United States General Accounting Office

GAO

Report to the Ranking Minority Member, Committee on Commerce, House of Representatives

April 1999

NUCLEAR WASTE

Process to Remove Radioactive Waste From Savannah River Tanks Fails to Work

GAO Accountability * Integrity * Reliability

GAO

United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

B-281907

April 30, 1999

The Honorable John D. Dingell
Ranking Minority Member
Committee on Commerce
House of Representatives

Dear Mr. Dingell:

The Department of Energy (DOE) is responsible for cleaning up the nuclear waste legacy created by over 50 years of producing nuclear weapons material. At DOE's Savannah River Site in South Carolina, 34 million gallons of liquids that contain highly radioactive waste (high-level waste) have accumulated in the storage tanks since the site became operational in 1951. The in-tank precipitation (ITP) process was selected in 1983 as the preferred method for separating the high-level waste from the liquid. In 1985, DOE estimated that it would take about 3 years and $32 million to construct the ITP facility. After a number of delays, the ITP facility was started up in 1995, but safety concerns about the amount of explosive, toxic benzene gas that the facility was generating halted start-up operations. Ultimately, in February 1998, after about a decade of delays and spending almost a half billion dollars, DOE suspended the ITP project because it would not work safely and efficiently as designed. DOE then directed its contractor, Westinghouse Savannah River Corporation (Westinghouse), to begin a process to identify and select an alternative process.

You asked us to (1) examine the factors causing the project's delays and cost growth, (2) identify the effect of the ITP project's suspension on the Savannah River Site's cleanup plans and costs, and (3) provide information on DOE's plans for developing an alternative technology for separating high-level waste from the liquid.

Results in Brief

A number of factors combined to cause the Department of Energy and Westinghouse to spend almost a half billion dollars and to take about a decade to decide that the in-tank precipitation process would not work safely and efficiently as designed. The most serious factors were the ineffectiveness of the contractor's management and of the Department's oversight of the project. For example, in 1993, a technical review team reported that the contractor tended to use "reactive discovery management" to solve problems after they occurred, rather than working to avoid problems in the first place. The team also found that the

Department lacked the necessary personnel for adequate oversight. Moreover, the Department and the contractor encountered delays in starting up the in-tank precipitation facility because they began construction before the design of the process was completed. Furthermore, because the Department funded the project with operating funds, rather than with construction funds, the project was less visible to congressional oversight. There was also an inadequate understanding by DOE and the contractor of the in-tank precipitation process and the cause of the benzene generation.

The failure of the in-tank precipitation process to operate as originally planned will delay the cleanup of high-level waste at the Savannah River Site and increase costs. Initially, the facility was planned to begin operating in 1988, and now, DOE estimates that an alternative process may not be available until as late as 2007 and could cost from about $2.3 billion to $3.5 billion over its lifetime. As a result, the site has had to modify its plans for processing waste. Depending on the alternative process selected, Westinghouse estimated that it could be as late as 2025 before the waste tanks are empty. Thus, the Department risks missing the dates in its waste removal plan and schedule agreement with the state of South Carolina and the U.S. Environmental Protection Agency to close certain high-level waste tanks by no later than 2022. More importantly, Westinghouse estimated that it could cost over $75 billion to construct and operate the facilities necessary to clean up the high-level waste if an alternative process is not developed for separating the waste in the tanks.

The Department’s plans for selecting an alternative process are still being formulated. Soon after the in-tank precipitation project was suspended in 1998, Westinghouse began evaluating 142 technologies to replace the process and pared them down to 4 final alternative technologies. On October 29, 1998, Westinghouse recommended to the Department that the small tank precipitation process be selected. Although this process is similar to the failed one, several differences exist that Westinghouse believes will address the safety hazards caused by the benzene generated by the process. For example, because small tanks will be used to process the waste, the processing time will be cut significantly, thereby reducing the time during which benzene can build up in the tanks. Westinghouse officials estimate that it could cost about $1 billion to build the small tank precipitation facility by 2005. Westinghouse ranked this process as being the most scientifically mature, having the most manageable risk, and having the greatest likelihood of success. Westinghouse also recommended that an alternative process, crystalline silicotitanate ion exchange, be developed as a backup, using a different method to remove the high-level waste from the tanks. The Department's Savannah River Site evaluated Westinghouse's recommendation and announced in December 1998 that testing and development work should continue on both processes before a final decision is made. In addition, the Department concluded that another process--direct disposal in grout--should not be eliminated from consideration. As a result, DOE has begun additional research and testing to obtain the information needed to select the preferred alternative by the end of fiscal year 1999.

Background

In the early 1980s, DOE's Savannah River Site in South Carolina initiated efforts to remove 34 million gallons of liquids containing high-level waste being stored in 49 underground tanks. It developed plans for constructing various facilities to treat the waste and transform it into a more stable glass form--a process referred to as vitrification.[1] The glass canisters would then be shipped to a repository for permanent disposal. The vitrification process is performed at Savannah River's Defense Waste Processing Facility, which began operating in 1996 and cost over $2 billion to construct.

The ITP project was designed to be an integral part of the high-level waste cleanup program that would speed up the process and reduce the overall cost. Since only about 10 percent of the 31 million gallons of waste in the tanks is highly radioactive, separating the high-level waste from the remaining liquids greatly reduces the volume to be vitrified.[2] The ITP facility was to separate (precipitate) the high-level waste (mainly cesium, but also trace amounts of strontium and plutonium) in the waste tanks. To remove the cesium, a chemical called sodium tetraphenylborate was to be mixed with liquids from the underground tanks in a 1.3 million-gallon processing tank. This chemical would react with the waste, causing the high-level waste to be separated from the liquids. The high-level waste was then to be removed from the tank through a filtering process. To remove the trace amounts of strontium and plutonium, another chemical was to be

[1]Vitrification is the process of blending liquid high-level waste with other substances and melting them at 2,100 degrees Fahrenheit to form a solid glass. Once the high-level waste is immobilized within the structure of the glass, it cannot dissolve the glass and migrate into the environment.

[2]Of the 34 million gallons of waste in the tanks, about 3 million gallons is sludge (highly radioactive insoluble waste that settles to the bottom of the storage tanks) that requires different handling than the 31 million gallons of liquid referred to here.

used, monosodium titanate. Once the high-level waste was separated, it was to be sent through a “late wash” facility, where nitrite concentrations would be reduced, and then sent to the Defense Waste Processing Facility to be vitrified with sludge wastes. After the separation process, the waste remaining in the tank would be a solution with a low level of radioactivity that could be safely treated and disposed of on site at Savannah River’s saltstone facility.[3]

DOE officials said that in selecting the ITP process they were looking for a less costly approach to separating the liquid wastes. The alternative to ITP available in 1982 was estimated to cost about $700 million to construct.[4] DOE officials said that the ITP option was selected because (1) existing scientific data indicated a reasonable chance for success, (2) the technological uncertainties were believed to be comparable to those of alternative technologies, and (3) the process could be performed in existing waste tanks, thereby eliminating the need to construct a new major facility and significantly reducing the estimated cost.

The development of the ITP process began in the early 1980s when the DuPont Chemical Company was DOE’s management and operating contractor at Savannah River. In 1985, the ITP facility was projected to cost an estimated $32 million to construct and to be operational in 1988. In addition, at that time, DOE estimated that it would need to build three other facilities to support ITP that would cost about $71 million to construct.[5] Westinghouse took over as the site’s management and operating contractor on April 1, 1989, and thus assumed responsibility for the ITP project. Ten years after the original completion date, about $489 million had been spent on the ITP process and its related facilities and

[3]The saltstone facility is a disposal facility for low-level radioactive waste that has been mixed with grout to make a concrete-like substance.

[4]A February 1982 final environmental impact statement included a construction cost estimate of $700 million (in constant 1980 dollars) for a process called ion exchange, which was to separate the highly radioactive waste from the tanks. A Westinghouse official said that this cost would have exceeded $900 million if escalated for inflation.

[5]The three facilities were the saltstone facility, the salt processing cell that readies the precipitate resulting from the ITP process for the Defense Waste Processing Facility melter, and the organic waste storage tank that would be used to store the benzene recovered from the process.

activities.[6] (App. I contains additional information on the costs of the ITP project and its associated facilities.)

The ITP facility began start-up operations in September 1995 using 130,000 gallons of waste solution and 37,300 gallons of sodium tetraphenylborate. During October and November, test results showed a nearly constant release of benzene. In December 1995, benzene was released at a much higher rate than expected, and the operations were stopped. This led to an expanded scope of experiments to investigate the generation, retention, and release of the excess benzene. In January 1996, the Defense Nuclear Facilities Safety Board[7] sent DOE a letter advising that additional safety precautions were needed because of the excess benzene generation and that DOE needed to better understand the mechanisms for the generation and release of the gas. In March 1996, ITP operations were suspended. On August 14, 1996, the Safety Board issued Recommendation 96-1 to address its safety concerns about ITP. In part, it recommended that DOE better understand ITP's sodium tetraphenylborate chemistry. It was eventually discovered that a catalyst existed in the waste tanks that was causing the excess benzene generation, a discovery that led to the formal suspension of the ITP process in February 1998.

Ineffective Management and Oversight and Lack of Understanding of the Process Delayed the Suspension Decision

A number of factors combined to cause DOE and Westinghouse to spend almost a half billion dollars and take about a decade to decide that the in-tank precipitation technology would not work safely and efficiently as designed. The ineffectiveness of management and oversight during the 1980s and early 1990s resulted in the problems with the ITP process not being dealt with adequately early on in the technology's development. In addition, the ITP process and the generation of benzene (a toxic, highly flammable, and explosive gas) were not fully understood.

[6] The $489 million includes total estimated construction costs of $157 million; other project costs of $151 million that include the costs of testing, training, and operational readiness reviews; operating costs of $19 million that include the cost to run the facility after it became operational; and other supporting facilities costs of $162 million that include the costs associated with activities needed to enhance the safety and efficiency of the ITP process.

[7] The Defense Nuclear Facilities Safety Board is an independent executive branch organization responsible for providing advice and recommendations to the Secretary of Energy on public health and safety issues at DOE's defense nuclear facilities.

Ineffective Management and Oversight Led to Project Delays and Cost Growth

Ineffective management and oversight by DOE and its operating contractor were principal factors contributing to the delays and increased costs of the ITP project. Management and oversight were ineffective during the 1980s and early 1990s primarily for the following reasons:

- the weaknesses in the contractor's management and DOE's oversight,
- the difficulty in managing the project's start-up, and
- the limited oversight and visibility of the project because of the budgetary treatment it received.

Weaknesses Existed in the Contractor's Management and DOE's Oversight

In 1993, a DOE technical review team (referred to as the Red Team) reported that the contractor tended to use "reactive discovery management" to solve problems after they occurred, rather than working to avoid problems in the first place.[8] The Red Team found that this approach resulted in a high potential for inadequate process development, lengthening the project and increasing its costs. The Red Team also found that there were inadequacies in ITP testing and in understanding the ITP process as well as uncertainties about whether the equipment to be used would function as expected.

The Red Team also reported that DOE Savannah River's oversight and support functions were not adequate because they lacked the necessary personnel. The Red Team found that, as a result, DOE's guidance and responsiveness to Westinghouse were limited. Moreover, the team found that DOE's organizational responsibilities appeared unclear and that the DOE staff were forced to respond in a reactive manner to emerging issues.

The contractor's management problems surfaced repeatedly in the evaluations DOE performed every 6 months to assess Westinghouse's eligibility for award fees.[9] For example, we found that in 14 of the 16 evaluations performed from April 1990 through March 1998, DOE identified weaknesses needing attention in contractor management or ITP planning activities. For example, a 1992 evaluation stated that performance against planned work was not adequately monitored and technical documents had

[8]Independent Technical Review of In-Tank Precipitation (ITP) at the Savannah River Site, DOE Office of Environmental Restoration and Waste Management (June 1993).

[9]In fiscal year 1995, the evaluation periods were 8 months and 4 months rather than 6 months. An award fee is an incentive for good performance as defined in the contractual agreement that DOE negotiates annually with a contractor.

deficiencies indicating a lack of management attention. In 1996, an evaluation noted that while the ITP benzene issue was a key issue, no single manager had been designated as having overall responsibility for the resolution of the issue and the implementation of the resolution program had been fragmented and was not integrated. In addition, a 1995 evaluation noted that insufficient resources had been assigned to meet the project's schedule. (See app. II for examples of the deficiencies identified in the award fee reports.)

Although DOE included the ITP project in its award fee determination for the high-level waste program as a whole, there was no indication that the deficiencies found in the ITP project affected the amount of the award fee until fiscal year 1998--when the project had been formally suspended. From 1990 through 1997, Westinghouse received, on average, 69 percent of the available fee, or about $3 million per fee period, for activities associated with the high-level waste program. In 1998, after DOE and Westinghouse had agreed to make the ITP project a performance-based incentive project, DOE evaluated Westinghouse on ITP performance. Had Westinghouse resolved the technical issues and put the ITP facility into operation, it could have earned up to a $2 million award. Instead, DOE deducted $1 million from Westinghouse's total fee award because the ITP facility remained inoperable.

The DOE Savannah River officials responsible for overseeing the ITP project told us that the project was poorly defined up front and that this had led to higher costs and greater delays. However, according to DOE, the site has made improvements in project management in recent years. For example, DOE noted that as a result of a National Research Council report, DOE and Westinghouse performed a self-assessment of the site's project management and developed and implemented a project management improvement plan in 1998.

Managing the Project's Start-up Posed Difficulties

The ITP project was managed on a fast-track schedule--design and construction being done concurrently--with an emphasis on pushing ahead in the belief that the problems could be solved later. Wanting to have the ITP process ready in time to provide precipitate to the Defense Waste Processing Facility, project managers began construction of the ITP facility before the design of the ITP process was completed. Rather than expediting the ITP project, this approach caused a series of delays that prolonged the project for 10 years while costs mounted. A number of studies in the early 1990s noted this problem, as the following examples show:

- A 1992 Westinghouse management assessment concluded that a number of start-up activities were begun prematurely--before the foundation for an efficient program was in place.[10] The key weaknesses observed included a lack of a technical baseline and a potential for disconnects and inconsistencies among the project's various activities because their integration was incomplete.
- Our 1992 report on Savannah River's Defense Waste Processing Facility, which included the ITP project, cited the fast-track management method being used as having contributed to the project's cost growth. Our report also stated that there was a risk associated with that method, especially when used with unique and complex facilities. We recommended that an assessment be made comparing ITP to an alternative technology.[11]
- The 1993 Red Team report noted that the project's start-up was not being managed as a first-of-a-kind chemical processing system. It stated that Westinghouse was not following the accepted chemical engineering practice of completing process development, demonstrating the operability of the process on a pilot scale, and assessing all long-term impacts and requirements for sustaining the process before beginning production plant operations. The Red Team recommended that alternatives to the ITP process be considered.

Westinghouse acknowledged that the risks associated with new applications of existing technologies were not managed well on the ITP project in terms of building enough time into the schedule to allow for the kinds of technical problems that arose. DOE Savannah River officials noted that ITP was a first-of-a-kind process for which no proven technology was available. They said that the project was complicated by the fact that, because of funding constraints, they had to scale up the technology from lab tests to full-scale without the benefit of additional test facilities. DOE officials explained that they considered alternatives to ITP as the project progressed. From 1992 through 1994, comparisons were made between ITP and alternative technologies. DOE said it determined that risks were inherent in ITP and the alternative processes but that costs still favored the ITP process, so the project proceeded.

[10] Management Assessment: In-Tank Precipitation Project, Westinghouse Savannah River Company (Mar. 1992).

[11] Nuclear Waste: Defense Waste Processing Facility—Cost, Schedule, and Technical Issues (GAO/RCED-92-183, June 17, 1992).

Some of the officials we interviewed characterized the ITP project's schedule as aggressive, while others described it as a fast-track project in which construction began without a complete design package in order to compress the project's schedule. Westinghouse managed the project's start-up phase through parallel activities, according to a former director of the DOE Savannah River High-Level Waste Program. The original scheduled completion date of 1988 was never realistic for a technical project like ITP, according to the director. Because DOE wanted to have the ITP process ready in time to provide precipitate to the Defense Waste Processing Facility, the design of the ITP process was completed at the same time as the construction of the ITP facility and was managed in a reactive manner, according to an ITP program manager.

In response to a recommendation in a 1998 National Research Council report,[12] the DOE Savannah River High-Level Waste Division Director said DOE is now attempting to manage the high-level waste program, of which ITP is a part, using a systems engineering approach that dictates more testing be done up front.

Oversight and Visibility Were Limited by the Project's Budgetary Treatment

DOE paid for the ITP project with operating funds instead of capital construction funds, which caused the project to receive less oversight and visibility. Capital construction projects are subject to periodic reviews and reports, and those costing $5 million or more are shown as line items in the budget requests DOE submits to the Congress.[13] Projects paid for with operating funds are not subject to these requirements. DOE officials said they used operating funds for the ITP project because throughout the life of the project, they had expected the technical issues to be solved shortly and thus believed the conversion of the project to a line item in the budget was not warranted.

We raised concerns about this budgeting practice in 1992, noting that because projects associated with Savannah River's Defense Waste Processing Facility were being funded from operating accounts, the Congress was not receiving enough information to fully understand the magnitude of the continuing cost increases and delays.[14] DOE, however,

[12]Assessing the Need for Independent Project Reviews in the Department of Energy, National Research Council (Jan. 1998).

[13]Prior to fiscal year 1997, capital-funded projects costing $2 million or more were to be line items.

[14]GAO/RCED-92-183, June 17, 1992.

continued its practice of using operating funds for the ITP project because it considered the technical issues to be solvable in the short term.

Inadequate Understanding of the ITP Process Extended the Project

For many years, DOE and its contractors did not completely understand the ITP chemistry that caused excess benzene to be generated. Until recently, the Westinghouse staff at the Savannah River Site believed that the principal cause was the decomposition of the sodium tetraphenylborate that was added to the high-level waste during the ITP process to precipitate cesium from the waste solution. They believed that the benzene became trapped in the solution and was released because of the addition of water and mixing. In 1997, after a recommendation by the Defense Nuclear Facilities Safety Board, additional research into the chemistry revealed that one or more catalysts were present in the waste solution that reacted with the sodium tetraphenylborate and produced large amounts of benzene.

The contractor based its initial belief on the results of a full-scale test conducted in 1983 and on subsequent bench-scale tests. For the 1983 test, sodium tetraphenylborate was added to a tank with about 500,000 gallons of waste. During the test, good separation of high-level waste occurred. However, a significant release of benzene was also observed that for 6 hours was higher than the instruments in the tank could register. As a result, additional studies were conducted. In the mid-1980s, work at the University of Florida showed similar benzene phenomena but concluded, incorrectly, that the cause was the benzene's being trapped in the solution and released by water. Defense Nuclear Facilities Safety Board officials told us that the University of Florida laboratory-scale testing provided an incomplete set of data that was consistent with observed data from the 1983 demonstration; however, the university's approach did not include a systematic evaluation of all potential contributors to benzene generation, retention, and release. The Safety Board also told us that additional tests in 1987 and 1994 by the Savannah River Technology Center could not reproduce the high benzene rates. These test results were an indication that the ITP process was not fully understood. In 1994, however, a Westinghouse High-Level Waste Review Committee examined the high-level waste process at the Savannah River Site and concluded that the ITP process was well understood and that the understanding of the chemistry was adequate. Until after the 1995 start-up test, no comprehensive analysis was done to determine why the benzene was being produced and released--DOE Savannah River and the contractor assumed they knew the reasons.

According to many DOE ITP project employees with whom we spoke, the test in 1983 was viewed as successful and provided credibility to the project's technology. An ITP engineer told us that the fact that the benzene level went over the instrumentation scale for 6 hours was not widely known. The test results that indicated that the release of benzene exceeded the levels the instrumentation could measure seemed to have been forgotten over time. For example, two ITP project managers involved with the project since 1997 told us they were unaware of this aspect of the test.

During the development of the ITP process, we and the Red Team raised the following concerns about the ITP process:

- In 1992, we raised concerns about the ITP process's unresolved technical issues and delays and recommended that the Secretary of Energy direct that an assessment of an alternative technology (the ion exchange process) be prepared to determine whether DOE should replace the ITP process.[15]
- In 1993, the Red Team noted that the chemistry of the ITP process was not adequately understood and that ITP appeared to cause more problems than it solved. These problems included a need to control benzene emissions; increased flammability risks; increased risk from aerosols, foams, and respirable particulates; increased chemical reactivity of high-level waste leading to possible explosions; and the introduction of extremely complex organic chemistry.
- The Red Team also questioned whether sodium tetraphenylborate, the chemical used in the ITP process, was the best way to remove cesium from the liquid waste. It concluded that effective technologies were available and could be implemented. It noted that if the environmental regulators in South Carolina adopted a more restrictive benzene emissions policy, the entire high-level waste complex, as well as the Savannah River Site itself, would be better served by a thorough reevaluation of alternative technologies.

DOE Savannah River officials told us that they considered the concerns that were raised but did not change their approach for a number of reasons. In their view, in 1992 and 1993, ITP was considered to be the best technology available for the type of high-level waste the Savannah River Site had. They said that the ion exchange technology for separating waste

[15]GAO/RCED-92-183, June 17, 1992.

that was in use at that time at the West Valley Site in New York would not have worked effectively on the Savannah River wastes. It was not until late 1995 that Sandia National Laboratory developed a new resin for ion exchange that should be able to process the Savannah River Site's type of waste, according to these officials. They noted that this alternative still poses a significant risk since it has only recently become available and has never been used on Savannah River's type of waste. In addition, they had believed that they understood ITP's benzene generation problems and thought the problems had been identified, evaluated, and resolved. A number of modifications were made to the ITP facility, primarily to address the generation of benzene and to meet more stringent safety standards that were adopted for all of DOE's facilities. Throughout this period, DOE Savannah River officials said that they considered the ITP process to have the lowest technical risk and the lowest cost of all the alternatives. They also noted that until the process was started up, there was no known scientifically based reason to believe that ITP would not be successful as designed.

ITP's Suspension Altered the Site's Plans and Delayed Cleanup

The failure of the ITP process has caused DOE to reexamine and modify its approach to cleaning up the high-level waste at Savannah River. If building and operating the alternative process is delayed, cost increases may be expected because the production of additional glass canisters may be necessary. The potential environmental impacts also may increase if delays cause high-level waste to be stored in the site's higher-risk tanks.

Originally, the plan was to clean up the high-level waste by having the Defense Waste Processing Facility produce glass canisters from a mixture of waste sludge and the high-level precipitate produced by the ITP facility. Westinghouse officials stated that the current plans are to rearrange the schedule to allow sludge-only processing until the high-level waste becomes available from whatever alternative process is used in place of ITP. Officials expect that they can process sludge-only canisters until 2007 without affecting the total number of canisters to be ultimately produced (about 5,200 canisters at a life-cycle cost of $13.6 billion to $17.4 billion). If the start-up of the alternative process is delayed beyond that time, Westinghouse officials said they would need to consider slowing down the sludge-only production or consider producing precipitate-only canisters. Either of these options may cause the program's costs to rise.

Slowing down the cleanup could raise costs because leaving the high-level waste in the deteriorating storage tanks for a longer period increases the risks of leaks and potential environmental impacts that may require expensive cleanup efforts. Producing precipitate-only canisters will also raise costs. When precipitate waste and sludge are used in combination, the waste dissolves into the glass and does not create additional volume; hence, fewer canisters need to be made if precipitate and sludge can be combined. If production is switched to precipitate-only and sludge-only canisters, extra canisters will have to be made. The present average life-cycle cost for each canister ranges from $2.6 million to $3.3 million.

Delaying the cleanup will also affect the site's ability to store newly generated high-level waste, a problem that carries risks and costs of its own. Savannah River's current operations could fill the available storage space by 2007. The site would then have to build additional tanks or use older storage tanks that are more prone to leaks to store the newly generated waste. DOE's 1998 High-Level Waste Plans state that should the older tanks be needed, they may have to be upgraded by installing modified leak detection systems and seals, refurbishing ventilation systems, repairing or upgrading pumps, and installing waste pipes and valves.

Using these older tanks or delays in building and operating the alternative to the ITP process may have an impact on an agreement the site has with the state of South Carolina and the U.S. Environmental Protection Agency. As part of the agreed waste removal plan and schedule for the site, DOE has committed to closing certain of the older high-level waste tanks by no later than 2022.

If no alternative is instituted for the ITP process, other approaches to cleaning up the wastes in Savannah River's storage tanks would need to be investigated. Westinghouse told us that if it is not possible to separate the high-level and low-level components of the liquid waste, all of the waste will have to be handled as high-level waste. That would mean processing the 31 million gallons of liquid waste into glass, yielding an additional 118,000 canisters at an estimated cost of over $75 billion. Recognizing the magnitude of this approach, DOE officials said that other options would need to be developed and pursued to address the Savannah River tank waste.

DOE Is in the Process of Selecting an Alternative to ITP

Soon after the suspension of the ITP project, a number of teams were formed to recommend an alternative technology and to evaluate the selection process. In October 1998, Westinghouse recommended to DOE Savannah River that the small tank precipitation process be adopted as the preferred alternative and that the ion exchange process be the secondary option. Westinghouse estimates that it could cost as much as $1 billion and take over 7 years to design, develop, construct, and test either of these alternatives. DOE's Savannah River office did not agree that there was sufficient differentiation between the options to focus only on small tank precipitation and recommended further development of three technologies: small tank precipitation, ion exchange, and direct disposal in grout. DOE's Office of Environmental Management approved this approach to explore the three alternatives. (See app. III for additional information on the three alternatives.)

The Selection Process Considered a Number of Alternatives

Soon after the ITP project was suspended, DOE and Westinghouse began activities to select an alternative. At DOE's direction, Westinghouse established the High-Level Waste Salt Disposition Systems Engineering Team (Westinghouse Systems Engineering Team) in March 1998. This team was composed of employees from Westinghouse and its partners, with outside consultant support from academia, the National Laboratories, and the DOE complex. The purpose of this team was to identify and recommend alternative processing options.

The Westinghouse Systems Engineering Team began its study by identifying 142 potential alternatives to ITP. The identification process included coordinating with various National Laboratories and conducting a literature search to define the universe of options. The team then narrowed down the options to 18 alternatives for further evaluation. In July 1998, after these alternatives were studied with visits to the facilities and laboratories involved in their development and use, the team further narrowed the selection to four alternatives. The Westinghouse Systems Engineering Team then performed a risk analysis and evaluation of the four alternatives. Using as criteria cost, technical maturity, risk management, safety, professional judgment of the team, historical experience, and the needs of the Savannah River Site and the DOE complex, the team recommended a preferred alternative and a secondary option.

In addition to the Westinghouse Systems Engineering Team, other teams were formed to assist in the process (app. IV provides additional information on the various teams):

- The Independent Project Evaluation Team (Independent Review Team), established by DOE headquarters, was to independently provide oversight of the process being followed in selecting the alternative.
- The Savannah River Review Team, established by DOE Savannah River, was to oversee the Westinghouse Systems Engineering Team.
- The Westinghouse Review Panel Team, established by Westinghouse, was to provide oversight and input on the approach and decision-making process for the final selection of the preferred alternatives. It has concurred with the Westinghouse Systems Engineering Team's recommendation.

Westinghouse Recommended Two Alternatives

On October 29, 1998, Westinghouse recommended the use of small tank precipitation. This process is similar to the ITP process. It uses the same chemical to cause the precipitation of the high-level waste constituents, and as a result, benzene is generated. However, several differences exist. For example, two 15,000-gallon tanks would be used to treat the high-level waste instead of two 1.3 million-gallon tanks, allowing for the process to be completed in about 24 hours rather than taking weeks and thus reducing the time during which benzene could build up in the tanks. In addition, the tanks would be made of stainless steel and cooled to reduce chemical volatility and benzene production. With these features, Westinghouse believes that the process can be used safely and effectively.

In its final report, the Westinghouse Systems Engineering Team noted that while the small tank precipitation process did not have the lowest life-cycle cost, it had the lowest project construction cost, the highest scientific maturity, and the most manageable risk and was judged to have the highest likelihood of success.[16] In addition, the report noted that the safety concerns caused by the generation of flammable benzene were considered and were addressed.

As a backup technology, the Westinghouse Systems Engineering Team selected crystalline silicotitanate non-elutable ion exchange. This process

[16]Final Report, High-Level Waste Salt Disposition Systems Engineering Team, Westinghouse, RP-98-00170 (Dec. 1998).

uses a crystalline silicotitanate resin to remove the cesium and monosodium titanate to remove the strontium, plutonium, and uranium in the liquid waste. Ion exchange has been used at DOE's Hanford and West Valley sites. However, the process recommended for Savannah River would use a different type of resin to cause the separation of the high-level waste. Crystalline silicotitanate was developed by Sandia National Laboratory and has been demonstrated on a small scale at Oak Ridge National Laboratory. It was selected as the second option because of its costs, its scientific maturity, and the opportunity for recovery from process performance problems.

The Savannah River Review Team evaluated the recommendations offered by Westinghouse. The team concluded that the information evaluated in the selection process and the resulting conclusions were not sufficiently discriminating to select a preferred alternative. The team recommended that additional research and development activities be undertaken to address the technical uncertainties associated with the ion exchange and small tank precipitation technologies. In addition, the team concluded that the option of direct disposal in grout should not be eliminated from consideration because it provides a way to significantly reduce construction and operating costs and the team had high confidence in its technology, safety, and technical feasibility. As a result, the Savannah River Review Team recommended actions be initiated to identify and resolve the potential regulatory, public, and legal risks and uncertainties associated with this option. Table 1 compares the costs and schedules for the small tank precipitation, ion exchange, and grout processes.[17]

[17]High-Level Waste Salt Disposition Systems Engineering Team. Dollars presented are escalated for inflation.

Table 1: Cost and Schedule Data for Westinghouse's Recommended Alternatives

	Small tank precipitation	Ion exchange	Disposal in grout
Project capital cost	$751 million	$843 million	$691 million
Other project costs	$417 million	$463 million	$300 million
Estimated life-cycle cost	$3,440 million	$3,081 million	$2,335 million
Estimated plant start-up	May 2006	March 2007	March 2006
Estimated plant start-up, with contingency	May 2010	January 2012	June 2015
Baseline date for tank emptying	October 2020	March 2020	April 2018
Date for tank emptying, with contingency	July 2024	February 2025	April 2028

The Independent Review Team established by DOE headquarters found that both the small tank precipitation and ion exchange alternatives are technically feasible and should meet all of Savannah River's high-level waste requirements. The team, using the same evidence and qualitative selection criteria that the Westinghouse Systems Engineering Team used, also found that ion exchange could have been selected as the preferred alternative. The Independent Review Team agreed that direct disposal in grout should be eliminated as an alternative because of large uncertainties involving institutional and regulatory issues.[18] The Independent Review Team recommended that (1) all essential research and development activities be completed for both alternatives, (2) quantitative criteria be formulated and applied at the end of the research and development activities to choose the primary alternative, and (3) a conceptual design phase be initiated but complete only those activities common to both alternatives until the primary alternative is chosen.

The Independent Review Team disagreed with the Westinghouse Systems Engineering Team's inclusion of $557 million in the cost of the ion exchange option to operate an incinerator over the life of the project. The Independent Review Team noted that the incinerator is not necessary for ion exchange and that excluding its cost would, over the life of the project, make ion exchange over $1 billion less expensive than the small tank

[18] The Independent Review Team noted that direct disposal in grout would require a full environmental impact statement be done. In addition, the team concluded that the grout containing the cesium would need to be reclassified by the Nuclear Regulatory Commission as incidental waste from high-level waste, which could require many years to complete. In commenting on a draft of this report, DOE stated that an environmental impact statement is under way considering all three alternatives. In addition, DOE commented that it, rather than the Nuclear Regulatory Commission, will make the incidental waste determination since this activity is covered by the Atomic Energy Act.

process. Westinghouse officials told us that they disagree and that the incinerator costs should be included in the cost of all options. They said that the incinerator is already constructed and will be operated regardless of the option selected. In addition, the officials told us that the benzene produced by the small tank process would be used as fuel for the incinerator, reducing the need to purchase fuel.

DOE Savannah River plans to conduct additional research and testing to further evaluate the technical, regulatory, and public acceptance risks associated with the three alternatives. (See app. V for information on the planned research, testing, and other activities to be conducted before a selection decision is made.) Because the three alternatives constitute a change in the previously planned operations, a supplemental environmental impact statement will be prepared to determine if a proposed action is (1) compatible with existing regulatory requirements, (2) acceptable to regulatory agencies, and (3) acceptable to the general public. DOE Savannah River is also studying ways to maximize the site's existing storage tank space to accommodate any of the three alternatives. DOE plans to complete the research and testing activities necessary to identify a preferred alternative by September 30, 1999. DOE headquarters will make the final decision on the preferred alternative and expects a record of decision document to be completed by mid-2000.

Conclusions

A number of factors contributed to the delays and cost increases of the in-tank precipitation project. In our view, among the most important were ineffective management and oversight. This project was not handled the way a high-risk, first-of-a-kind construction project should be, and as a result, the associated program structures and project designs were not adequate. Allowing the project to be funded with operating funds rather than making it a capital line item contributed to this situation because it limited the visibility of the project. Additionally, while the Department of Energy's award fee process noted numerous significant deficiencies on the part of the contractor, there is no evidence that the deficiencies affected the fees until 1998.

Another contributing factor was the lack of adequate early testing and a complete understanding of the in-tank precipitation process. In 1983, when the first test was conducted, benzene was produced in amounts that went off the scale of the tank's instruments. However, the test was viewed as a success because the high-level waste was separated from the solution. Even though we, the Red Team, and others raised concerns, the

Department of Energy and the contractor assumed they knew the reason for the benzene problem and thought they could work out a solution, so they proceeded. Unfortunately, the testing that was done did not correctly identify the specific cause of the excess benzene nor were large-scale tests attempted again before Westinghouse started up the facility in 1995.

Since the project's suspension, the Department and Westinghouse have taken steps that, if fully implemented, should better ensure a successful alternative. For example, the Department and Westinghouse have identified and evaluated numerous alternatives to the in-tank precipitation process. Independent review processes are being used to consider alternatives as well as to examine the selection process being used.

Agency Comments

We provided a draft of this report to the Department of Energy for its review and comment, and the Department provided its comments in a letter and three enclosures. The letter and enclosure I, which contain the Department's overall comments and a historical and technical perspective on the in-tank precipitation project, are included in this report as appendix VI. DOE's enclosures II and III, which are not included in this report, contain more detailed comments that we incorporated into the report as appropriate.

DOE recognized that weaknesses within the Department and on the part of the contractor contributed to the failure of the in-tank precipitation process. Moreover, DOE stated that it recognized that there were management and oversight issues identified that were not adequately addressed in a timely fashion. DOE also pointed out two other reasons for the difficulty with the in-tank precipitation project: (1) The project was attempting to solve a very challenging technical problem in that no proven technologies were available for the Savannah River high-level waste stream, and (2) the project was implemented at a time of rapidly changing standards as the DOE complex made the transition from chemical to nuclear safety standards. We agree that the two factors that DOE cited could have contributed to the delays and cost growth. For example, our report discusses the technical challenges that DOE and the contractor faced and identifies the changing standards as a reason for some of the delays. While these factors contributed to the delays and cost growth, the weaknesses in management and oversight were the primary factor.

DOE also stated that it has taken a number of positive steps in the past 18 months to ensure that a safe, economical, and high-confidence alternative is successfully implemented to treat the Savannah River Site's tank waste. Examples the Department cited include (1) the use of a disciplined systems engineering approach in the selection of final alternatives; (2) the use by both headquarters and Savannah River of independent review teams to provide oversight feedback directly to senior management; (3) the use of pilot-scale demonstrations to validate technology and engineering; (4) a higher level of safety awareness for all aspects of activities at Savannah River through the implementation of DOE's Functions, Responsibilities, and Authorities Manual; and (5) the application of lessons learned not only to project management but also to high-level waste processing across DOE's complex. This report discusses many of the activities that DOE identified. While DOE has taken a number of actions that, if fully implemented, should better ensure a successful alternative will be found, it will be many months before the selection process is complete and the alternative selected is ultimately built. Until that time, it will not be known whether these activities have been sufficient to achieve the desired results.

Scope and Methodology

To examine the factors for the ITP project's delays and cost growth, we examined various internal and external reports about ITP and the high-level waste cleanup process. In addition, we interviewed DOE and contractor officials involved with the project at the Savannah River Site in South Carolina and officials at DOE headquarters in Washington, D.C. We also discussed the issues with officials of the Defense Nuclear Facilities Safety Board and DOE's Office of Inspector General and with the University of Florida professor who was involved with ITP testing.

To determine the effect of the ITP project's suspension on the Savannah River Site's cleanup plans and costs, we examined the site's cleanup plans prior to the suspension and afterwards. We also interviewed DOE and contractor officials to get their views on any potential impact that the suspension may have on the cleanup program.

To gather information on DOE's plans for developing an alternative technology, we met with the leader of the Westinghouse Systems Engineering Team. We also reviewed the team's final report and the supporting documents generated by the team. We discussed the final selection with DOE officials at the Savannah River Site and reviewed the final report completed by DOE headquarters' Independent Review Team.

We conducted our work from April 1998 through April 1999 in accordance with generally accepted government auditing standards.

As arranged with your office, we plan no further distribution of this report until 15 days after the date of this letter unless you publicly announce the contents earlier. At that time, we will send copies to the Honorable Bill Richardson, Secretary of Energy; the Honorable Jacob Lew, Director, Office of Management and Budget; and other interested parties. We will make copies available to others on request.

If you or your staff have any questions about this report, please contact me at (202) 512-3841. Major contributors to this report were Gene M. Barnes, Gary Malavenda, and Glen Trochelman.

Sincerely yours,

(Ms.) Gary L. Jones
Associate Director, Energy,
Resources, and Science Issues

Contents

Tables

Abbreviations

CST	crystalline silicotitanate
DOE	Department of Energy
GAO	General Accounting Office
ITP	in-tank precipitation

Cost of the In-Tank Precipitation Project and Its Associated Facilities

Dollars in thousands

Facility	Total estimated construction costs	Other project costs[a]	Operating cost[b]	Total
In-tank precipitation	$157,096	$151,234	$18,800	$327,130
Late wash facility[c]	51,720	10,334	4,000	66,054
Salt process cell[d]	15,000	15,000	-	30,000
Organic waste storage tank[e]	4,000	1,000	-	5,000
Saltstone facility[f]	25,392	2,539	32,698	60,629
Total	$253,208	$180,107	$55,498	$488,813

[a]Other project costs include testing, training, and operational readiness reviews.

[b]Operating costs include the cost to run the facility after it became operational.

[c]This facility reduces the nitrite concentration of the precipitate from the in-tank precipitation (ITP) process. If not removed, nitrites could foul the Defense Waste Processing Facility's heat transfer surfaces and plug filters and instrumentation.

[d]This part of the Defense Waste Processing Facility prepares the precipitate to be fed to the melter.

[e]This tank stores benzene for recovery.

[f]This facility processes low-level radioactive liquid waste from the ITP facility. The waste remaining after the high-level precipitate has been removed is mixed with a blend of cement, fly ash, and blast furnace slag to form a grout. This grout is pumped into disposal vaults where it hardens into a nonhazardous form of waste.

Sources: The Department of Energy and Westinghouse Savannah River Corporation.

Examples of ITP Deficiencies Identified by the Award Fee Board

The following examples of deficiencies were identified in Department of Energy's (DOE) Award Fee Board reports covering the period from April 1, 1990, through March 31, 1998. The deficiencies are shown in chronological order.

April 1, 1990-September 30, 1990. Progress was slow in the establishment of detailed schedules and in commitment to meeting scheduled dates. Schedules were finally developed for the in-tank precipitation (ITP) project but lacked some required details for the operations readiness and start-up reviews.

October 1, 1990-March 31, 1991. Overall start-up management and planning is weak (in reference to efforts to meet or exceed commercial nuclear industry standards). The lack of overall planning and management of restart and start-up activities for ITP continues to further impose delays.

April 1, 1991-September 30, 1991. The contractor's performance in the ITP start-up activities fell far below expectations as evidenced by a lack of commitment to the continually revised schedules. Overall start-up management is weak for ITP; Westinghouse's commitment to schedule is lacking. The scheduled start-up for ITP was delayed during this period from April 1991 to early 1992. The schedule currently presented to DOE has several deficiencies, and it appears that start-up will be further delayed. DOE has identified concerns in training, testing, operations readiness review, design basis documentation, and the quality of the schedules. The management of ITP is a carryover concern from the last award fee period, and no improvements have been made. In fact, DOE's concern has heightened over this period. Immediate Westinghouse management attention is required to correct this problem. Westinghouse submitted an integrated plan for interim waste activities, but there is a concern that these schedules may not be effectively treated as a management tool. It appears that Westinghouse facility managers are not held accountable to these schedules.

October 1, 1991-March 31, 1992. Management attention was needed to ensure the inclusion of complete resource loading for the ITP schedules. ITP project work also experienced some problems with project costs. The culture change required to improve the conduct of operations sitewide has not been effectively emphasized by lower-level management to bring it to reality.

April 1, 1992-September 30, 1992. Westinghouse delayed initiation of the DOE operational readiness review for the ITP simulant testing phase because of major deficiencies in the ITP training program. Although this caused delays in the overall schedule, Westinghouse's decision to delay the operations readiness review probably avoided even more significant delays in the schedule had the training deficiencies not been resolved. The potential for ITP to experience considerable cost overruns was identified in April, and the revised budget remains undefined. Performance against planned work was not adequately monitored, technical documents had deficiencies indicating a lack of management attention, and performance of the waste removal program was poor because of the lack of basis and adequate planning for waste removal to support the Defense Waste Processing Facility.

October 1, 1992-March 31, 1993. The milestones for initiating radioactive operation of ITP and starting removal from one storage tank, Tank 41, were not met. This is evidence of continued poor planning and management of activities associated with ITP. An unanticipated criticality issue prevented the milestone to start the removal of waste from Tank 41 from being realized and has required new efforts to identify alternative feed sources for ITP. A number of prominent technical issues, such as the soils and geotechnical issue and the benzene stripper issue, continue to delay ITP start-up.

April 1, 1993-September 30, 1993. Major program milestones were not met for ITP. Poor budget management resulted in the curtailment of key activities late in the fiscal year. Because of poor implementation of the cost collection and maintenance system, Westinghouse reported a shortage of funding for important programs, including ITP, that would delay work. Westinghouse has not performed adequate staffing reviews. Engineering support for equipment and process problems at ITP has been poor. Weaknesses in the general management of the ITP project resulted in Westinghouse not being ready for facility start-up. The ITP start-up schedule revision has not been submitted, even though it has been known for several months that the October 20, 1993, operations readiness review date was unachievable. A realistic date for being ready to start the operations readiness review has not yet been determined. Several other plant modifications that remain to be completed could further delay the schedule.

April 1, 1994-September 30, 1994. Cost and schedule overruns incurred at ITP were not adequately managed to minimize the impact (i.e., forecasting was not timely, effective workarounds were not proposed). Senior Westinghouse management effort on cost reduction and productivity initiatives appears to be diminishing, is not integrated, and lacks creativity and innovation. Inadequate planning resulted in items being identified by the ITP readiness self-assessment that contributed to cost overruns. ITP operators have not been adequately trained prior to conducting drills on emergency operating procedures. Westinghouse did not take the actions necessary to prevent procedure development from becoming a critical path to the operations readiness review, and this has contributed to a delay in the start of the Westinghouse operations readiness review and potentially in the start of operations. Management of the readiness self-assessment process following initial field assessments was not effective in supporting the schedule. Finding closure was not well organized, and management did not readily make a clear, defensible declaration of readiness to start the Westinghouse operations readiness review. Cost overruns on ITP required downturns in other high-level waste programs during the last half of fiscal year 1994. Downturn actions were initiated with little or no communication with DOE counterparts. Consequently, some items that were thought to be priority tasks were eliminated without DOE's concurrence. Management attention needs to be focused on cost control. Accountability for maintaining cost control needs to be established as a management priority. Cost reduction and productivity efforts have diminished from what was a fairly aggressive program at the beginning of the period. Proposed reductions to meet fiscal year 1995 budget reduction goals lacked innovation and were not aggressive. Most efforts in this area are driven by DOE's initiatives.

October 1, 1994-May 31, 1995. ITP scheduling remains a significant weakness in that it is not always resource-loaded properly, resulting in missed milestones (e.g., the radiological operations start date is projected to slip). The commitment date for ITP operating safety requirement implementation was missed, and a revised commitment date was not provided. The ITP schedule for completing the activities that are required to start operations in July 1995 is projected to slip until September 1995 or later. Schedule deficiencies continue at ITP in that the schedules are not resource-loaded to project realistic and achievable milestone dates in all cases. Improvement in recovery planning is needed at ITP to minimize schedule slippage. ITP lacked aggressive effort to resolve readiness self-assessment and Westinghouse operations readiness review findings.

October 1, 1995-March 31, 1996. Effective management of critical engineering issues, project activities, and technology development demonstrations at ITP and the tank farms do not meet DOE's expectations in that they are not timely or properly resource-loaded to meet projected schedules. While the ITP benzene issue is a key issue, no single manager has been designated overall responsibility for resolving it. Schedule logic and supporting details are not identified. Implementation of the resolution program for the ITP benzene issue has been fragmented and is not integrated. In addition, the plan does not clearly identify the actions necessary to develop a bounding model for benzene generation and release for future operations. Conduct-of-operations issues were experienced that involved status control and conduct of special procedures. System status control involving special procedures resulted in the failure to maintain proper system status during the performance of a special procedure, which led to the inadvertent draining of an ITP filter. Communication failure had a further impact on this multifacility operation, causing uncoordinated efforts between a tank farm and ITP.

April 1, 1996-September 30, 1996. Progress at ITP toward the resolution of benzene problems for the precipitate feed to the Defense Waste Processing Facility was slow. There has been a lack of significant progress. Significant weaknesses exist in management's commitment to the resolution of technical issues, which resulted in inefficiencies in engineering services, schedule slippage, and ultimately rendered the high-level waste system inoperable for precipitate feed. Conduct of operations was less than expected at ITP. During the rating period, management and leadership did not pursue issues in an effective and integrated manner to resolve the benzene issue, even with emphasis from DOE. The lack of final needs input from the chemistry team and authorization basis is resulting in at-risk designs and schedules. What was projected as a $13 million safety upgrade in August 1996 has grown to an estimated $28.06 million. An additional concern is the number of lapses in conduct of operations. The contractor did not fully meet customer expectations in terms of bringing ITP into fully integrated operation because of the excessive benzene generated in the process. DOE's main concern from the last report—that is, poor project management resulting in schedule slippage and cost overruns--was not adequately addressed.

October 1, 1996-March 31, 1997. System status control execution at ITP is below DOE's expectations. The development of a path forward and progress toward the resolution of the ITP vapor space mixing issue (testing, computer modeling) were unacceptable in support of the ITP safety analysis report development. This issue was critical to the successful resolution of the Defense Nuclear Facilities Safety Board's

Recommendation 96-1 and to providing a defensible safety basis for resuming ITP processing. Attention by Westinghouse management is needed on the resolution of these issues. Several operational programs have not progressed as expected. During a January 1996 assessment at ITP, DOE staff identified numerous deficiencies with the system status files that resulted in a concern being issued. DOE staff again looked at the status files in October 1996, and although a noticeable improvement was evident, numerous deficiencies were still noted.

April 1, 1997-September 30, 1997. ITP had several events that indicated the need for increased personnel awareness of authorization basis requirements as well. Examples included the failure to recognize the requirements for slurry pump lockout during air-based operations and the use of inoperable equipment to satisfy limited condition for operation action items. While increased management attention resulted in significant improvements in many areas, improvement in the basic conduct of operations principles did not meet DOE's expectations for the ITP facilities. Of particular concern was the number of instances involving the failure to execute the fundamental principle of procedural compliance, and the number of minor equipment and programmatic deficiencies identified by DOE personnel that were not been previously identified by facility personnel and entered into corrective action processes.

October 1, 1997-March 31, 1998. At the ITP facility, high liquid level conductivity probes were positioned incorrectly, which failed to preserve assumptions from the safety analysis review. The distributed control system replacement work at the ITP control room was behind schedule because it was not well planned; the outage was disorganized without a predetermined path to complete, test, and exit the outage. Completion of ITP cost project physical work was slower than expected. Facility modifications were scheduled to be completed for a June 1997 start-up, then for an October 1997 start-up, and then for a January 1998 start-up. None of the dates were met.

Final Three Alternative Technologies

Alternative	Description
Small tank precipitation	This process involves adding sodium tetraphenylborate to remove cesium and monosodium titanate to remove strontium, plutonium, and uranium. Once these radioactive elements are removed, some additional processing is done. The solidified chemicals would then be sent to the Defense Waste Processing Facility for vitrification.
Crystalline silicotitanate ion exchange	A crystalline silicotitanate resin is used to remove cesium, and monosodium titanate is used to remove strontium, plutonium, and uranium. Once these radioactive elements are removed, some additional processing is done. The solidified chemicals would be sent to the Defense Waste Processing Facility for vitrification.
Direct disposal in grout	In this process, the cesium is not separated from the liquid waste. Instead, the salt solution is made directly into grout. Monosodium titanate would be used to remove strontium, plutonium, and uranium; after some additional processing, these radioactive elements would be sent to the Defense Waste Processing Facility for vitrification.

Source: Westinghouse Savannah River Corporation.

Characteristics of Teams Involved in Selecting Alternatives to the ITP Process

Review team	Members	Charter and timeframes
Westinghouse Systems Engineering Team	10 members (6 from Westinghouse, 3 from external contractors, and 1 from a university affiliate)	Formed in March 1998 by Westinghouse at DOE's direction. Determine the best path forward for processing liquid waste. Recommendations were provided to DOE Savannah River on October 29, 1998.
Savannah River Review Team	10 members (8 from DOE Savannah River's High-Level Waste Division and 2 from DOE Savannah River's Science and Technology Division)	Formed in March 1998 by DOE Savannah River. Provide technical oversight of the day-to-day activities of the Westinghouse Systems Engineering Team. Review System Engineering Team's results and provide a recommendation to the Manager of Savannah River. Final site team report issued on December 17, 1998.
Independent Review Team	11 members (2 from DOE, 8 from private firms, and 1 from a university affiliate)	Formed in June 1998 by DOE headquarters. Evaluate the process used by, and the results of, the Westinghouse Systems Engineering Team. Review the cost estimates developed by the Systems Engineering Team. Final review and assessment issued on December 26, 1998.
Westinghouse Review Panel Team	8 members (4 senior Westinghouse managers and 4 outside consultants)	Formed in June 1998 by Westinghouse. Provide oversight and input on the approach and the decision-making process for the final selection of the preferred alternative(s). Final report issued November 14, 1998.

Sources: Westinghouse Savannah River Corporation and the Department of Energy.

Research, Testing, and Other Activities Planned to Support the Final Technology Decision

DOE Savannah River and Westinghouse are planning to conduct additional research and testing before selecting the preferred alternative technology for processing the high-level waste at the Savannah River Site. The alternative technologies under consideration are small tank precipitation, ion exchange, and direct disposal in grout. DOE has developed a management plan that describes the actions necessary to (1) further evaluate the technical, regulatory, and public acceptance risks associated with the three alternatives; (2) initiate a supplemental environmental impact statement to address the alternatives; and (3) further develop the management strategies for the site's high-level waste tanks. In addition, a scope-of-work matrix has been prepared for each alternative that identifies such items as the testing and development activities to be undertaken, their costs, and the organizations involved.

Small Tank Precipitation

The purpose of the small tank precipitation experimental program outlined for fiscal year 1999 is to demonstrate that cesium and strontium can be removed from high-level radioactive waste using a continuous process. The precipitation of cesium by tetraphenylborate and the absorption of strontium with monosodium titanate have only been demonstrated on a batch scale. This proof-of-concept testing has several components, including the following:

- Proper sizing of the components for the continuous processing of the waste is to be determined. Tests are planned in a single continuous test unit to provide such data. These tests will develop data for cesium and strontium removal that will be used to operate the small-scale continuous integrated tests.
- The impact of washing the sodium from the precipitate is to be studied to ensure that the excess sodium tetraphenylborate that is added to the waste is removed before the precipitate is transferred to the Defense Waste Processing Facility. Tests that determine the dissolution rate will be used to answer this question.
- Tests are also to be conducted to demonstrate that the filtration required for continuous concentration and washing can be done using equipment that has been demonstrated on a batch basis.

The results of these tests will be used to provide input for a small-scale integrated test that will demonstrate the feasibility of a continuous small tank process. These tests will use simulated waste solutions. An integrated test using actual waste will be conducted to demonstrate that the simulated tests are representative of the actual expected performance of the small tank precipitation process. Testing will also examine the continuous stirred tanks and verify that the product from the small tank process is compatible with the Defense Waste Processing Facility's requirements. DOE estimates that it will spend about $2 million to conduct the research and testing on the small tank precipitation process.

Ion Exchange

One of the principal alternatives to ITP in the 1980s and early 1990s was a process referred to as resorcinol-formaldehyde ion exchange. In this process, originally developed at the Savannah River Site, a bed of resin-like material would capture cesium as waste solution passes over the resin. The resin, in this case resorcinol-formaldehyde, would then be washed to remove the cesium. DOE officials told us that while this process was a promising alternative, significant technical issues and potential costs were involved. For example, there were problems with the resin's swelling and shrinking, the instability of the resin in the presence of various chemicals and in the presence of radiation, the generation of gases, and a complex pretreatment that was required. In 1983, DOE's contractor estimated that the cost of using this technology was similar to the cost of ITP, but the need for and cost of additional research and development led to the selection of ITP. DOE officials said they continued working on this resin until 1993, when work was halted because of budget constraints. DOE was unable to provide an estimate of the costs associated with this development effort because it funded the activities with operating funds.

Crystalline silicotitanate (CST) ion exchange was invented by researchers at Texas A&M University and Sandia National Laboratory in 1992. CST ion exchange appeared to offer a number of advantages over other types of ion exchange. For example, it appeared to work on a wide variety of wastes. In 1993, as part of DOE's Office of Science and Technology programs, Sandia and a company, UOP, entered into a cooperative research and development agreement in which UOP was to develop CST in powder form and in an engineered form (beads, pellets, or granules) suitable for ion exchange use. It took UOP about 18 months to complete its efforts. In 1996, Oak Ridge National Laboratory began operating the Melton Valley demonstration project, which uses the CST ion exchange technology. Over an 8-month period, Oak Ridge processed more than 30,000 gallons of waste and removed more than 1,000 curies of cesium.[1] Oak Ridge plans to continue using the demonstration plant to separate the cesium from its tank waste. DOE estimates that about $25 million was spent developing and demonstrating the CST ion exchange process.

DOE Savannah River and Westinghouse have identified a number of uncertainties with the CST ion exchange process. The management plan identifies research and development to be conducted to address the following issues:

- the effect of the waste solution, pressure, and processing flow rates on CST capacity;
- gas generation within the ion exchange column and its effect on performance;
- heat generation by radiological decay of large accumulated quantities of cesium and its impact on CST's stability, waste steam, and heat removal;
- chemical stability during long-term exposure to heat and the process stream;
- CST's performance on actual Savannah River waste; and
- Defense Waste Processing Facility glass issues, including the effect of a component of CST (titanium) that may exceed the current glass limits and operational issues associated with hydrogen generation and potential foaming.

To conduct some of these tests, a bench-scale ion exchange column will be used on actual Savannah River waste. In addition, some tests have been conducted at Oak Ridge National Laboratory's demonstration plant that uses the CST ion exchange technology. About $2.5 million is expected to be spent conducting the ion exchange activities during fiscal year 1999.

Direct Disposal in Grout

The direct disposal in grout alternative is based on what DOE considers to be generally mature and viable technology. Testing is planned to address (1) the use of monosodium titanate, which is needed to ensure that the grout waste form does not exceed radioactive concentration limits, and (2) the leaching characteristics of the grout waste form and its physical characteristics and stability. Other physical properties of the waste form

[1]A curie is the amount of radioactivity in 1 gram of radium. DOE officials told us that the concentration of cesium in the Savannah River Site's waste is about 150 times that of the Oak Ridge waste that was processed.

will be tested to determine whether they meet DOE's requirements. For example, according to the management plan, the waste must exhibit higher resistance to cracking when compressed than a similar waste containing a much lower concentration of cesium.

DOE Savannah River will take additional actions to evaluate the regulatory, legal, and public acceptance risks associated with the direct disposal in grout alternative. These actions include the following:

- development of an "incidental waste" determination to support disposal of the cesium in grout;
- discussion and consultation with DOE headquarters' organizations;
- feedback discussions with the U.S. Environmental Protection Agency and the South Carolina Department of Heath, Environment, and Conservation; and
- feedback discussions with the Citizen's Advisory Board and the South Carolina Governor's Office.

Oversight and Final Selection

According to the management plan, the DOE Savannah River Review Team will provide technical oversight of Westinghouse's day-to-day activities, including attending meetings and discussions, reviewing test plans and engineering documents, and evaluating test results. The team will also review the final results and provide a recommendation to the DOE Savannah River Manager about which of the three alternative technologies should be used. The recommendation is to be based on a selection process that involves both quantitative and qualitative evaluations of the alternatives. For example, a level of confidence will be developed for each alternative in the areas of technical uncertainty, schedule and mission impacts, safety and environmental impacts, and regulator and public acceptance. An evaluation of life-cycle and project costs will be considered in comparing the alternatives and will be weighed against the levels of confidence.

The Independent Review Team organized by DOE headquarters is continuing to provide oversight to the Westinghouse and Savannah River activities. The team will conduct an assessment of the research and development plan, perform an analysis of its implementation, review test results, and offer advice and assistance on technical issues to Westinghouse and DOE Savannah River.

After the Savannah River Review Team makes its recommendation, the Savannah River Manager will consider it and provide a recommendation to DOE's Environmental Management office. Environmental Management, with input from the Independent Review Team, is to decide on the preferred alternative. Once authorization is given, conceptual design activities are to proceed. Detailed design is not to begin until the supplemental environmental impact statement process has confirmed the selection of the preferred alternative by designating it in the final supplemental environmental impact statement and the record of decision. DOE estimates that this may occur in mid-2000.

Comments From the Department of Energy

Department of Energy
Washington, DC 20585

April 22, 1999

Ms. Gary L. Jones
Associate Director, Energy, Resources, and Science Issues
U.S. General Accounting Office
Washington, D.C. 20548

Dear Ms. Jones:

Thank you for the opportunity to comment on your report entitled "Nuclear Waste: Process to Remove Radioactive Waste from Savannah River Tanks Fails to Work" (GAO/RECD-99-69), April 1999. Enclosed you will find the Department's historical and technical perspective on this issue (Enclosure I) and detailed comments on the draft report (Enclosures II and III).

The report attributes ineffectiveness of the contractor's management and the Department of Energy's oversight as the most serious factor contributing to the failures of the In-Tank Precipitation (ITP) project. The Department recognizes there were management and oversight issues identified that were not adequately addressed in a timely fashion; however, this factor was not the sole reason for the difficulty with the ITP project. Two key reasons not identified in the report that were major contributors to the delays and cost growth are: 1) the project was attempting to solve a very technically challenging problem where no proven technologies were available for the SR high-level waste stream; and 2) the project was implemented in a time of rapidly changing standards (from chemical to nuclear safety standards) in the DOE complex.

The Department recognizes that weaknesses within the Department and the contractor did contribute to the failure of the ITP process. As a direct result, the Department has taken a number of positive steps over the past 18 months to ensure that a safe, economical, and high-confidence alternative is successfully implemented to treat the salt waste at the Savannah River Site (SRS). Examples of such improvements are: the use of a disciplined systems engineering approach to the selection of final alternatives; the use by both Headquarters and SRS of Independent Review Teams to provide oversight feedback directly to senior management; use of pilot scale demonstrations to validate technology and engineering; a higher level of safety awareness for all aspects of activities at SRS through implementation of the DOE Office of Environmental Management (EM) Functions, Responsibilities and Authorities Manual (FRAM); and the application of lessons learned relative to not only project management but also high-level waste processing across the EM complex.

Printed with soy ink on recycled paper

Current plans to reach a safe, economical, high-confidence solution to this issue include implementation of these lessons learned and involve the preparation and public involvement in a Supplemental Environmental Impact Statement; the selection of a preferred alternative in September 1999; the final selection of the alternative via the Record of Decision in mid-FY2000; the continuing review by the Independent Review Teams; and the research and development and pilot scale testing program. These activities are designed to provide the necessary and sufficient information that will lead to a decision best suited to the SRS waste from both a safety and technical perspective.

The Department will continue to work diligently to ensure that we move forward in a deliberate and systematic method in the final selection and implementation of the alternative salt process. Ralph Erickson of my office is available to discuss our comments as needed and can be reached at (301) 903-7188.

Sincerely,

James M. Owendoff

James M. Owendoff
Acting Assistant Secretary
for Environmental Management

Enclosures

ENCLOSURE I

Historical and Technical Perspective on GAO Report "Nuclear Waste: Process to Remove Radioactive Waste from Savannah River Tanks Fails to Work" (GAO/RECD-99-69), March 1999

The HLW system has always been constrained by one prevailing issue: the task must be safely accomplished at the lowest possible cost, in a way that reduces the volume of glass that has to be produced to stabilize the 34 million gallons of liquid high-level radioactive waste stored in aging tanks at the Savannah River Site.

In the early 1980s, DOE and the operating contractor at SRS decided to stop building additional tanks to store the millions of gallons of radioactive waste generated by weapons production. It was appropriate to stabilize this waste to reduce the risk of continued storage of the liquid in the aging carbon steel tanks.

The decision was made to solidify the waste into an impermeable and immobile glass. This minimizes risk to the workers at SRS and the surrounding population as well as put the waste in a form acceptable for disposal in a mixed geologic repository. The initial proposal included a pair of chemical processing "canyon" facilities. One facility was a processing "canyon" that would house a large ion exchange facility that could separate the radioactive cesium and strontium from the remaining material. The other was a vitrification "canyon" used to convert the cesium strontium waste to glass, called the Defense Waste Processing Facility (DWPF). That plant is operating today and has safely solidified more than 600 canisters of high-level nuclear waste glass. Since the cesium and strontium makeup only about 10 percent of volume, a dramatic reduction in vitrified waste occurs, which reduces operating costs of the high-level waste system (especially DWPF) and disposal fees DOE would expend to have the waste disposed at the repository. When this project was proposed to Congress, the Department was directed to rethink the project to reduce the overall project cost.

The Department decided to proceed with the vitrification facility and seek a less expensive way to reduce the volume. Based on best engineering and safety judgement, the only other alternative available (in 1983) for the SRS high-level waste stream was a newly developed precipitation method called in-tank precipitation. This process was chosen because:

- It fit within the constraints of cost, schedule, and technology. All of the existing scientific data indicated a reasonable chance for success.
- The technical uncertainties were no greater than those inherent with ion exchange.
- The process could be performed in existing waste tanks, thereby substantially reducing the cost and eliminating the need to build a second expensive "canyon" facility.

The precipitation process was then tested in an existing tank and the results were very encouraging. Although some problems, such as benzene generation were identified, they all appeared to have reasonable engineering solutions. This was verified by outside experts such as the University of Florida. Throughout the developmental process, outside experts were used to verify the methods used and findings from studies done by the site.

Throughout the implementation of the In-Tank Precipitation process, the development of better ion exchange resins was closely tracked and evaluated by SRS. All of them were considered more expensive and had at least as much technical risk as ITP. It was not until late 1995 that scientists at Sandia National Laboratory developed a resin that appeared to be promising for SRS wastes. During this time period, DWPF had completed cold chemical runs and was advancing toward radioactive operations. This resin has technical risk and has never been used in large scale on waste similar to SRS waste; these issues are being examined as part of the ongoing evaluation at SRS before a preferred alternative(s) is selected for final development and implementation.

Ordering Information

The first copy of each GAO report and testimony is free. Additional copies are $2 each. Orders should be sent to the following address, accompanied by a check or money order made out to the Superintendent of Documents, when necessary, VISA and MasterCard credit cards are accepted, also.

Orders for 100 or more copies to be mailed to a single address are discounted 25 percent.

Orders by mail:

U.S. General Accounting Office
P.O. Box 37050
Washington, DC 20013

or visit:

Room 1100
700 4th St. NW (corner of 4th and G Sts. NW)
U.S. General Accounting Office
Washington, DC

Orders may also be placed by calling (202) 512-6000
or by using fax number (202) 512-6061, or TDD (202) 512-2537.

Each day, GAO issues a list of newly available reports and testimony. To receive facsimile copies of the daily list or any list from the past 30 days, please call (202) 512-6000 using a touchtone phone. A recorded menu will provide information on how to obtain these lists.

For information on how to access GAO reports on the INTERNET, send an e-mail message with “info” in the body to:

info@www.gao.gov

or visit GAO’s World Wide Web Home Page at:

http://www.gao.gov

PRINTED ON RECYCLED PAPER