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AN ANALYSIS OF CAPITAL AND OPERATING COSTS ASSOCIATED
WITH HIGH LEVEL WASTE SOLIDIFICATION PROCESSES

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WITH HIGH-LEVEL WASTE
SOLIDIFICATION PROCESSES*

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Reprocessing of spent nuclear fuel from light water reactors will generate quantities of liquid high-level radioactive wastes (HLW) at the fuel reprocessing plant. Current Federal regulations require that such high-level waste be converted to a chemically, thermally, and radiolytically stable dry solid and be sealed in a container prior to shipment to a Federal waste repository (FWR). Further, these containers are required to be transferred to the repository within 10 years after separation of the fission products from the irradiated fuel (10 CFR 50, Appendix F).

Performance criteria are being established by the NRC for evaluating the acceptability of the solidified waste forms with regard to the health and safety of the public. The performance criteria will address the maintenance of an acceptable level of protection for both normal and accident conditions. The NRC principle of environmental protection is that the risks from a planned activity should not only be reduced below an acceptable level but should be reduced to levels considered "as low as reasonably achievable." This principle requires that incremental changes in levels of protection be weighed against the incremental cost to achieve further protection.

An analysis has been performed to evaluate the sensitivity of annual operating costs and capital costs of waste solidification processes to various parameters defined by the requirements of a proposed FWR.

The process methods and waste forms examined were:

- Salt Cake
- Spray Calcine
- Fluidized Bed Calcine

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- Borosilicate Glass
- Supercalcine Multibarrier

The cost estimates are the differential operating and maintenance costs and capital costs associated with each of the five waste form alternates. The methodology employed to develop the differential cost estimates is summarized as follows:

- Develop conceptual process designs for the alternate solidification process systems.
- Determine processing rates, quantities and capacities to meet the process requirements for each alternate.
- Develop major equipment lists and perform equipment sizing calculations based on the process requirements.
- Exclude from consideration equipment and facilities which are common to all five alternates.
- Exclude from consideration operating costs which are common and equal for all five alternates.
- Prepare capital cost estimates for the installed cost of the equipment and facilities.
- Prepare cost estimates of the annual operating and maintenance costs for each alternate.
- Sum the differential capital and operating and maintenance costs for each alternate and determine the total costs differential between the alternates.

Differential cost estimates of the annual operating and maintenance costs and the capital costs for five HLW solidification alternates were developed. In order to develop these estimates, it was necessary to generate conceptual system designs and process flow diagrams for the five alternates. The key study bases and common assumptions for this analysis were categorized as follows:

HIGH-LEVEL WASTE (HLW) CHARACTERIZATION

BASES

- The LWR spent fuel from the uranium cycle is reprocessed after irradiation of 33,000 MWD/MTU at 30 MW/MTU.
- Spent fuel is reprocessed 150 days after discharge from the reactor.
- HLW is raffinate from the first stage extraction in the Purex Process and does not include intermediate or low-level wastes.

ASSUMPTIONS

- HLW waste generation rate from the Purex Process is 5,000 liter/MTU.

- A preconcentration and nitric acid recovery step is performed prior to interim storage or solidification processing.
- The concentrated HLW feed rate to the interim storage tanks is 756 liter/MTU and 378 liter/MTU to the solidification process.
- HLW composition is similar to the reference PW-7* composition.

SOLIDIFICATION FACILITY DESIGN

BASES

- The reprocessing plant capacity is 2,000 MTU/year.
- Solidified waste is shipped from the facility within 10 years after separation from fuel.
- Fuel reprocessing plant represents mature technology.

ASSUMPTIONS

- Solidification facility availability is 300 days/year.
- Solidification equipment sizing is based on an 80% capacity factor.
- Solidification facilities are integral with the reprocessing facilities.
- The solidification facilities which share common support equipment and services with the reprocessing plant are excluded from the cost estimates. Such items as: decontamination facilities, building crane, laboratories, contact and remote maintenance cells, control room, supply and storage areas, technical support offices, HP services, and security are shared.
- Equipment and operations which are identical for all alternates are excluded from the cost estimates. Such items as canister welding, inspection, decontamination, transfer and handling facilities are included in this category.
- Solidification facility is designed for a service life of 15 years.
- Component service life for major components is equal to that of the facility.
- Facilities housing the solidification equipment, interim HLW storage tanks and canister storage pool are designed to Seismic Category I (0.25g).
- Solidification process equipment handling liquids are classified Seismic Category I.

* PW is shorthand for Purex process Wastes. PW-7 is "clean" HLW (clean is equivalent to low sodium) which contains an excess of gadolinium used as a burnable poison, plus more iron, (PO₄), and uranium and some sodium.

- Interim HLW tank storage is provided prior to solidification as necessary to meet canister centerline temperature limits.
- Canister post-filling storage is in an underwater storage pool until time of shipment.

WASTE CANISTER

BASES

- Canister dimensions are 0.305 m in diameter and 3.05 m long. Fill capacity is 0.2 m³.
- Maximum allowed heat content of canister is 3.5 kw at shipment to the Federal repository. A diluent (inert filler material) is utilized as required to meet this limit.

ASSUMPTIONS

- Waste product sealed in canisters is denitrified and dehydrated for stability reasons.
- Canisters are fabricated of 304 L stainless steel.
- Internal heat transfer fins will be provided as necessary to minimize interim storage requirements.
- Canisters are designed for in-can denitrification and product compaction as required.

CANISTER TRANSPORTATION

BASES

- 50-ton HLW rail casks and 20-ton truck casks are used.
- Four canisters per 50-ton cask and one canister per 20-ton cask are shipped.
- Shipping distance from reprocessing plant to Federal Waste Repository is 1,500 miles one way.
- Cask shipments are by rail or truck. "Special" trains are not required.

ASSUMPTION

- HLW casks in the required number are owned by the reprocessor. This assumption was made because of the high usage factor (~100%) required for these casks once waste shipments begin. This would appear to be the most economical method of providing casks at such a high usage factor.

ASSUMPTIONS

- Operating basis will be three shifts - seven days/week coverage.
- Cost estimates are developed on the basis of constant 1977 dollars.
- Indirect field cost, engineering cost contingency and interest during construction (IDC) cost factors are included which are typical of nuclear facility construction costs.
- IDC is applied for a three-year period to the capital cost at an interest rate of 8 percent per year.

Variations in process design and some limited efforts to vary the study bases were undertaken and the impact on the costs are discussed.

Two major cost components were evaluated - capital costs and operating and maintenance (O&M) costs.

From the simplified flow diagrams of the waste solidification processes considered, equipment lists were developed for the major components. The equipment sizing was based on the processing rates and capacities required by each alternate waste form. Based on the equipment lists, capital equipment cost estimate sheets were generated for each alternate. The estimate sheets present the component costs and the installation costs for each component. The installation manhours were charged at \$11/hour. The direct field labor costs were multiplied by 1.9 to account for field indirect costs. The direct equipment and labor costs and the indirect field costs were added to yield the total field cost for the installed component.

The estimated equipment costs were derived from other cost studies, vendor quotes and engineering estimates. The installation manhours were derived from other cost studies and engineering estimates. The total equipment field cost was added to the building field cost estimates for each alternate. This total field cost was multiplied by 1.8 to compute the total capital cost for the alternates. The 1.8 factor includes 20 percent home office, 20 percent contingency and 25 percent interest during construction (IDC).

The estimates for the operating and maintenance costs for the waste form alternates include: operating labor costs, maintenance costs, costs of consumables, cost of utilities, shipping costs, cask costs and handling charges, and canister disposal costs.

Annual O&M cost estimate sheets for the five waste forms were developed. Thus, a total annual cost comparison was made between the waste form alternates. Three alternative system designs were discussed. These include variations in interim waste storage times (from immediate solidification to five years storage in the liquid form), and process design characteristics of the waste alternates (modify the diluent material and final product physical characteristics). Summary cost information for two of the alternative designs is presented in Tables 1 and 2.

TABLE 1
SUMMARY
TOTAL ANNUAL COST COMPARISON^{1,2}

ITEM	SALT CAKE	SPRAY CALCINE	FLUIDIZED BED CALCINE	SUPERCALCINE MULTIBARRIER	BOROSILICATE GLASS
Differential Annual Operating & Main. Cost	\$1,774,000	\$1,844,000	\$1,939,000	\$7,571,000	BASE
Differential Annualized Capital Cost	4,790,000	5,017,000	5,242,000	(205,000) ³	BASE
Total Annual Cost Differential	\$6,564,000	\$6,861,000	\$7,181,000	\$7,366,000	BASE

1. Based upon system design using minimal interim storage of liquid waste and modified waste form characteristics.
2. Differential annualized capital costs were computed using a fixed charge rate of 12% per year.
3. Parentheses () indicate negative differential.

TABLE 2
SUMMARY
TOTAL ANNUAL COST COMPARISON^{1,2}

ITEM	SALT CAKE	SPRAY CALCINE	FLUIDIZED BED CALCINE	SUPERCALCINE MULTIBARRIER	BOROSILICATE GLASS
Differential Annual Operating & Main. Cost	\$1,774,000	\$1,844,000	\$1,939,000	\$7,571,000	BASE
Differential Annualized Capital Cost	9,483,000	9,709,000	9,933,000	(205,000) ³	BASE
Total Annual Cost Differential	\$11,257,000	\$11,553,000	\$11,872,000	\$7,366,000	BASE

1. Based upon system design using 5 year interim storage of liquid wastes for salt cake, spray and fluidized bed calcine, 1 year for borosilicate glass, and 150 days for supercalcine multibarrier waste floor.
2. Differential annualized capital costs were computed using a fixed charge rate of 12% per year.
3. Parentheses () indicate negative differential.