,153	351	5,504

TABLE 3.1. (contd)

Case		Discounted Costs in Thousands Capital	Operating	Total
Silo Storage (consolidated fuel)	15 yr	7,906	2,441	10,347
	5 yr	5,307	857	6,164
	1 yr	4,004	207	4,211
Silo Loading Facility (add for in-pool consolidated fuel)	15 yr	5,115	2,354	7,469
	5 yr	5,139	1,058	6,197
	1 yr	5,153	294	5,447
Air Cooled Vault-600 Assemblies		32,094	12,191	44,285
Transfer Cask Loading and Decommissioning (add if uncanned fuel)			1,648	1,648
Transfer Cask Unloading (add if in-pool canned)			267	267
Air Cooled Vault-345 Canisters		25,593	9,142	34,735
Transfer Cask Unloading (add if in-pool consolidation)			155	155

combination of reracking and consolidation was not considered in the example. Additionally, some storage options became clearly uneconomical for shorter storage times; calculations for those instances were omitted.

3.3 RESULTS OF CALCULATIONS

Results of the example calculations are displayed as total discounted costs for the various storage options in Table 3.3 and Figure 3.1, and as unit costs per kilogram of uranium in Table 3.4 and Figure 3.2.

The relative ranking of results will depend upon the specific conditions at a given site, but these results indicate that the most cost-effective storage option available at the hypothetical site is the in-pool consolidation of fuel, with subsequent storage of the consolidated fuel in the pool. However, this option by itself is inherently limited by the capacity of the

TABLE 3.2. Fuel Canning and Consolidation Cost Summary

Case		Discounted Costs in Thousands		
		Capital	Operating	Total
In-pool Canning	15 yr	527	3,544	4,071
	5 yr	528	1,430	1,958
	1 yr	528	317	845
Canning in Separate Facility	15 yr	13,999	10,015	24,014
	5 yr	14,308	4,504	18,812
	1 yr	14,493	1,213	15,706
In-pool Consolidation	15 yr	1,673	2,355	4,028
	5 yr	1,711	866	2,577
	1 yr	1,734	198	1,932
Consolidation and Canning in Separate Facility	15 yr	14,879	8,697	23,576
	5 yr	15,208	3,733	18,941
	1 yr	15,404	1,066	16,470
In-pool Consolidation Only	5 yr	1,711	1,285	2,996
	1 yr	1,734	279	2,013

pool's storage racks. In the example case, using a consolidation factor of 1.75, the use of consolidation achieves only eight years' added storage capability.

The second most cost-effective method of storage augmentation for this hypothetical site, and the only one of the study options (except construction of a new storage pool) which is now considered licensable, is the reracking of a pool--the installation of high-density storage racks. Such racks have been installed or are planned for installation in many U.S. LWR storage pools; the option is still an attractive one for those sites which have not yet been reracked.

The combined use of reracking and fuel consolidation provides the potential for considerable increase in storage capacity at favorable unit costs. As was previously mentioned, this combination was not considered in the specific example calculations, since consolidation for that example was superfluous once the pool was reracked. In general, however, the storage of consolidated fuel in high-density racks may be a favorable option.

TABLE 3.3. Cost Comparison for Storage Options

Case	Example Case Discounted Costs in Thousands of Dollars 1 Year	5 Years	15 Years
In-pool consolidation only	2,013	2,996	NF[a]
Rerack	5,306	5,712	6,851
Casks - as discharged	3,832	8,325	17,311
- In-pool consolidation	4,866	8,019	14,960
- Separate consolidation		24,367	34,475
Drywells - as discharged	6,566	10,092	17,699
- In-pool consolidation	8,240	11,030	17,045
- In-pool canning	7,381	11,908	21,408
- Separate consolidation		27,320	36,438
- Separate canning		28,634	41,084
Silos - In-pool consolidation		14,938	21,844
- In-pool canning		16,133	26,744
- Separate consolidation		25,105	33,923
- Separate canning		26,533	38,612
Vault - as discharged			46,200
- In-pool consolidation			38,918
- In-pool canning			48,623
- Separate consolidation			58,311
- Separate canning			67,861
Water Basin - as discharged			67,473

(a) NF = Not feasible (insufficient storage capability).

At some reactor sites, structural or seismic limitations would prevent full utilization of storage augmentation by use of either high-density racks or consolidation. At others, the perceived storage requirements may exceed the capacity attainable through in-pool modifications. For those cases, dry storage technologies offer the primary options for increasing spent fuel storage capability. Dry storage also may be the logical choice if a utility chose to develop a common site to accommodate all its spent fuel storage needs.

Comparative costs of the dry storage options, as shown, indicate that for the hypothetical site chosen the use of storage casks is the least expensive

TABLE 3.4. Unit Cost Comparison for Storage Options

Case	Example Case Unit Costs in Dollars per Kilogram Uranium		
	1 Year	5 Years	15 Years
In-pool consolidation only	144	46	
Rerack	379	87	41
Casks - as discharged	274	127	104
- In-pool consolidation	348	123	90
- Separate consolidation		373	207
Drywells - as discharged	469	155	106
- In-pool consolidation	589	169	102
- In-pool canning	527	182	128
- Separate consolidation		418	219
- Separate canning		438	247
Silos - In-pool consolidation		229	131
- In-pool canning		247	161
- Separate consolidation		384	204
- Separate canning		406	232
Vault - as discharged			277
- In-pool consolidation			234
- In-pool canning			292
- Separate consolidation			350
- Separate canning			407
Water Basin - as discharged			405

option, followed successively by utilization of drywells and concrete silos (for some specific storage situations the order of preference may vary). The cask option may also be the only dry storage option for which the use of as-discharged fuel would be authorized. However, consolidation offers cost advantages for this as well as other options, if the consolidation may be performed in-pool. If separate consolidation facilities must be provided, their use with the cask storage option would compete with storage of as-discharged fuel only for larger quantities and/or longer times of storage than considered in the example calculations. Also, the cost figures indicate that silos may be competitive with casks, and perhaps drywells also would, for larger storage requirements.

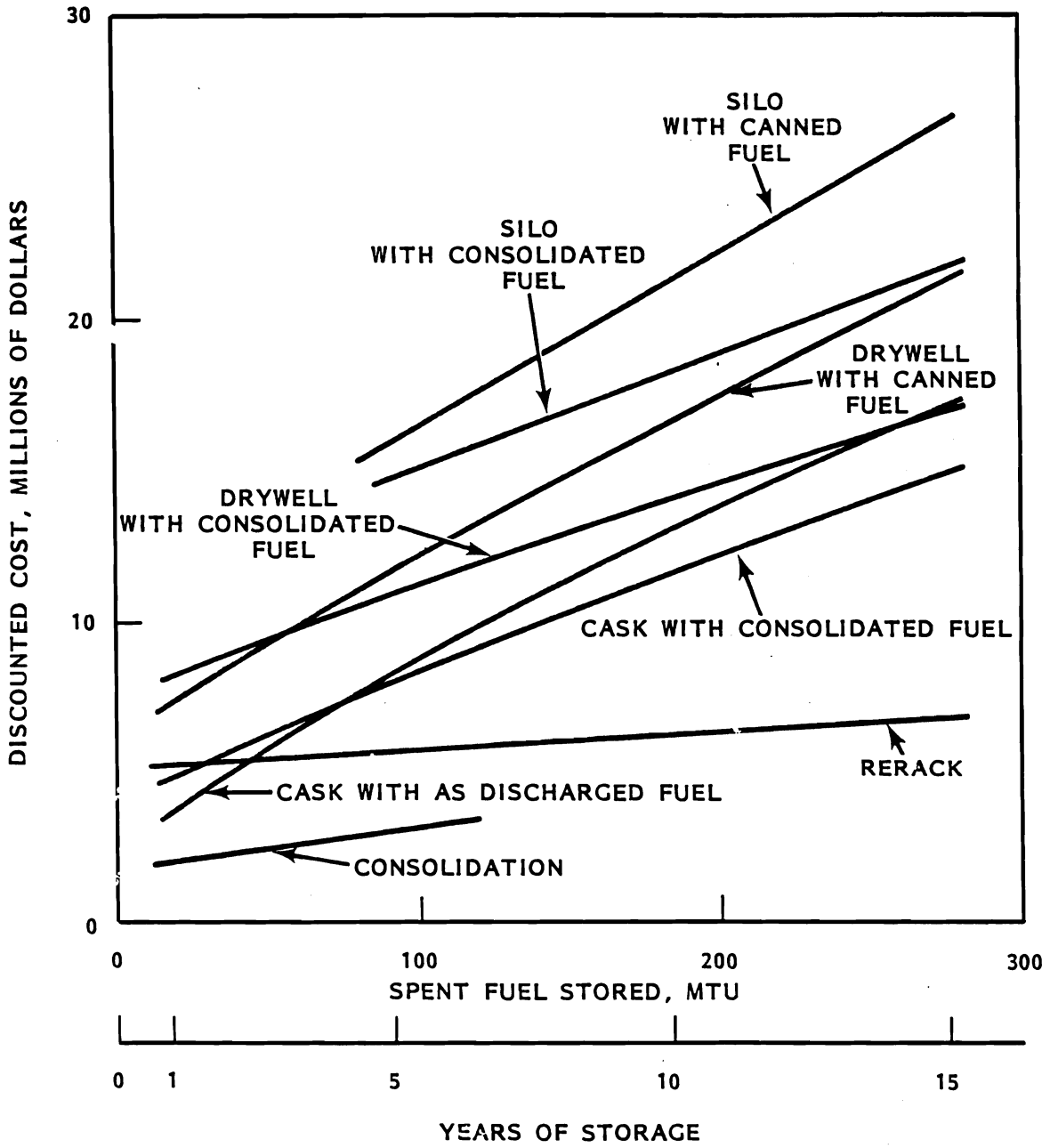

FIGURE 3.1. Life Cycle Cost Comparisons for Storage Options

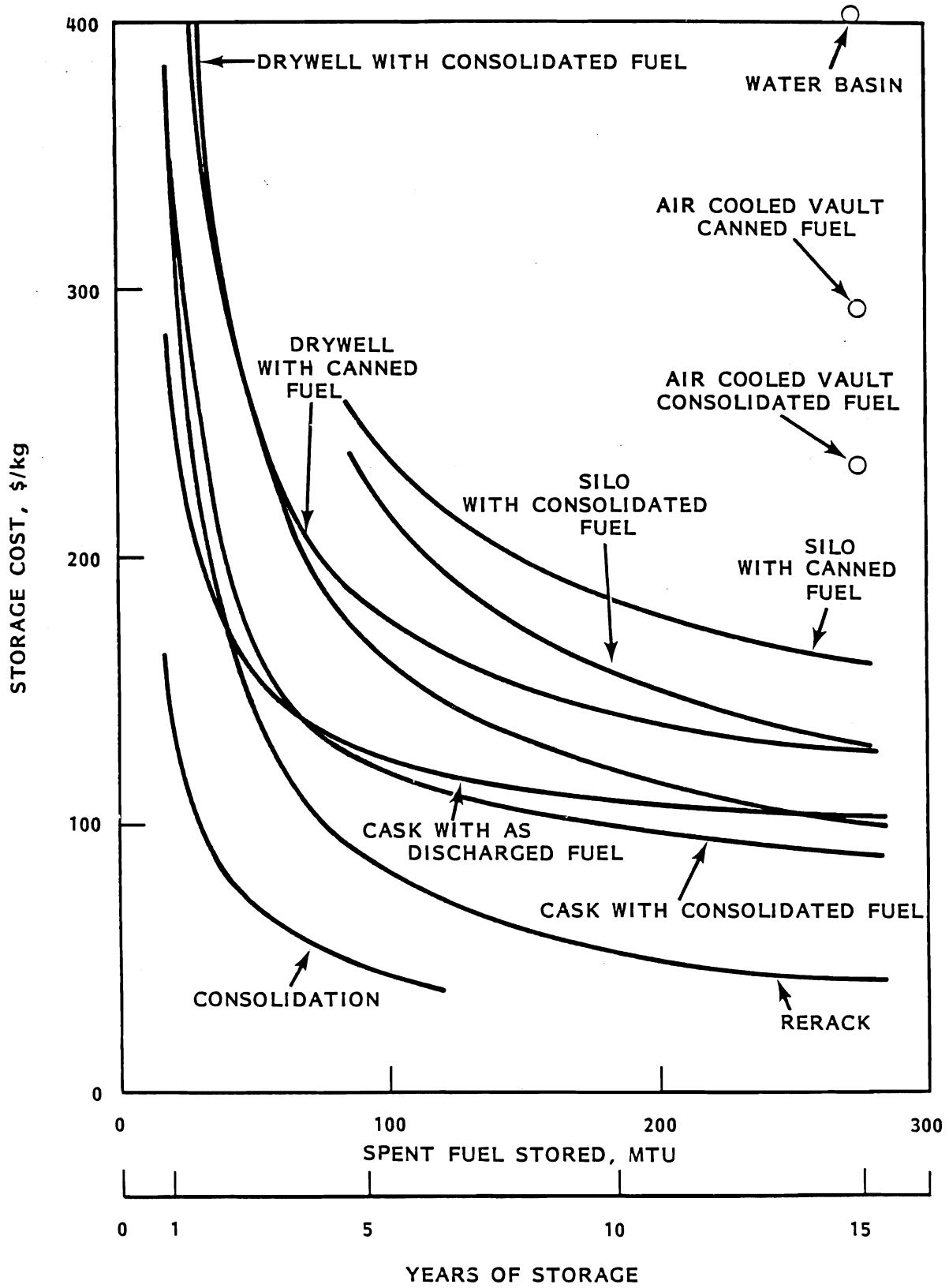

FIGURE 3.2. Unit Cost Comparisons for Spent Fuel Storage Options

The cost advantage of casks is primarily because at many installations they can be loaded, handled and deployed using less costly equipment than for other options. The casks themselves are more expensive than either drywells or silos, but the latter two technologies require use of more expensive auxiliary facilities. If storage requirements were sufficiently large, the use of drywells or silos might appear more advantageous.

The use of dry storage vaults or the construction of new storage pools would be of interest only for very large storage facilities. In the example calculations, the unit costs for these options were well above those for any of the other options considered.

The relative ranking of storage costs will depend on the specific conditions at a given site. However, based on the results of the example calculations, the most cost-effective additions to spent fuel storage, for a single-reactor situation, would be 1) development of in-pool storage capability, through high-density storage racks and consolidation, to the extent possible, and 2) use of storage casks (preferably with fuel consolidation) to achieve the remaining storage capacity required.

4.0 REFERENCES

Clark, H. J. November 1981. Spent LWR Fuel Storage Costs. DP-MS-81-40, Savannah River Laboratory, Aiken, South Carolina.

E. R. Johnson Associates. November 1981. A Preliminary Assessment of Alternative Dry Storage Methods for the Storage of Commercial Spent Nuclear Fuel. DOE/ET/47929-1, E. R. Johnson Associates, Reston, Virginia.

E. R. Johnson Associates. September 1982. "Spent Fuel Storage Requirements." E. R. Johnson Associates, Reston, Virginia. Paper presented at ANS Topical Meeting on Spent Fuel Storage Options, Savannah, Georgia.

APPENDIX

LIFE CYCLE COST CALCULATION DETAILS

TABLE A1. Rerack Reactor Pool

Capital Costs by Year

Year	Required Storage Assemblies	Required Storage Canisters	Cumulative Storage Assemblies	Cumulative Storage Canisters	Costs in Thousands of Dollars: Inpool or Separate Canning or Consolidation and Canning	Storage Yard or Facility or Pool Modifications	Casks, Drywells or Silos	Total	Discounted Total
1983									
1984									
1985									
1986									
1987						1195		1195	1006
1988						1195		1195	972
1989						299		299	235
1990	40		40			3285		3285	2495
1991	40		80						
1992	40		120						
1993	40		160						
1994	40		200						
1995	40		240						
1996	40		280						
1997	40		320						
1998	40		360						
1999	40		400						
2000	40		440						
2001	40		480						
2002	40		520						
2003	40		560						
2004	40		600						
2005			300						
2006			0						
2007						599		597	253
Total								6571	4961
								6571	5091 (5 yr)
								6571	5147 (1 yr)

TABLE A2. Rerack Reactor Pool

Operating and Maintenance Cost by Year in Thousands

Year	Cumulative Investment: Yard or Facility	Cumulative Investment: Transfer Equipment	Cumulative Investment: Casks, Drywells or Silos	Cumulative Investment: Total Capital	Maintenance Supplies 1.4% of Investment	Property Tax and Insurance	Labor and General Supplies: Canning	Labor and General Supplies: Storage	Total	Discounted Total
1983										
1984										
1985										
1986										
1987	1195			1195		11			11	9
1988	2390			2390		22			22	18
1989	2689			2689		25			25	20
1990	5974			5974	84	56		7	147	112
1991	5974			5974	84	56		15	155	114
1992	5974			5974	84	56		22	162	115
1993	5974			5974	84	56		30	170	116
1994	5974			5974	84	46		37	177	117
1995	5974			5974	84	56		44	184	118
1996	5974			5974	84	56		52	192	119
1997	5974			5974	84	56		59	199	119
1998	5974			5974	84	56		67	207	119
1999	5974			5974	84	56		74	214	119
2000	5974			5974	84	56		81	221	119
2001	5974			5974	84	56		89	229	119
2002	5974			5974	84	56		96	236	119
2003	5974			5974	84	56		104	244	118
2004	5974			5974	84	56		111	251	118
2005	5974			5974	42	56		56	154	70
2006	2987			2987		28			28	12
2007										
Total									3228	1890
									869	621 (5 yr)
									205	159 (1 yr)

TABLE A3. Water Basin Storage for 276 MTU

Capital Costs by Year

Year	Required Storage Assemblies	Required Storage Canisters	Cumulative Storage Assemblies	Cumulative Storage Canisters	Costs in Thousands of Dollars: Inpool or Separate Canning or Consolidation and Canning	Storage Yard or Facility or Pool Modifications	Casks, Drywells or Silos	Total	Discounted Total
1983					2,700			2,700	2,609
1984					3,600			3,600	3,361
1985					0			0	0
1986					450			450	450
1987					11,700			11,700	10,196
1988					19,350			19,350	16,292
1989					7,200			7,200	5,857
1990	40		40						
1991	40		80						
1992	40		120						
1993	40		160						
1994	40		200						
1995	40		240						
1996	40		280						
1997	40		320						
1998	40		360						
1999	40		400						
2000	40		440						
2001	40		480						
2002	40		520						
2003	40		560						
2004	40		600						
2005			300						
2006									
2007					4,500			4,500	1,904
Total								49,500	40,625

TABLE A4. Water Basin Storage for 276 MTU Unconsolidated Fuel

Operating and Maintenance Cost by Year in Thousands

Year	Cumulative Investment: Yard or Facility	Cumulative Investment: Transfer Equipment	Cumulative Investment: Casks, Drywells or Silos	Cumulative Investment: Total Capital	Maintenance Supplies 1.4% of Investment	Property Tax and Insurance	Labor and General Supplies: Canning	Labor and General Supplies: Storage	Total	Discounted Total
1983	2,700			2,700						
1984	6,300			6,300						
1985	6,300			6,300						
1986	6,750			6,750						
1987	18,450			18,450						
1988	37,800			37,000						
1989	45,000			45,000						
1990	45,000			45,000					2,700	2,050
1991	45,000			45,000					2,700	1,981
1992	45,000			45,000					2,700	1,914
1993	45,000			45,000					2,700	1,849
1994	45,000			45,000					2,700	1,787
1995	45,000			45,000					2,700	1,726
1996	45,000			45,000					2,700	1,669
1997	45,000			45,000					2,700	1,612
1998	45,000			45,000					2,700	1,558
1999	45,000			45,000					2,700	1,504
2000	45,000			45,000					2,700	1,453
2001	45,000			45,000					2,700	1,404
2002	45,000			45,000					2,700	1,358
2003	45,000			45,000					2,700	1,311
2004	45,000			45,000					2,700	1,266
2005	45,000			45,000					2,700	1,223
2006	45,000			45,000					2,700	1,183
2007										
Total									45,900	26,848

TABLE A5. Storage in Casks

Capital Costs by Year

Year	Required Storage Assemblies	Required Storage Canisters	Cumulative Storage Assemblies	Cumulative Storage Canisters	Costs in Thousands of Dollars: Inpool or Separate Canning or Consolidation and Canning	Storage Yard or Facility or Pool Modifications	Casks, Drywells or Silos	Total	Discounted Total
1983									
1984									
1985									
1986						698		698	609
1987						167		167	141
1988						0		0	0
1989						1,925	1,404	3,329	2,617
1990	40		40				1,404	1,404	1,066
1991	40		80				702	702	515
1992	40		120				1,404	1,404	995
1993	40		160				1,404	1,404	962
1994	40		200				702	702	465
1995	40		240				1,404	1,404	898
1996	40		280				1,404	1,404	867
1997	40		320				702	702	419
1998	40		360				1,404	1,404	810
1999	40		400				1,404	1,404	782
2000	40		440				702	702	378
2001	40		480				1,404	1,404	730
2002	40		520				1,404	1,404	706
2003	40		560				702	702	341
2004	40		600						
2005			312						
2006									
2006									
2007						279	1,755	2,034	861
Total						3,069	19,305	22,374	14,162
						3,069	6,950	10,019	7,468 (5 yr)
						3,069	1,544	4,613	3,675 (1 yr)

TABLE A6. Storage in Casks

Operating and Maintenance Cost by Year in Thousands

Year	Cumulative Investment: Yard or Facility	Cumulative Investment: Transfer Equipment	Cumulative Investment: Casks, Drywells or Silos	Cumulative Investment: Total Capital	Maintenance Supplies 1.4% of Investment	Property Tax and Insurance	Labor and General Supplies: Canning	Labor and General Supplies: Storage	Total	Discounted Total
1983										
1984										
1985										
1986	698			698		6			6	9
1987	865			865		8			8	7
1988	865			865		8			8	7
1989	1,790		1,404	4,194		39			39	31
1990	2,790		2,808	5,598	59	52		15	126	96
1991	2,790		3,510	6,300	78	59		15	152	112
1992	2,790		4,914	7,704	88	72		8	168	119
1993	2,790		6,318	9,108	108	85		16	209	143
1994	2,790		7,020	9,810	127	91		16	234	155
1995	2,790		8,424	11,212	137	104		9	230	160
1996	2,790		9,828	12,610	159	117		17	291	180
1997	2,790		10,530	13,320	176	124		17	317	189
1998	2,790		11,934	14,724	186	137		10	333	192
1999	2,790		13,338	16,128	206	150		18	374	208
2000	2,790		14,040	16,830	226	157		18	401	216
2001	2,790		15,444	18,234	236	170		11	417	217
2002	2,790		16,848	19,638	255	183		19	457	230
2003	2,790		17,550	20,340	275	189		19	483	235
2004	2,790		17,550	20,340	285	189		12	486	228
2005	2,790		17,550	20,340	285	189		90	564	256
2006	2,790		9,126	11,916	167	111		95	373	163
2007										
Total									5,696	3,149
									1,234	857 (5 yr)
									202	157 (1 yr)

TABLE A7. Storage of Consolidated Fuel in Casks

Capital Costs by Year

Year	Required Storage Assemblies	Required Storage Canisters	Cumulative Storage Assemblies	Cumulative Storage Canisters	Costs in Thousands of Dollars: Inpool or Separate Canning or Consolidation and Canning	Storage Yard or Facility or Pool Modifications	Casks, Drywells or Silos	Total	Discounted Total
1983									
1984									
1985									
1986						698		698	609
1987						167		167	141
1988						0		0	0
1989						1,925	702	2,627	2,065
1990	40	23	40	23			702	702	533
1991	40	23	80	46			702	702	515
1992	40	23	120	69			702	702	498
1993	40	23	160	92			702	702	481
1994	40	23	200	115			702	702	465
1995	40	23	240	138			702	702	449
1996	40	23	280	161			702	702	434
1997	40	23	320	184			702	702	419
1998	40	23	360	207			702	702	405
1999	40	23	400	230			702	702	391
2000	40	23	440	253			702	702	378
2001	40	23	480	276			702	702	365
2002	40	23	520	299			702	702	353
2003	40	23	560	322			702	702	341
2004	40	23	600	345					
2005			308	177					
2006									
2007									
Total						2,790	10,530	13,320	8,842
						2,790	3,510	6,300	4,842 (5-yr)
						2,790	702	3,492	2,815 (1-yr)

TABLE A8. Storage of Consolidated Fuel in Casks

Operating and Maintenance Cost by Year in Thousands

Year	Cumulative Investment: Yard or Facility	Cumulative Investment: Transfer Equipment	Cumulative Investment: Casks, Drywells or Silos	Cumulative Investment: Total Capital	Maintenance Supplies 1.4% of Investment	Property Tax and Insurance	Labor and General Supplies: Canning	Labor and General Supplies: Storage	Total	Discounted Total
1983										
1984										
1985										
1986	698			698		6			6	5
1987	865			865		8			8	7
1988	865			865		8			8	7
1989	2,790		702	3,492		32			32	25
1990	2,790		2,404	4,194	49	39		3	91	69
1991	2,790		2,106	4,896	59	46		3	108	79
1992	2,790		2,808	5,598	69	52		3	124	88
1993	2,790		3,510	6,300	78	59		3	240	96
1994	2,790		4,212	7,002	88	65		3	156	103
1995	2,790		4,914	7,704	98	72		3	173	111
1996	2,790		5,616	8,406	108	78		4	190	117
1997	2,790		6,318	9,108	118	85		4	207	124
1998	2,790		7,020	9,810	128	91		4	223	129
1999	2,790		7,722	10,512	137	98		4	239	133
2000	2,790		8,424	11,214	147	104		4	255	137
2001	2,790		9,126	11.916	157	111		5	273	142
2002	2,790		9,828	12,618	167	117		5	289	145
2003	2,790		10,530	13,320	177	124		5	306	149
2004	2,790		10,530	13,320	186	124		5	315	148
2005	2,790		10,530	13,320	186	124		18	328	149
2006	2,790		5,616	8,406	118	78		19	215	94
Total									3,686	2,057
									838	584 (5 yr)
									147	115 (1 yr)

TABLE A9. Storage in Drywells

Capital Costs by Year

Year	Required Storage Assemblies	Required Storage Canisters	Cumulative Storage Assemblies	Cumulative Storage Canisters	Cost in Thousands of Dollars: Inpool or Separate Canning or Consolidation and Canning	Storage Yard or Facility or Pool Modifications	Casks, Drywells or Silos	Total	Discounted Total
1983									
1984									
1985						1,380		1,380	1,245
1986						985		985	858
1987						0		0	0
1988						1,708		1,708	1,389
1989						2,497	720	3,217	2,528
1990	40	40	40	40			720	720	547
1991	40	40	80	80			720	720	528
1992	40	40	120	120			720	720	510
1993	40	40	160	160			720	720	493
1994	40	40	200	200			720	720	477
1995	40	40	240	240			720	720	460
1996	40	40	280	280			720	720	445
1997	40	40	320	320			720	720	430
1998	40	40	360	360			720	720	415
1999	40	40	400	400			720	720	401
2000	40	40	440	440			720	720	388
2001	40	40	480	480			720	720	374
2002	40	40	520	520			720	720	362
2003	40	40	560	560			720	720	350
2004	40	40	600	600					
2005			300	300					
2006									
2007						131	216	347	147
Total						6,701	11,016	17,717	12,347
						6,701	3,672	10,373	8,225 (5 yr)
						6,701	734	7,435	6,127 (1 yr)

TABLE A10. Storage in Drywells

Operating and Maintenance Cost by Year in Thousands

Year	Cumulative Investment: Yard or Facility	Cumulative Investment: Transfer Equipment	Cumulative Investment: Casks, Drywells or Silos	Cumulative Investment: Total Capital	Maintenance Supplies 1.4 of Investment	Property Tax and Insurance	Labor and General Supplies: Canning	Labor and General Supplies: Storage	Total	Discounted Total
1983										
1984										
1985	1,380			1,380		13			13	12
1986	2,365			2,365		22			22	19
1987	2,365			2,365		22			22	19
1988	4,073			4,073		38			38	31
1989	6,570		720	7,290		68			68	53
1990	6,570		1,440	8,010	102	74		117	293	223
1991	6,570		2,160	8,730	112	81		125	318	233
1982	6,570		2,880	9.450	122	88		132	342	242
1983	6,570		3,600	10,170	132	95		140	367	251
1984	6,570		4,320	10,890	142	101		147	390	258
1995	6,570		5,040	11,610	152	108		154	414	265
1996	6,570		5,760	12,330	163	115		162	440	272
1997	6,570		6,480	13,050	173	121		169	463	276
1998	6,570		7,200	13,770	183	128		177	488	281
1999	6,570		7,920	14,490	193	135		184	512	285
2000	6,570		8,640	15,210	203	141		191	535	288
2001	6,570		9,360	15,930	223	148		199	560	291
2002	6,570		10,080	16,650	223	155		206	584	294
2003	6,570		10,800	17,370	233	162		214	609	296
2004	6,570		10,800	17,370	243	162		221	626	294
2005	6,570		10,800	17,370	243	162		290	695	315
2006	6,570		5,400	11,970	168	111		234	513	225
2007										
Total									8,212	4,723
									2,272	1,597 (5 yr)
									487	380 (1 yr)

TABLE A11. Storage of Consolidated Fuel in Drywells

Capital Costs by Year

Year	Required Storage Assemblies	Required Storage Canisters	Cumulative Storage Assemblies	Cumulative Storage Canisters	Cost in Thousands of Dollars: Inpool or Separate Canning or Consolidation and Canning	Storage Yard or Facility or Pool Modifications	Casks, Drywells or Silos	Total	Discounted Total
1983									
1984									
1985						1,380		1,380	1,245
1986						985		985	858
1987						0		0	0
1988						1,708		1,708	1,389
1989						2,497	414	2,911	2,288
1990	40	23	40	23			414	414	314
1991	40	23	80	46			414	414	304
1992	40	23	120	69			414	414	293
1993	40	23	160	92			414	414	284
1994	40	23	200	115			414	414	274
1995	40	23	240	138			414	414	265
1996	40	23	280	161			414	414	256
1997	40	23	320	184			414	414	247
1998	40	23	360	207			414	414	239
1999	40	23	400	230			414	414	231
2000	40	23	440	253			414	414	223
2001	40	23	480	276			414	414	215
2002	40	23	520	299			414	414	208
2003	40	23	360	322			414	414	201
2004	40	23	600	345					
2005			300	173					
2006									
2007						131	124	255	108
Total						6,701	6,334	13,035	9,442
						6,701	2,111	8,812	7,133 (5 yr)
						6,701	422	7,123	5,968 (1 yr)

TABLE A12. Storage of Consolidated Fuel in Drywells

Operating and Maintenance Cost by Year in Thousands

Year	Cumulative Investment: Yard or Facility	Cumulative Investment: Transfer Equipment	Cumulative Investment: Casks, Drywells or Silos	Cumulative Investment: Total Capital	Maintenance Supplies 1.4% of Investment	Property Tax and Insurance	Labor and General Supplies: Canning	Labor and General Supplies: Storage	Total	Discounted Total
1983										
1984										
1985	1,380			1,380		13			13	12
1986	2,365			2,365		22			22	19
1987	2,365			2,365		22			22	19
1988	4,073			4,073		38			38	31
1989	6,570		414	6,984		65			65	51
1990	6,750		828	7,398	98	69		68	235	235
1991	6,570		1,242	1,812	104	73		72	249	183
1992	6,570		1,656	8,226	109	76		76	261	185
1993	6,570		2,070	8,640	115	80		80	175	188
1994	6,570		2,484	9,054	121	84		85	290	192
1995	6,570		2,898	9,468	127	88		89	304	194
1996	6,570		3,312	9,882	133	92		93	318	197
1997	6,570		3,726	10,296	138	96		97	331	198
1998	6,570		4,140	10,710	144	100		102	346	200
1999	6,570		4,554	11,124	150	103		106	359	200
2000	6,570		4,968	11,538	156	107		110	373	201
2001	6,570		5,382	11,952	162	111		114	387	201
2002	6,570		5,796	12,366	167	115		119	401	202
2003	6,570		6,210	12,780	173	119		123	415	202
2004	6,570		6,210	12,780	179	119		127	425	199
2005	6,570		5,210	12,780	179	119		166	465	210
2006	6,570		3,114	9,684	136	90		135	361	158
2007										
Total									5,954	3,420
									1,765	1,246 (5 yr)
									413	323 (1 yr)

NOTE: Discounted costs for unloading the transfer cost if a separate facility is not included in the case are $155K, $74K, $17K for 15 yr, 5 yr, 1 yr cases.

TABLE A13. Storage in Silos (Unconsolidated Fuel)

Capital Costs by Year

Year	Required Storage Assemblies	Required Storage Canisters	Cumulative Storage Assemblies	Cumulative Storage Canisters	Cost in Thousands of Dollars: Inpool or Separate Canning or Consolidation and Canning	Storage Yard or Facility or Pool Modifications	Casks, Drywells or Silos	Total	Discounted Total
1983									
1984									
1985						758		758	683
1986						463		463	403
1987						0		0	0
1988						1,052		1,052	856
1989						1,937	800	2,737	2,151
1990	40	40	40	40			800	800	607
1991	40	40	80	80			800	800	587
1992	40	40	120	120			800	800	567
1993	40	40	160	160			800	800	548
1994	40	40	200	200			800	800	530
1995	40	40	240	240			800	800	512
1996	40	40	280	280			800	800	494
1997	40	40	320	320			800	800	478
1998	40	40	360	360			800	800	462
1999	40	40	400	400			800	800	446
2000	40	40	440	440			800	800	431
2001	40	40	480	480			800	800	416
2002	40	40	520	520			800	800	402
2003	40	40	560	560			800	800	389
2004	40	40	600	600					
2005			300	300					
2006									
2007						84	240	324	136
Total						4,294	12,240	16,534	11,096
						4,294	4,080	8,374	6,602 (5 yr)
						4,294	816	5,110	4,329 (1 yr)

TABLE A14. Storage in Silos (Unconsolidated Fuel)

Operating and Maintenance Cost by Year in Thousands

Year	Cumulative Investment: Yard or Facility	Cumulative Investment: Transfer Equipment	Cumulative Investment: Casks, Drywells or Silos	Cumulative Investment: Total Capital	Maintenance Supplies 1.4% of Investment	Property Tax and Insurance	Labor and General Supplies: Canning	Labor and General Supplies: Storage	Total	Discounted Total
1983										
1984										
1985	758			758		7			7	6
1986	1,221			1,221		11			11	10
1987	1,221			1,221		11			11	9
1988	2,273			2,273		21			21	17
1989	4,210		800	5,010		47			47	37
1990	4,210		1,600	5,810	70	54		78	202	153
1991	4,210		2,400	6,610	81	61		80	222	163
1992	4,210		3,200	7,410	93	69		82	244	173
1993	4,210		4,000	8,210	104	76		83	263	180
1994	4,210		4,800	9,010	115	84		85	284	188
1995	4,210		5,600	9,810	126	91		87	304	194
1996	4,210		6,400	10.610	137	99		89	325	201
1997	4,210		7,200	11,410	149	106		91	346	207
1998	4,210		8,000	12,210	160	114		93	367	212
1999	4,210		8,800	13,010	171	121		95	387	216
2000	4,210		9,600	13,810	182	128		96	406	218
2001	4,210		10,400	14,610	193	136		98	427	222
2002	4,210		11,200	15,410	205	143		100	448	225
2003	4,210		12,000	16,210	216	151		102	469	228
2004	4,210		12,000	16,210	227	151		104	482	226
2005	4,210		12,000	16,210	227	151		155	553	251
2006	4,210		6,000	10,210	143	95		142	379	166
2007										
Total									6,205	3,502
									1,605	1,119 (5 yr)
									318	246 (1 yr)

TABLE A15. Silo Loading Facility for Inpool Canning

Capital Costs by Year

Year	Required Storage Assemblies	Required Storage Canisters	Cumulative Storage Assemblies	Cumulative Storage Canisters	Cost in Thousands of Dollarss: Inpool or Separate Canning or Consolidation and Canning	Storage Yard or Facility or Pool Modifications	Casks, Drywells or Silos	Total	Discounted Total
1983									
1984									
1985						1107		1107	999
1986						677		677	590
1987						0		0	0
1988						1537		1537	1250
1989						2829		2829	2224
1990	40	40	40	40					
1991	40	40	80	80					
1992	40	40	120	120					
1993	40	40	160	160					
1994	40	40	200	200					
1995	40	40	240	240					
1996	40	40	280	280					
1997	40	40	320	320					
1998	40	40	360	360					
1999	40	40	400	400					
2000	40	40	440	440					
2001	40	40	480	480					
2002	40	40	520	520					
2003	40	40	460	560					
2004	40	40	600	600					
2005			300	300					
2006									
2007						123		123	52
Total						6273		6273	5115
						6273		6273	5139 (5 yr)
						6273		6273	5153 (1 yr)

TABLE A16. Silo Loading Facility for Inpool Canning

Operating and Maintenance Cost by Year in Thousands

Year	Cumulative Investment: Yard or Facility	Cumulative Investment: Transfer Equipment	Cumulative Investment: Casks, Drywells or Silos	Cumulative Investment: Total Capital	Maintenance Supplies 1.4% of Investment	Property Tax and Insurance	Labor and General Supplies: Canning	Labor and General Supplies: Storage	Total	Discounted Total
1983										
1984										
1985	1107			1107		10			10	9
1986	1784			1784		17			17	15
1987	1784			1784		17			17	14
1988	3321			3321		31			31	25
1989	6150			6150		57			57	45
1990	6150			6150	86	57		97	240	182
1991	6150			6150	86	57		97	240	176
1992	6150			6150	86	57		97	240	170
1993	6150			6150	86	57		97	240	164
1994	6150			6150	86	57		97	240	159
1995	6150			6150	86	57		97	240	153
1996	6150			6150	86	57		97	240	148
1997	6150			6150	86	57		97	240	143
1998	6150			6150	86	57		97	240	138
1999	6150			6150	86	57		97	240	134
2000	6150			6150	86	57		97	240	129
2001	6150			6150	86	57		97	240	125
2002	6150			6150	86	57		97	240	121
2003	6150			6150	86	57		97	240	117
2004	6150			6150	86	57		97	240	112
2005	6150			6150	86	57		621	764	346
2006	6150			6150	86	57		621	764	335
2007										
Total									5250	2960
									1889	1315 (5 yr)
									455	351 (1 yr)

TABLE A17. Storage in Silos (Consolidated Fuel)

Capital Costs by Year

Year	Required Storage Assemblies	Required Storage Canisters	Cumulative Storage Assemblies	Cumulative Storage Canisters	Cost in Thousands of Dollars: Inpool or Separate Canning or Consolidation and Canning	Storage Yard or Facility or Pool Modifications	Casks, Drywells or Silos	Total	Discounted Total
1983									
1984									
1985						758		758	683
1986						463		463	403
1987						0		0	0
1988						1,052		1,052	856
1989						1,937	480	2,417	1,900
1990	40	23	40	23			480	480	364
1991	40	23	80	46			480	480	352
1992	40	23	120	69			400	480	284
1993	40	23	160	92			480	480	329
1994	40	23	200	115			480	480	318
1995	40	23	240	138			480	480	307
1996	40	23	280	161			480	480	247
1997	40	23	320	184			480	480	287
1998	40	23	360	207			480	480	277
1999	40	23	400	230			480	480	267
2000	40	23	440	253			480	480	215
2001	40	23	480	276			480	480	250
2002	40	23	520	299			480	480	251
2003	40	23	560	322			480	480	233
2004	40	23	600	345					
2005			301	173					
2006									
2007						84	139	223	93
Total						4,294	7,097	11,393	7,906
						4,294	2,366	6,660	5,307 (5 yr)
						4,294	490	4,784	4,004 (1 yr)

TABLE A18. Storage in Silos (Consolidated Fuel)

Operating and Maintenance Cost by Year in Thousands

Year	Cumulative Investment: Yard or Facility	Cumulative Investment: Transfer Equipment	Cumulative Investment: Casks, Drywells or Silos	Cumulative Investment: Total Capital	Maintenance Supplies 1.4% of Investment	Property Tax and Insurance	Labor and General Supplies: Canning	Labor and General Supplies: Storage	Total	Discounted Total
1983										
1984										
1985	758			758		7			7	6
1986	1,221			1,221		11			11	10
1987	1,221			1,221		11			11	9
1988	2,273			2,273		21			21	17
1989	4,210		480	4,690		44			44	35
1990	4,210		960	5,170	66	48		47	161	122
1991	4,210		1,440	5,650	72	53		48	173	127
1992	4,210		1,840	6,050	79	56		49	184	130
1993	4,210		2,320	6,530	85	61		42	188	129
1994	4,210		2,800	7,010	91	65		51	207	137
1995	4,210		3,280	7,490	98	70		52	220	141
1996	4,120		3,680	7,890	105	73		53	231	143
1997	4,210		4,160	8,370	110	78		47	235	140
1998	4,210		4,640	8,850	117	82		55	254	147
1999	4,210		5,120	9,330	124	87		56	267	149
2000	4,210		5,520	9,730	130	90		57	277	149
2001	4,210		6,000	10,210	136	95		51	282	147
2002	4,210		6,480	10,690	143	99		59	301	151
2003	4,210		6,960	11,170	150	104		61	315	153
2004	4,210		6,960	11,170	156	104		62	322	151
2005	4,210		6,960	11,170	156	104		89	349	158
2006	4,120		3,520	7,730	108	72		83	273	120
2007										
Total									4,333	2,441
									1,218	857 (5 yr)
									266	207 (1 yr)

TABLE A19. Silo Loading Facility for Inpool Consolidation

Capital Costs by Year

Year	Required Storage Assemblies	Required Storage Canisters	Cumulative Storage Assemblies	Cumulative Storage Canisters	Cost in Thousands of Dollars: Inpool or Separate Canning or Consolidation and Canning	Storage Yard or Facility or Pool Modifications	Casks, Drywells or Silos	Total	Discounted Total
1983									
1984									
1985						1107		1107	999
1986						677		677	590
1987						0		0	0
1988						1537		1537	1250
1989						2829		2829	2224
1990	40	23	40	23					
1991	40	23	80	46					
1992	40	23	120	69					
1993	40	23	160	92					
1994	40	23	200	115					
1995	40	23	240	138					
1996	40	23	280	161					
1997	40	23	320	184					
1998	40	23	360	207					
1999	40	23	400	230					
2000	40	23	440	253					
2001	40	23	480	276					
2002	40	23	520	299					
2003	40	23	560	322					
2004	40	23	600	345					
2005			301	173					
2006									
2007						123		123	52
Total						6273		6273	5115
						6273		6273	5139 (5 yr)
						6273		6273	5153 (1 yr)

TABLE A20. Silo Loading Facility for Inpool Consolidation

Operating and Maintenance Cost by Year in Thousands

Year	Cumulative Investment: Yard or Facility	Cumulative Investment: Transfer Equipment	Cumulative Investment: Casks, Drywells or Silos	Cumulative Investment: Total Capital	Maintenance Supplies 1.4% of Investment	Property Tax and Insurance	Labor and General Supplies: Canning	Labor and General Supplies: Storage	Total	Discounted Total
1983										
1984										
1985	1107			1107		10			10	9
1986	1784			1724		17			17	15
1987	1784			1784		17			17	14
1988	3321			3321		31			31	25
1989	6150			6150		57			57	45
1990	6150			6150	86	57		56	199	151
1991	6150			6150	86	57		56	199	146
1992	6150			6150	86	57		56	199	141
1993	6150			6150	86	57		56	199	136
1994	6150			6150	86	57		56	199	132
1995	6150			6150	86	57		56	199	127
1996	6150			6150	86	57		56	199	123
1997	6150			6150	86	57		56	199	119
1998	6150			6150	86	57		56	199	115
1999	6150			6150	86	57		56	199	111
2000	6150			6150	86	57		56	199	107
2001	6150			6150	86	57		56	199	103
2002	6150			6150	86	57		56	199	100
2003	6150			6150	86	57		56	199	97
2004	6150			6150	86	57		56	199	93
2005	6150			6150	86	57		356	499	226
2006	6150			6150	86	57		358	501	219
2007										
Total									4117	2354
									2508	1058 (5 yr)
									379	294 (1 yr)

TABLE A21. Air Cooled Vault, 600 Canister Capacity

Capital Costs by Year

Year	Required Storage Assemblies	Required Storage Canisters	Cumulative Storage Assemblies	Cumulative Storage Canisters	Cost in Thousands of Dollars: Inpool or Separate Canning or Consolidation and Canning	Storage Yard or Facility or Pool Modifications	Casks, Drywells or Silos	Total	Discounted Total
1983						2,661		2,661	2,570
1984						3,042		3,042	2,840
1985						0		0	0
1986						380		380	331
1987						9,505		9,505	8,003
1988						14,448		14,448	11,753
1989						7,984		7,894	6,275
1990	40	40	40	40					
1991	40	40	80	80					
1992	40	40	120	120					
1993	40	40	160	160					
1994	40	40	200	200					
1995	40	40	240	240					
1996	40	40	280	280					
1997	40	40	320	320					
1998	40	40	360	360					
1999	40	40	400	400					
2000	40	40	440	440					
2001	40	40	480	480					
2002	40	40	520	520					
2003	40	40	560	560					
2004	40	40	600	600					
2005			300	300					
2006									
2007						760		760	322
Total								38,780	32,094

TABLE A22. Air Cooled Vault, 600 Canister Capacity

Operating and Maintenance Cost by Year in Thousands

Year	Cumulative Investment: Yard or Facility	Cumulative Investment: Transfer Equipment	Cumulative Investment: Casks, Drywells or Silos	Cumulative Investment: Total Capital	Maintenance Supplies 1.4% of Investment	Property Tax and Insurance	Labor and General Supplies: Canning	Labor and General Supplies: Storage	Total	Discounted Total
1983	2,661			2,661		25			25	24
1984	5,703			5,703		53			53	49
1985	5,703			5,703		53			53	48
1986	6,083			6,083		57			57	50
1987	15,588			15,588		145			145	122
1988	30,036			30,036		279			279	227
1989	38,020			38,020		354			354	278
1990	38,020			38,020	532	354		198	2,084	823
1991	38,020			38,020	532	354		205	1,091	800
1992	38,020			38,020	532	354		213	1,099	779
1993	38,020			38,020	532	354		220	1,106	758
1994	38,020			38,020	532	354		227	1,113	737
1995	38,020			38,020	532	354		235	1,121	717
1996	38,020			38,020	532	354		242	1,128	697
1997	38,020			38,020	532	354		250	1,136	678
1998	38,020			38,020	532	354		257	1,143	659
1999	38,020			38,020	532	354		264	1,150	641
2000	38,020			38,020	532	354		272	1,158	623
2001	38,020			38,020	532	354		279	1,165	606
2002	38,020			38,020	532	354		287	1,173	590
2003	38,020			38,020	532	354		294	1,180	573
2004	38,020			38,020	532	354		302	1,188	557
2205	38,020			38,020	532	354		437	1,323	600
2006	38,020			38,020	532	354		381	1,267	555
2007										
Total									20,591	12,191

TABLE A23. Air Cooled Vaults, 345 Canister Capacity

Capital Costs by Year

Year	Required Storage Assemblies	Required Storage Canisters	Cumulative Storage Assemblies	Cumulative Storage Canisters	Cost in Thousands of Dollars: Inpool or Separate Canning or Consolidation and Canning	Storage Yard or Facility or Pool Modifications	Casks, Drywells or Silos	Total	Discounted Total
1983						2,122		2,122	2,050
1984						2,426		2,426	2,265
1985						0		0	0
1986						303		303	264
1987						7,580		7,580	6,382
1988						11,521		11,521	9,372
1989						6,367		6,367	5,004
1990	40	23	40	23					
1991	40	23	80	46					
1992	40	23	120	69					
1993	40	23	160	92					
1994	40	23	200	115					
1995	40	23	240	138					
1996	40	23	280	161					
1997	40	23	320	184					
1998	40	23	360	207					
1999	40	23	400	230					
2000	40	23	440	253					
2001	40	23	480	276					
2002	40	23	520	299					
2003	40	23	560	322					
2004	40	23	600	345					
2005			301	173					
2006									
2007						606		606	256
Total								30.925	25,593

TABLE A24. Air Cooled Vault, 345 Canister Capacity

Operating and Maintenance Cost by Year in Thousands

Year	Cumulative Investment: Yard or Facility	Transfer Equipment	Casks, Drywells or Silos	Total Capital	Maintenance Supplies 1.4% of Investment	Property Tax and Insurance	Labor and General Supplies: Canning	Storage	Total	Discounted Total
1983	2,122			2,122		20			20	19
1984	4,548			4,548		42			42	39
1985	4,548			4,548		42			42	38
1986	4,851			4,851		45			45	39
1987	12,431			12,431		116			116	98
1988	23,952			23,952		223			223	181
1989	30,319			30,319		282			282	222
1990	30,319			30,319	424	282		114	820	623
1991	30,319			30,319	424	282		118	824	605
1992	30,319			30,319	424	282		122	828	587
1993	30,319			30,319	424	282		127	833	571
1994	30,319			30,319	424	282		131	837	554
1995	30,319			30,319	424	282		135	841	538
1996	30,319			30,319	424	282		139	845	522
1997	30,319			30,319	424	282		143	849	507
1998	30,319			30,319	424	282		148	854	492
1999	30,319			30,319	424	282		152	858	478
2000	30,319			30,319	424	282		156	862	464
2001	30,319			30,319	424	282		161	867	451
2002	30,319			30,319	424	282		165	871	438
2003	30,319			30,319	424	282		169	875	425
2004	30,319			30,319	424	282		173	879	412
2005	30,319			30,319	424	282		252	958	434
2006	30,319			30,319	424	282		218	924	405
2007										
Total									15,395	9,142

TABLE A25. Inpool Canning

Capital Costs by Year

Year	Required Storage Assemblies	Required Storage Canisters	Cumulative Storage Assemblies	Cumulative Storage Canisters	Cost in Thousands of Dollars: Inpool or Separate Canning or Consolidation and Canning	Storage Yard or Facility or Pool Modifications	Casks, Drywells or Silos	Total	Discounted Total
1983									
1984									
1985									
1986					122			122	106
1987					122			122	104
1988					32			32	26
1989					366			366	288
1990	40	40	40	40					
1991	40	40	80	80					
1992	40	40	120	120					
1993	40	40	160	160					
1994	40	40	200	200					
1995	40	40	240	240					
1996	40	40	280	280					
1997	40	40	320	320					
1998	40	40	360	360					
1999	40	40	400	400					
2000	40	40	440	440					
2001	40	40	480	480					
2002	40	40	520	520					
2003	40	40	450	560					
2004	40	40	600	600					
2005					0			0	
2006					0			0	
2007					6			6	3
Total								648	527
								648	528 (5 yr)
								648	528 (1 yr)

TABLE A26. Inpool Canning

Operating and Maintenance Cost by Year in Thousands

Year	Cumulative Investment: Yard or Facility	Cumulative Investment: Transfer Equipment	Cumulative Investment: Casks, Drywells or Silos	Cumulative Investment: Total Capital	Maintenance Supplies 1.4% of Investment	Property Tax and Insurance	Labor and General Supplies: Canning	Labor and General Supplies: Storage	Total	Discounted Total
1983										
1984										
1985										
1986	122			122		1			1	1
1987	244			244		2			2	2
1988	276			276		3			3	2
1989	642			642		6			6	5
1990	642			642	9	6	331		346	263
1991	642			642	9	6	332		346	254
1992	642			642	9	6	331		346	245
1993	642			642	9	6	331		346	237
1994	642			642	9	6	331		346	229
1995	642			642	9	6	331		346	221
1996	642			642	9	6	331		346	214
1997	642			642	9	6	331		346	207
1998	642			642	9	6	331		346	200
1999	642			642	9	6	331		346	193
2000	642			642	9	6	331		346	186
2001	642			642	9	6	331		346	180
2002	642			642	9	6	331		346	174
2003	642			642	9	6	331		346	168
2004	642			642	9	6	331		346	162
2005							450		450	204
2006							450		450	197
2007										
Total									6102	3544
									2042	1430 (5 yr)
									418	317 (1 yr)

TABLE A27. Separate Canning Facility

Capital Costs by Year

Year	Required Storage Assemblies	Required Storage Canisters	Cumulative Storage Assemblies	Cumulative Storage Canisters	Cost in Thousands of Dollars: Inpool or Separate Canning or Consolidation and Canning	Storage Yard or Facility or Pool Modifications	Casks, Drywells or Silos	Total	Discounted Total
1983					954			954	922
1984					1,749			1,749	1,633
1985					0			0	0
1986					318			318	318
1987					4,134			4,134	3,481
1988					5,088			5,088	4,139
1989					3,657			3,657	2,874
1990	40	40	40	40					
1991	40	40	80	80					
1992	40	40	120	120					
1993	40	40	160	160					
1994	40	40	200	200					
1995	40	40	240	240					
1996	40	40	280	280					
1997	40	40	320	320					
1998	40	40	360	360					
1999	40	40	400	400					
2000	40	40	440	440					
2001	40	40	480	480					
2002	40	40	520	520					
2003	40	40	560	560					
2004	40	40	600	600					
2005			300	300					
2006			0	0					
2007					1,590			1,590	673
Total								17,490	13,999
								17,490	14,308 (5 yr)
								17,490	14,493 (1 yr)

TABLE A28. Separate Canning Facility

Operating and Maintenance Cost by Year in Thousands

Year	Cumulative Investment: Yard or Facility	Cumulative Investment: Transfer Equipment	Cumulative Investment: Casks, Drywells or Silos	Cumulative Investment: Total Capital	Maintenance Supplies 1.4% of Investment	Property Tax and Insurance	Labor and General Supplies: Canning	Labor and General Supplies: Storage	Total	Discounted Total
1983	954			954		9			9	9
1984	2,703			2,703		25			25	23
1985	2,703			2,703		25			25	23
1986	3,021			3,021		28			28	24
1987	7,155			7,155		67			67	56
1988	12,243			12,243		114			114	93
1989	15,900			15,000		148			148	116
1990	15,900			15,000	223	148	582		953	724
1991	15,900			15,900	223	148	582		953	699
1992	15,900			15,900	223	148	582		953	676
1993	15,900			15,900	223	148	582		953	653
1994	15,900			15,900	223	148	582		953	631
1995	15,900			15,900	223	148	582		953	609
1996	15,900			15,900	223	148	582		953	589
1997	15,900			15,900	223	148	582		953	569
1998	15,900			15,900	223	148	582		953	550
1999	15,900			15,900	223	148	582		953	531
2000	15,900			15,900	223	148	582		953	513
2001	15,900			15,900	223	148	582		953	496
2002	15,900			15,900	223	148	582		953	479
2003	15,900			15,900	223	148	582		953	463
2004	15,900			15,900	223	148	582		953	447
2005	15,900			15,900	223	148	798		1,169	530
2006	15,900			15,900	223	148	798		1,169	512
2007										
Total									17,049	10.015
									6,023	4,504 (5 yr)
									1,565	1,213 (1 yr)

TABLE A29. Inpool Consolidation

Capital Costs by Year

Year	Required Storage Assemblies	Required Storage Canisters	Cumulative Storage Assemblies	Cumulative Storage Canisters	Cost in Thousands of Dollars: Inpool or Separate Canning or Consolidation and Canning	Storage Yard or Facility or Pool Modifications	Casks, Drywells or Silos	Total	Discounted Total
1983									
1984									
1985									
1986									
1987					257			257	224
1988					198			198	167
1989					1483			1483	1166
1990	40	40	40	23					
1991	40	23	80	46					
1992	40	23	120	69					
1993	40	23	160	92					
1994	40	23	200	115					
1995	40	23	240	138					
1996	40	23	280	161					
1997	40	23	320	184					
1998	40	23	360	207					
1999	40	23	400	230					
2000	40	23	440	253					
2001	40	23	480	276					
2002	40	23	520	299					
2003	40	23	560	322					
2004	40	23	600	345					
2005									
2006									
2007					198			198	84
Total								2176	1673
								2176	1711 (5 yr)
								2176	1734 (1 yr)

TABLE A30. Inpool Consolidation

Operating and Maintenance Cost by Year in Thousands

Year	Cumulative Investment: Yard or Facility	Cumulative Investment: Transfer Equipment	Cumulative Investment: Casks, Drywells or Silos	Cumulative Investment: Total Capital	Maintenance Supplies 1.4% of Investment	Property Tax and Insurance	Labor and General Supplies: Canning	Labor and General Supplies: Storage	Total	Discounted Total
1983										
1984										
1985										
1986	257			257		2			2	2
1987	455			455		4			4	3
1988	495			495		5			5	4
1989	1978			1978		18			18	15
1990	1978			1978	28	18	304		350	266
1991	1978			1978	28	18	304		350	257
1992	1978			1978	28	18	304		350	248
1993	1978			1978	28	18	304		340	240
1994	1978			1978	28	18	304		350	232
1995	1978			1978	28	18	304		350	224
1996	1978			1978	28	18	304		350	216
1997	1978			1978	28	18	304		350	209
1998	1978			1978	28	18	304		350	209
1999	1978			1978	28	18	304		350	195
2000	1978			1978	28	18	304		350	188
2001	1978			1978	28	18	304		350	182
2002	1978			1978	28	18	304		350	176
2003	1978			1978	28	18	304		350	170
2004	1978			1978	28	18	304		350	164
2005							-941		-941	-426
2006							-941		-941	-412
2007										
Total									3397	2355
									1152	866 (5 yr)
									254	198 (1 yr)

TABLE A31. Separate Facility for Consolidation and Canning

Capital Costs by Year

Year	Required Storage Assemblies	Required Storage Canisters	Cumulative Storage Assemblies	Cumulative Storage Canisters	Cost in Thousands of Dollars: Inpool or Separate Canning or Consolidation and Canning	Storage Yard or Facility or Pool Modifications	Casks, Drywells or Silos	Total	Discounted Total
1983					1,014			1,014	980
1984					1,859			1,859	1,735
1985					0			0	0
1986					338			338	295
1987					4,394			4,394	3,700
1988					5,408			5,408	4,399
1989					3,887			3,887	3,055
1990	40	23	40	23					
1991	40	23	80	46					
1992	40	23	120	69					
1993	40	23	160	92					
1994	40	23	200	115					
1995	40	23	240	138					
1996	40	23	280	161					
1997	40	23	320	184					
1998	40	23	360	207					
1999	40	23	400	230					
2000	40	23	440	253					
2001	40	23	480	276					
2002	40	23	520	299					
2003	40	23	560	322					
2004	40	23	600	345					
2005			299	172					
2006				0					
2007					1,690			1,690	715
Total								18,590	14,879
								18,590	15,208 (5 yr)
								18,590	15,404 (1 yr)

TABLE A32. Separate Facility for Consolidation and Canning

Operating and Maintenance Cost by Year in Thousands

Year	Cumulative Investment: Yard or Facility	Transfer Equipment	Casks, Drywells or Silos	Total Capital	Maintenance Supplies 1.4% of Investment	Property Tax and Insurance	Labor and General Supplies: Canning	Storage	Total	Discounted Total
1983	1,014			1,014		9			9	9
1984	2,873			2,873		27			27	25
1985	2,873			2,873		27			27	24
1986	3,211			3,211		30			30	26
1987	7,605			7,605		71			71	60
1988	13,013			13,013		121			121	98
1989	16,900			16,900		157			157	123
1990	16,900			16,900	237	157	520		914	694
1991	16,900			16,900	237	157	529		914	671
1992	16,900			16,900	237	157	520		914	648
1993	16,900			16,900	237	157	520		914	626
1994	16,900			16,900	237	157	520		914	605
1995	16,900			16,900	237	157	520		914	584
1996	16,900			16,900	237	157	520		914	565
1997	16,900			16,900	237	157	520		914	546
1998	16,900			16,900	237	157	520		914	527
1999	16,900			16,900	237	157	520		914	509
2000	16,900			16,900	237	157	520		914	492
2001	16,900			16,900	237	157	520		914	475
2002	16,900			16,900	237	157	520		914	459
2003	16,900			16,900	237	157	520		914	444
2004	16,900			16,900	237	157	520		914	429
2005	16,900			16,900	237	157	-330		64	29
2006	16,900			16,900	237	157	-327		67	29
2007										
Total										8,697
									5,207	3,733 (5 yr)
									1,365	1,066 (1 yr)

TABLE A33. Inpool Consolidation Only

Capital Costs by Year

Year	Required Storage Assemblies	Required Storage Canisters	Cumulative Storage Assemblies*	Cumulative Storage Canisters	Cost in Thousands of Dollars: Inpool or Separate Canning or Consolidation and Canning	Storage Yard or Facility or Pool Modifications	Casks, Drywells or Silos	Total	Discounted Total
1983									
1984									
1985									
1986					257			257	224
1987					198			198	167
1988					40			40	32
1989			460		1483			1483	1166
1990	40	54	406	54					
1991	40	54	352	108					
1992	40	54	298	162					
1993	40	54	244	215					
1994	40	54	190	270					
1995									
1996					198			198	122
Total								2176	1711
								2176	1734 (1 yr

*As discharged. Ninety-four (94) assemblies are consolidated into 54 canisters each year to provide 40 spaces for the discharge.

TABLE A34. Inpool Consolidation

Operating and Maintenance Cost by Year in Thousands

Year	Cumulative Investment: Yard or Facility	Cumulative Investment: Transfer Equipment	Cumulative Investment: Casks, Drywells or Silos	Cumulative Investment: Total Capital	Maintenance Supplies 1.4% of Investment	Property Tax and Insurance	Labor and General Supplies: Canning	Labor and General Supplies: Storage	Total	Discounted Total
1983										
1984										
1985										
1986	257			257		2			2	2
1987	455			455		4			4	3
1988	495			495		5			5	4
1989	1978			1978		18			18	15
1990	1978			1978	28	18	575		621	472
1991	1978			1978	28	18	575		621	456
1992	1978			1978	28	18	575		621	440
1993	1978			1978	28	18	575		621	425
1994	1978			1978	28	18	575		621	411
1995					28		-1475		-1475	-943
1966										
Total									1659	1285
									355	279 (1 yr)

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