THE DEFENSE WASTE PROCESSING FACILITY CAPITAL COST ESTIMATE

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ABSTRACT

The Defense Waste Processing Facility (DWPF) will be the Nation's first production-scale facility to immobilize high-level nuclear waste for disposal. The DWPF will be built at the Department of Energy's Savannah River Plant near Aiken, South Carolina. Approximately 30 million gallons of high-level waste, stored as liquid, salt cake, and sludges in underground tanks, have accumulated from almost 30 years of operation of the Savannah River Plant. The DWPF will immobilize this waste in borosilicate glass for eventual disposal in a Federal repository.

The DWPF project includes (1) remotely operated facilities to immobilize the high-activity fraction of the waste in borosilicate glass in stainless steel canisters; (2) facilities to solidify the low-level fraction (decontaminated liquid and salt) for disposal on the Savannah River Plant site; and (3) support facilities for safe and efficient plant operation. Construction began in 1983, and the facilities will be completed and operational in 1989. The total estimated cost to design and construct all of the facilities included in the DWPF project is $870 million.

The focus of this paper is on the DWPF cost estimate. The paper briefly describes the facilities included in the DWPF project and describes the assumptions and methodology used to prepare the detailed cost estimate for design and construction. The cost estimating and risk analysis models used to verify the detailed estimate are also discussed. The paper also describes the design improvements and innovations which have resulted in cost reductions for the DWPF project from the $2.8 billion estimated in 1978 to the present estimate of $870 million. Finally, the paper describes the cost control methods that are being used to insure that the DWPF will be completed within the estimated cost.

INTRODUCTION

The Defense Waste Processing Facility (DWPF) will be the Nation's first full-scale production facility to immobilize high-level radioactive waste for disposal. The DWPF is being built at the Department of Energy's Savannah River Plant near Aiken, South Carolina. The Savannah River Plant has been operating since 1954 producing nuclear materials for national defense, energy research and development, medical, and other purposes. These operations have produced over 30 million gallons of high-level waste. The waste is stored in large underground tanks. The waste consists of alkaline liquid, crystalline salts, and sludges. The DWPF will immobilize the high-activity fraction of the waste in borosilicate glass cast into stainless steel canisters. The filled canisters will be stored on the Savannah River Plant site until a Federal repository is available for disposal. The DuPont Company, the operating contractor for the Savannah River Plant, is responsible for research and development, design, construction, and operation of the DWPF for the Department of Energy.

Conceptual design and project planning for the DWPF began in the late 1970's. Since that time many cost estimates of varying quality have been made for the total project and for the various component facilities and systems. These estimates have served a variety of purposes. Cost estimates together with engineering feasibility studies have been used in trade-off studies to optimize the vitrification system, the individual components, and the overall facility capacity and configuration. As project planning evolved, estimates of total project cost were used to select programmatic alternatives to determine waste processing and disposal strategy. When the project reached the stage where it was presented to Congress for authorization, the cost and schedule estimates were very important in establishing funding profiles for Congressional appropriations and budget planning. In the design and construction phase the cost estimate serves as a management tool for cost and scope control as well as financial planning.

Construction of the DWPF began in October 1983, and the design is about 50 percent complete. The project capital cost estimate was updated in December 1983. The total estimated cost to design and construct the facilities in the DWPF project is $870 million. This paper discusses the December 1983 cost estimate and how it was prepared. The paper also discusses the evolution of the project cost estimate and how the cost estimate will be used to help control project scope as well as cost.

PROJECT SCOPE

Facilities

The DWPF will consist of a main process building containing remotely operated equipment to immobilize the high-level waste, a building for temporary storage of the waste canisters, facilities to solidify and dispose of the decontaminated salt solution, and service and support facilities.

The main process building will be a reinforced concrete "canyon" type structure 110 meters long, 36 meters wide and 28 meters high. The building will be seismic and tornado resistant, and will meet DOE criteria and standards for nuclear facilities. Running the length of the building will be remotely operated and maintained process cells containing the immobilization equipment interconnected through systems of piping. The process equipment is arranged to minimize building volume and facilitate material flow. The concrete walls of the process cells will provide shielding from the highly radioactive waste solutions and solids. Cold feed chemicals and service systems such as instruments, cooling water, steam, electric power, etc., will be provided from adjacent areas to facilitate maintenance and reduce exposure to operating personnel. Building ventilation is designed for contamination control, and ventilation air will be monitored and filtered before discharge to the atmosphere.

An air-cooled, concrete storage vault will be built near the main process building to provide temporary storage of the glass waste canisters. It will be cooled by natural convection and require minimum surveillance. This vault has space for about 1,000 canisters of borosilicate glass waste, which is approximately 2 year's production.

Facilities for disposal of the decontaminated salt include an underground transfer line to the disposal area, liquid/solid mixing equipment, solids handling equipment, and control equipment and instrumentation.

Also included in the DWPF project are the necessary support facilities for safe and efficient operation of the plant. These include a service building, bulk chemical storage area, warehouse, guardhouse, and water treatment facilities. Exhaust ventilation facilities will include a sand filter, fan house, and exhaust stack. Support facilities such as electrical substations, water wells, sanitary and storm sewers, roads, and railroads are also being provided.

Immobilization Process

The process for immobilizing Savannah River Plant high-level waste for disposal will begin in the waste storage tank farm where the waste will be separated into high-activity and very low-activity fractions. The high-activity fraction will be immobilized in borosilicate glass. The low-activity fraction will be solidified and disposed of onsite as low-level waste.

The high-level waste sludge (containing most of the strontium and actinides) will be washed in the tank farm to remove excess aluminum and sodium. The slurry, containing about 19 weight percent solids, will be pumped directly to a sludge receipt tank in the DWPF canyon where it will be treated with formic acid to remove mercury. The sludge slurry will then be mixed with glass-forming material (frit) and fed to a joule-heated ceramic melter where the waste will be melted at approximately 1150° C with the glass frit. The off-gas from the process will be cooled, filtered, and decontaminated before being released. The immobilization equipment will operate at a rate of about 100 kgs of glass per hour. The molten glass waste will be poured into stainless steel canisters approximately 3.0 meters long and 0.6 meters in diameter.

Each canister will contain about 1480 kgs of glass. The canisters will be cooled, plugged, and decontaminated by abrasive blasting with a mixture of glass frit, water, and air. The glass frit used for decontamination will be mixed with sludge as feed for the melter, thereby not generating another waste stream. The canister will be sealed with an outer plug by an upset-resistance welding technique and then leak tested. The canisters will then be transferred to the air-cooled storage vault for later shipment to a geologic repository. All of these operations will be done remotely.

The liquid and soluble salt fraction of the high-level waste will be decontaminated in the tank farm. The salt will be redissolved and combined with the liquid waste. In a specially prepared underground waste tank, sodium tetraphenyl borate will be added to the waste solution to precipitate the cesium. Sodium titanate will also be added to adsorb the trace strontium and plutonium. The liquid will be filtered using sintered metal cross-flow filters to remove the solids. The solids from the precipitation process will be pumped to the DWPF canyon as a slurry and treated to decompose the tetraphenyl borate and remove benzene. The cesium and other radioactive materials will then be fed to the DWPF melter to be immobilized in glass. Alternatively, the cesium could be purified for beneficial use. However, the capability to do this is not included in the DWPF project.

The decontaminated liquid will be disposed of on the Savannah River site as low-level waste. The decontaminated liquid will be pumped to a disposal area where it will be mixed with specially prepared cement to form a low permeability monolith. The "saltstone" will be poured into trenches, allowed to solidify, and then covered with about 5 meters of backfill. The salt disposal facilities will process the decontaminated liquid at a rate of about 10 gallons per minute. The salt disposal site will occupy about 100 acres.

Except for a relatively small amount of modifications needed for initial processing of the waste in the waste tank farm, all of the equipment and facilities needed to accomplish the above process are included in the DWPF project cost estimate.

DWPF COST ESTIMATE

The total estimated capital cost for the DWPF project is $870 million. This consists of $800 million for the Vitrification Plant with a high quality estimate and $70 million for facilities and equipment originally planned for a subsequent project (Stage 2). These are facilities to dispose of decontaminated salt, equipment to prepare the cesium precipitate for immobilization (acid hydrolysis), canister shipping facilities, and storage for contaminated excess equipment. The estimates for the Stage 2 elements are less well defined because of lack of firm designs.

This paper will discuss the $800 million Vitrification Plant cost estimate. The cost estimate was prepared by DuPont. The following information was obtained primarily from briefings and presentations to Department of Energy staff.

Estimate Basis

The basis for the cost estimate is the project requirements prepared by the operating contractor, which define project objectives and contain the fundamental data on process operation, maintenance, and services which will permit the best design for the facility. Adequate technical definition is a significant factor in the reliability of the cost estimate. All of the vitrification system unit processes are well defined and have been demonstrated at or near full scale. Since DuPont is responsible for R&D and operation of the DWPF, as well as design and construction, the flow of technical information is simplified. This integrated approach, along with well defined requirements, enhances the credibility of the cost estimate.

The estimate is based on 40 percent complete firm design, including updated drawings, equipment lists, and scopes of work, which provide the engineering interpretation of the project requirements. At this point in the project, quotes were available for only a few pieces of equipment. The schedule basis for this estimate is a preliminary project schedule which defines the overall schedule for facility completion.

Estimate Summary

A summary of the December 1983 estimate for the Vitrification Plant is as follows. Escalation and contingency are based on physical construction completion in second quarter calendar 1988.

Cost Estimate Summary ($Million)

Direct		$383
Building and Lighting	138	
Major Equipment	134	
Instrument	31	
Piping	46	
Insulation	4	
Electrical	19	
Site	11	
Indirect		$232
Construction Indirect Cost	70	
Engineering Design	127	
Engineering Control and Inspection	35	
Escalation		$105
Contingency		$ 80
Total		$800

Estimate Preparation

One of the first steps in preparing the cost estimate was the development of an estimate plan which specified the estimate preparation and review procedures. The December 1983 estimate for DWPF is a completely new estimate in which the identified subcontracts were adjusted to the latest concept, offering the economic advantage of fixed price versus cost plus fixed-fee contracts. Engineering packages were prepared for all DWPF facilities. Reviews were conducted to insure that scopes, drawings, and equipment lists for the various design areas were up-to-date and correct. There were seven key design areas, representing 40 percent of project cost, that received formal scope review.

Examples of how costs were estimated are:

1. The concrete portion of the process building was estimated by making a cubic yards of concrete take-off from design drawings. The unit cost for concrete was developed from verbal quotes.

2. Service building labor and materials were priced using quantity take-offs from drawing.

3. Piping quantities were developed directly from piping and instrument diagrams, process flow diagrams, and building arrangement drawings. Pricing was accomplished from quotes and current catalog prices.

Pricing details for the estimate are based on third quarter calendar year 1983, and equipment quotes are as of September 1983. Included in this estimate are the most up-to-date labor rates, completely new material take-offs, and field material pricing, as well as the latest escalation forecasts and revised allowances and contingency.

Composite yearly escalation rates for the DWPF cost estimate for calendar years 1984 through 1988 are as follows:

1984	1985	1986	1987	1988	Average
5.3%	6.2%	6.0%	7.5%	8.0%	6.6%

These composite rates are made up of escalation for labor, material, and project administration developed by DuPont.

Cost Estimate Verification

Since cost estimating is not an exact science, DuPont uses a system of checks and balances to help insure that cost estimates are reliable. The DWPF cost estimate was verified using various methods. The independent DuPont estimating team verified 45 percent of the total direct costs broken down into categories such as building, electrical and instrumentation, piping, equipment, and ductwork. For example, a survey was conducted of costs of Savannah River facilities, other DOE installations, and commercial power reactors. The results of this survey showed that average concrete unit costs tend to be relatively constant for large concrete buildings regardless of the construction mix of floors and walls. The Vitrification Building installed concrete cost of $579 per cubic yard is well within the survey results. Other items were similarly verified using extensive unit cost libraries, which reflect actual experience with this type of facility.

Allowances and contingencies for this estimate were generated using three methods, with a fourth validation being conducted by the Department of Energy's Independent Cost Estimating Staff. The first method, the DuPont historical approach, consists of including engineering and design development allowances, and estimating allowances in the estimate. Design development allowances cover changes in quantity and quality within the intent of the process, while estimating allowances cover errors or omissions in pricing and performance within the intent of the process. These allowances are added to arrive at a most probable cost. A financial risk allowance is then added to provide a higher confidence that the estimate will not be exceeded. This approach has evolved over 30 years of experience with large nuclear facility design, construction, and operation at Savannah River.

The second method was a classic Monte Carlo risk analysis which breaks the estimate down into areas of work which are rated against five variables (scope, unit price, indirect field cost, escalation, and home office hours). The probability of meeting these variables is assumed (e.g., the probability that the Vitrification Building scope will stay the same is either "least probable," 50/50, or "most probable"). When all areas of work have been rated, a Monte Carlo simulation is run which produces a probability and contingency distribution.

The third method used to determine allowances and contingency was the Hackney Definition Rating System. In this method, the cost allowance is based on historical data (43 large projects) combined with experienced judgments of John Hackney, a consultant in the field of capital projects. In this method, project information is divided into six element groups (basic data, process flowsheet design, site information, engineering design, detailed design, and performance of construction projects). Each group was evaluated to determine an overall definition rating. This rating was then used to determine contingency.

Comparing these three methods of determining contingency and allowances, the results are within about 1 percent of each other. The higher confidence level estimates provide 80 to 85 percent confidence that the estimate will not be exceeded. The $800 million estimate for the DWPF Vitrification Plant was selected to provide that level of confidence in response to Congressional and others' concerns about cost overruns.

Allowance and Contingency
Vitrification Plant Estimate
($ million)

	Base Estimate	Most Probable Cost	Higher Confidence Level
DuPont Historical	-	720	800
Monte Carlo	640	707	790
Hackney Definition Rating	648	716	808
DOE Independent Cost Estimate	-	690	-

The DOE Independent Cost Estimating staff performed an Independent Cost Estimate (ICE) of the DWPF in December 1983. The results of this independent estimate were that the $800 million is a reasonable estimate for the Vitrification Plant.

COST ESTIMATE HISTORY

The first cost estimate for the DWPF project was $2.8 billion (escalated to year of expenditure). This estimate was prepared in 1978 for a facility producing a borosilicate glass waste form with capability to process all of the Savannah River high-level waste. The process utilized a calcine-fed melter and ion exchange to decontaminate the large volume of liquid and salt. As the design evolved, changes were made which reduced costs. In 1979 it was determined that a canister overpack was not required and tank farm modifications could be reduced. Also, the flowrate and equipment size were optimized. These and other improvements resulted in an estimate of $2.3 billion (escalated). In 1980 several process improvements were made which resulted in further cost reductions. An in-tank sludge washing process was developed and the slurry-fed melter was adopted. Also, it was decided to use closed circuit TV to view canyon operations. These changes greatly reduced the required canyon space and reduced the cost estimate to $1.6 billion (escalated).

In 1981 the decision was made to divide the project into stages to reduce the initial capital cost and allow time to improve the salt processing technology. Stage I, with the vitrification process for sludge, was estimated to cost $900 million (escalated), and Stage II for decontaminating the liquid and salt using ion-exchange was estimated at $600 million (1980 dollars). In 1982 the in-tank precipitation process for decontaminating the liquid and salt was adopted. This was the most significant cost reduction since it virtually eliminated the Stage 2. All that remained from Stage 2 was equipment to treat the precipitate in the DWPF so it could be immobilized in glass and facilities to dispose of the decontaminated salt. In 1983 all of the facilities were recombined into a single project. Escalation and contingency have been reduced and this, along with other design improvements, has resulted in the present $870 million estimate.

COST CONTROL

The detailed cost estimate is an important part of the DWPF project control system because it serves as the baseline against which cost variations are measured. The estimate is used in several ways. The estimate and its supporting documentation provide a baseline for project scope. Equipment and material quantities and capacities, building sizes and specifications, labor hours for specific tasks, and other scope parameters are monitored and compared to the scope on which the estimate was based. Variations are reported giving an early indication of scope changes. The estimate also serves as the baseline for pricing. Actual dollars spent in procurements are checked against the estimate for equipment, materials, and labor. The estimate also serves as a baseline for costs which are affected by field conditions. Such items as schedule delays, labor efficiency, and indirect field costs are compared to the estimate. These checks are usually made on a unit basis such as cost per drawing or cost per foot of piping or cubic foot of building space. All of these checks help to provide early indication of problems and aid in implementation of corrective action if needed.

CONCLUSION

The technology and design for the DWPF have undergone substantial development and improvement. The accuracy and reliability of the cost estimate have also improved along with the design. The December 1983 cost estimate is based on 40 percent complete design and well- developed technology. The project requirements which determine the scope of the project, and hence the cost estimate, are well defined. The project schedule is well developed and portrays the sequence and relation of activities necessary to build this large, complex facility. And finally, the estimate has been validated using several methods, and the results compare favorably. All of these factors contribute to a high confidence that the DWPF can be built within the $870 million cost estimate and that the estimate will provide a solid basis for project planning and control.

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