

Evaluation of Nitrate and Nitrite Destruction/Separation Technologies

by

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**EVALUATION OF NITRATE AND NITRITE
DESTRUCTION/SEPARATION TECHNOLOGIES**

**Prepared for
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**Revision 0
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1.0 EXECUTIVE SUMMARY

This report describes and evaluates four types of nitrate and nitrite destruction and separation technologies that could be used to treat the aqueous, alkaline, nitrate-bearing mixed waste that is generated by the In-Tank Precipitation (ITP) process at the Savannah River Site (SRS). The technologies considered in this report include thermal, hydrothermal, chemical, and electrochemical technologies.

During the treatment of high-level tank wastes at the SRS, the ITP process generates large quantities of an aqueous, alkaline mixed waste that contains high-levels of sodium nitrate and nitrite. This waste stream is commonly referred to as the decontaminated salt solution.

The treatment plan for the decontaminated salt solution specifies that it will be stabilized in a pozzolonic substance (Saltstone) and disposed of in engineered land disposal units (vaults) at the SRS in strict accordance with the requirements of the Environmental Protection Agency (EPA) regulations codified under 40 CFR Part 141, Part 264 Subpart N, and Part 268, as well as the Nuclear Regulatory Commission (NRC) rules codified under 10 CFR Part 61. However, the high-levels of nitrate and nitrite in the decontaminated salt solution will be leachable in the solid Saltstone matrix. The operators of the SRS are concerned that the leaching of nitrates and nitrites will threaten groundwater at the final disposal site and significantly increase costs by necessitating disposal of the Saltstone in engineered structures (i.e., vaults).

To prevent groundwater contamination at the disposal site and reduce the costs of the engineered disposal site, the U.S. Department of Energy (DOE) has determined that it will be necessary to pretreat the decontaminated salt solution to destroy or separate the nitrates and nitrites prior to stabilization in Saltstone.

DOE has authorized the operators of the SRS to develop a pretreatment system for the nitrate-bearing, alkaline, low-level mixed wastes. In accordance with this mission, personnel at the SRS have been actively involved in the research and development of pretreatment alternatives for several years. Based on their work to date, the researchers have tentatively determined that the electrochemical process of denitration exhibits the most favorable combination of technical and economic benefits.

In this report, the technical and economic merits of the electrochemical process are presented and compared to those of competing thermal, hydrothermal, and chemical destruction technologies. The principal findings of this report are as follows:

- All of the technologies studied would require extensive development before a full-scale process for treating the decontaminated salt solution could be constructed and operated.
- The technical and economic feasibility of the nitrate to ammonia and ceramic (NAC), vitrification, and electrochemical processes are more attractive than the other alternatives investigated.

- More robust treatment technologies, such as plasma arc or vitrification, are more versatile than the electrochemical, hydrothermal, and NAC processes and offer the ability to treat additional waste streams.

The electrochemical reduction process has been extensively tested on SRS waste streams and is more mature in this application than the other technologies. Significant uncertainties remain in the development of all of the technologies investigated; however, the uncertainties associated with electrochemical reduction are much smaller than those associated with the other technologies.

2.0 DEFINITION OF THE PROBLEM

This document describes the results of an independent technical and economic feasibility study of several alternative technologies for destroying nitrates and nitrites in the decontaminated salt solution waste stream at the Savannah River Site (SRS). This waste stream is a low-level mixed waste that is one of a wide variety of nitrate- and nitrite-bearing aqueous mixed waste streams generated and stored at U.S. Department of Energy (DOE) facilities.

At the SRS, the primary source of nitrate-bearing aqueous waste is the In-Tank Precipitation (ITP) process, which is a pretreatment process for high-level tank wastes that are undergoing vitrification at the Defense Waste Processing Facility (DWPF). This nitrate-bearing waste stream, produced by the neutralization and precipitation of acidic high-level aqueous waste, is commonly referred to as the decontaminated salt solution.

The SRS stores approximately 130 million liters (34 million gallons) of high-level waste liquids. Pretreatment of this high-level waste is expected to generate approximately 92 million gallons of decontaminated salt solution over the next 20 to 25 years.^{1,2}

All DOE sites that store and generate aqueous low-level mixed wastes have been tasked with developing treatment plans for the stabilization and disposal of the wastes. Although the treatment plans vary from site to site, common elements in each involve two sequential steps:

- (1) stabilization or immobilization in a solid and
- (2) disposal in a secure land-based unit (landfill or vault).

Some of the stabilization and immobilization processes being considered include stabilization in a pozzolonic matrix (cementation), immobilization in a ceramic matrix, and vitrification to a glass matrix. The SRS has tentatively elected to stabilize the nitrate wastes in a pozzolonic matrix (Saltstone) and to dispose of the stabilized solid in on-site burial vaults.

¹Kapline Enterprises, Inc., "Aqueous Nitrate Waste Treatment: Technology Comparison, Cost/Benefit, and Market Analysis, DOE/OR 2013, January 1994.

²"High-level Waste Systems Plan," Revision 7 (u), HLW-OVP-96-0083, October 1996.

The presence of nitrates and nitrites in these wastes presents several problems in the context of the stabilization processes. These include:

- Reduced compressive strength of the final waste matrix
- Increased leachability of the final waste matrix due to high nitrate solubility
- Potential for unstable reactions with organic constituents during processing
- Generation of off-gases containing oxides of nitrogen (NO_x), ammonia, and hydrogen.

To effectively remedy the problems outlined above, the nitrate and nitrite in the waste must be either destroyed or separated from the liquid undergoing stabilization. Toward this objective, the operators of most DOE facilities, including the SRS, are considering some form of pretreatment to destroy or separate the nitrates and nitrites prior to the stabilization/immobilization step in the treatment process.

For several years, the Westinghouse Savannah River Company (WSRC) and other organizations have been researching treatment alternatives for the decontaminated salt solution, including biological, chemical reduction, electrochemical reduction, thermal, and hydrothermal processes. Based on this research, WSRC has tentatively elected to pretreat the decontaminated salt solution waste using electrochemical reduction to destroy the nitrates and nitrites and then solidify the remaining liquid in a special hydraulic cement (Saltstone).

WSRC would construct a new electrochemical pretreatment facility at the SRS to destroy the nitrates and nitrites and would use the existing Z-Area Saltstone Processing Facility to immobilize the pretreated wastes in a cement/fly ash/slag matrix. The Saltstone product would, in turn, be disposed of in concrete vaults at the SRS, as shown on Figure 2-1.

Currently, 34 million gallons of the high-level waste are stored at the SRS, mainly in underground tanks. In the course of pretreating the high-level waste for processing in the DWPF, the ITP process is expected to generate approximately 92 million gallons of decontaminated salt solution over the next 25 years. Consequently, the nitrate pretreatment plant to be constructed at the SRS will be required to process approximately 92 million gallons of the decontaminated salt solution waste stream during its operational life of approximately 25 years. The average processing rate will be approximately 4 million gallons per year (gpy).

Preconceptual engineering plans have been completed for a nominal 2 million gallon per year

(gpy) industrial-scale electrochemical denitration plant at the SRS.³ This preconceptual design was completed before the current version of the SRS high-level waste systems plan was published and was, therefore, based on a smaller system capacity. Some changes to the preconceptual design that are discussed in later sections of this report will be necessary to upgrade the electrochemical denitration system to meet the requirements spelled out in the current high-level waste systems plan.

At this time, WSRC is awaiting funding from DOE to proceed with the refinement of the conceptual and detailed engineering designs for the electrochemical denitration plant.

In June 1997, the RCS Corporation of Aiken, South Carolina, was contracted by WSRC to perform an independent literature review of the state-of-the-art in nitrate waste treatment. RCS was specifically tasked to review the following denitration technologies and report on their relative technical and economic merits:

- Thermal (calcination, steam reforming, vitrification, etc.)
- Hydrothermal
- Chemical
- Electrochemical

The results of this independent review are documented in this report.

3.0 REQUIREMENTS FOR PRETREATMENT TECHNOLOGIES

This section discusses the performance requirements for the pretreatment technologies, including chemical and radiological characteristics of the decontaminated salt solution, processing rates, and performance standards. The primary objective of the proposed pretreatment is to change the chemical characteristics of the waste so as to increase its stability and decrease its leachability following subsequent stabilization and final disposal. With this objective in mind and the causal relationship between leachability and nitrate content understood, the most important performance criterion discussed in this section is nitrate and nitrite destruction and removal efficiency. Technologies that cannot be shown to appreciably destroy or remove the nitrates and nitrites in the waste solution will not be considered viable, regardless of their abilities to satisfy other performance criteria.

³Bechtel Savannah River, Inc., "Preconceptual Design Study for the Salt Solution Electrochemical Denitration and Caustic Recovery Facility Phase I," WAD No. LIW2EE002, September 1996.

3.1 CHEMICAL AND RADIOLOGICAL CHARACTERISTICS OF DECONTAMINATED SALT SOLUTION

The pretreatment technology must be capable of accepting a feed stream that is aqueous, alkaline, and high in sodium and nitrates. The decontaminated salt solution is reported to be approximately 68% water by weight. It is alkaline, having a pH greater than 10. Although the waste stream has not yet been formally categorized, it will likely be considered a mixed waste bearing the EPA waste codes D002 (corrosivity) and D007 (toxic because of chromium content).

The waste contains high-levels of nitrate, nitrite, and hydroxide. The chemical composition of the waste is variable. The average composition is shown in Table 3-1.⁴

Table 3-1. Average Composition of Decontaminated Salt Solution	
Salt	Concentration (Molarity)
NaNO ₃	1.95
NaNO ₂	0.6
NaOH	1.33
NaAl(OH) ₄	0.31
Na ₂ CO ₃	0.16
Na ₂ SO ₄	0.14

Radioactive species that are present in the decontaminated salt solution include ⁹⁰strontium, ¹³⁷cesium, ⁹⁹technetium, and ¹⁰⁶ruthenium.

3.2 REQUIRED PROCESSING RATES

For the purposes of this study, it was assumed that all of the decontaminated salt solution in storage and that to be generated during the continuing life of the ITP process would be treated over a period not to exceed 25 years. As stated previously, the subject volume of waste is approximately 92 million gallons. The required processing rate is, therefore, approximately 4 million gpy.

3.3 PERFORMANCE STANDARDS

This section of the report describes the technical and procedural performance standards that are applicable to the proposed pretreatment system.

⁴ E-mail from David Hobbs (Savannah River Technology Center) to Mike Navetta (RCS Corporation), June 19, 1997.

3.3.1 Nitrate / Nitrite Destruction Efficiency

Although the decontaminated salt solution is a mixed waste falling under the purview of both the Atomic Energy Act (AEA) and the Resource Conservation and Recovery Act (RCRA), the nitrate and nitrite constituents of the waste are not specifically regulated by either the Nuclear Regulatory Commission (NRC) or the Environmental Protection Agency (EPA). Also, the South Carolina Department of Health and Environmental Control does not specifically regulate nitrate and nitrite constituents of mixed wastes. Any regulation of the nitrate or nitrite constituents is indirect, through the provisions of RCRA, dealing with reactivity of the waste matrix, and the Safe Drinking Water Act (SDWA) dealing with the protection of groundwater resources. Consequently, the environmental regulations applicable to the proposed pretreatment plant do not address nitrate or nitrite destruction efficiency.

In the case of this proposed facility, the required nitrate/nitrite destruction efficiency is determined by the waste acceptance criteria (WAC) and the performance standards for the downstream facilities (Saltstone processing and disposal vaults).

The upper tolerance limits for nitrate and nitrite documented in the WAC for the Saltstone process are 4.5 molar (M) and 1.0 M, respectively.⁵ These tolerance limits are above the average levels of nitrates and nitrites found in the decontaminated salt solution. Thus, there is no logical correlation between the required nitrate/nitrite destruction efficiency and the current waste acceptance criteria for the Saltstone facility.

The required nitrate/nitrite destruction efficiency, however, is correlated with the desired long-term performance of the solidified Saltstone waste form. Nitrates are highly soluble in water, and their presence in the Saltstone poses long-term risks to the groundwater underlying the disposal site. Reductions in nitrate and nitrite concentrations are desired to ensure that nitrates do not pose an unreasonable threat to groundwater in the vicinity of the Saltstone disposal vaults. For the purposes of this study, an arbitrary minimum nitrate and nitrite destruction efficiency of 90% was established.

3.3.2 Worker Protection, Radiological Safety, and Process Safety Standards

The following DOE Orders prescribe that the pretreatment system be designed and operated in a manner that minimizes the potential for process accidents and radiological and nonradiological hazards to personnel:

- 5480.1B, Environment, Safety, and Health program for DOE Operations

⁵Westinghouse Savannah River Company, "WSRC 1S Waste Acceptance Criteria Manual: Procedure 4.01, Acceptance Criteria for Aqueous Waste Sent to the Z-Area Saltstone Production Facility," Rev. No. 1, May 30, 1997.

- 5481.1B, Safety Analysis and Review System
- 6430.1, General Design Criteria Manual

These DOE Orders, in turn, reference hundreds of related codes and standards including those of the Occupational Safety and Health Administration (OSHA), the National Fire Protection Association (NFPA), the American National Standards Institute (ANSI), and other outside agencies.

3.3.3 Environmental Protection Standards

The applicable environmental protections standards are of three basic types: (1) groundwater protection, (2) air emissions, and (3) surface water releases. These standards are documented in the South Carolina Hazardous Waste Management Regulations, the South Carolina Air Pollution Regulations, the National Pollutant Discharge Elimination System (NPDES), the National Emission Standards for Hazardous Air Pollutants (NESHAPs), and RCRA.

The treatment system to be constructed at the SRS will probably require permits under the South Carolina hazardous waste and air pollution control regulations. However, based on recent experience at SRS with a vitrifier for mixed wastes, it may be possible to permit the treatment system by rule as a wastewater treatment unit, thereby bypassing the hazardous waste permit. This report assumes that hazardous waste and air pollution permits will be required.

The treatment system to be constructed at the SRS will be a line-item capital project and, as such, will be required to comply with the provisions of the National Environmental Policy Act (NEPA). At a minimum, an environmental assessment (EA) will be needed to address NEPA requirements. It is possible that a more rigorous environmental impact statement (EIS) could be required.

3.3.3.1 Groundwater Protection

The groundwater protection standards applicable to the proposed pretreatment system require that it be designed and operated in a manner that prevents the migration of hazardous constituents from the decontaminated salt solution into the underlying groundwater. Given that the pretreated waste will be solidified as Saltstone prior to final disposal in vaults, the groundwater protection standard also mandates that the product of pretreatment be amenable to the formulation of a stable and nonleaching Saltstone matrix.

Under the universal treatment standards of RCRA codified at 40 CFR 268.40 and 268.48, the decontaminated salt solution must be treated prior to land disposal to neutralize its corrosivity and reduce its leachability when tested using the Toxicity Characteristic Leaching Procedure (TCLP) to a level below 0.86 mg/L.

3.3.3.2 Air Protection

The proposed pretreatment plant will be subject to permitting under the Clean Air Act and will fall under the NESHAP regulations. The air permits for the facility will be required before construction begins and will probably specify monitoring and emission limits for uranium, particulate, NO_x, and other hazardous air pollutants.

3.3.3.3 Surface Water Protection

The applicable surface water protection standards will place limits on any releases of hazardous constituents from the pretreatment system to surface water. These limits may be implemented through the issuance of a new NPDES permit or the modification of an existing permit.

4.0 EXPERIENCE WITH NITRATE/NITRITE DESTRUCTION AND SEPARATION

Substantial research and development (R&D) into chemical, electrochemical, thermal, and hydrothermal processes has been conducted at various DOE facilities and universities over the past 15 years. With the exceptions of the engineering-scale electrochemical cells at the SRS and the New Waste Calcining Facility (NWCF) at the Idaho National Engineering Laboratory (INEL), this research has been restricted to the bench- and pilot-scale studies. Some research and engineering-scale operations have occurred in Europe and Japan. This domestic and international experience is summarized below.

Chemical Reduction

Domestic and international experience with chemical reduction technologies in treating radioactive aqueous wastes is very limited. For many years in Europe and Japan, chemical reduction using organic reductants has been used to treat acidic high-level wastes. The experience in Japan and Europe has shown, however, that the chemical reduction process using organic reductants does not destroy a high percentage of the nitrate in high-level waste and does not work in alkaline solutions.⁶

The Oak Ridge National Laboratory (ORNL) and Florida International University have been developing variations of chemical reduction, the nitrate to ammonia and ceramic (NAC) and nitrate to ammonia and glass (NAG) chemical reduction processes, for several years. Bench-scale testing with nitrate-bearing wastes has been completed. Scale-up to a pilot plant or engineering-scale system has not yet occurred and, given DOE's increasing reliance on privatization as a solution to environmental remediation and waste management, may not occur in the foreseeable future.

⁶Taylor, P.A, Kurath, D.E., "Evaluation of Nitrate Destruction Methods," DOE/MWIP-10, March 30, 1993.

Thermal

Calcining, one form of thermal processing, has been used to treat nitrate-bearing high-level wastes in a full-scale process at the Idaho Chemical Processing Plant (ICPP) near Idaho Falls, Idaho. The calcining process at the ICPP employs fluidized bed technology and has been used for over a decade to treat acidic low sodium wastes generated as raffinates during the reprocessing of spent nuclear fuel. This process, though well-established for these acidic low sodium wastes, will not work on the high sodium alkaline wastes at the SRS because the sodium will cause slagging and sintering in the fluidized bed.

Vitrification is another thermal process being extensively pursued throughout the DOE complex as the treatment choice for high-level tank wastes. The Defense Waste Processing Facility (DWPF) at the SRS is a full-scale vitrification system. The West Valley Demonstration Plant is another operational full-scale plant. A similar facility is planned for the Hanford site.

Under a fixed price contract, GTS Duratek has been treating low-level mixed wastes at the SRS for the past year using the largest vitrifier ever deployed into the field for radioactive application. The contract calls for GTS Duratek to treat 660,000 gallons of mixed waste for \$14 million. The first 5-metric-ton-per-day melter that GTS Duratek mobilized to the site experienced severe corrosion after one year and had to be replaced. GTS Duratek is in the process of bringing the replacement unit on-line. The melter at the SRS is the prototype for the 10-metric-ton-per-day unit that GTS Duratek intends to construct and operate at Hanford under its partnership with British Nuclear Fuels Limited (BNFL).⁷

Sandia National Laboratory (SNL) was involved in the development of steam reforming in the early 1990s. SNL's efforts were directed at the treatment of tank wastes at Hanford. According to SNL personnel involved in this work, the principle of the technology was demonstrated on the bench-scale. Process reliability at the pilot-scale could not be achieved, however. Due to these failures and funding shortages, SNL phased out its involvement in steam reforming several years ago.⁸ GTS Duratek has continued to work with steam reforming. GTS Duratek representatives stated that the technology is being used in Oak Ridge to process contaminated animal carcasses and at the Trojan nuclear plant for radioactive waste applications. GTS Duratek claims that the technology will be used to process various organics and solids at the INEL under subcontract to BNFL.⁹ Attempts to acquire more detailed information on the latest developments in steam reforming from cognizant GTS Duratek personnel were unsuccessful.

⁷Telephone communication between James M. Pope (GTS Duratek) and Mike Navetta (RCS), August 18, 1997.

⁸Telephone communication between Larry Bustard (Sandia National Laboratories) and Mike Navetta (RCS), July 31, 1997.

⁹Telephone communication between Andrew Smith (GTS Duratek) and Mike Navetta (RCS), August 7, 1997.

Plasma arc technology has been researched as an alternative for treating radioactive and mixed wastes by Westinghouse, Science Applications International Corporation (SAIC), and others. Westinghouse has treated small quantities of radioactive wastes using its plasma arc system beginning in the early 1990s. In the early and middle 1990s, SAIC constructed and operated a pilot plant at a location in California. Presently, ATG Incorporated is building a plasma arc treatment system for mixed wastes at the Hanford site.

Hydrothermal

Los Alamos National Laboratory (LANL) has been engaged for a decade in R&D related to the hydrothermal processing of nitrate wastes. The application of the process to the destruction of nitrates has been successfully tested on the bench-scale, but has not yet been demonstrated on the pilot-plant- or engineering-scales.

DOE sponsorship of hydrothermal research has diminished in recent years. Most of the R&D is occurring in the private and Department of Defense (DOD) sectors. Much of the ongoing research is aimed at the treatment of chemical warfare agents, with General Atomics Corporation and Foster Wheeler leading the development of competing variations of the technology. General Atomics has an operational pilot plant that is used for treatability and other studies at its facility in San Diego, California.¹⁰

Electrochemical

Throughout the 1990s, the SRS has been heavily involved in the development of the electrochemical process. Testing at the bench-scale and pilot-scale has been completed using both surrogate and actual waste streams. An engineering-scale test facility has also been constructed and operated at the SRS.

With the exceptions of the full-scale NWCF, the operational vitrifiers at the SRS, and the electrochemical research at the SRS, the R&D efforts described above have been limited to the bench- and pilot-scale. Full-scale plants using NAC, NAG, plasma, and hydrothermal technology have not yet been constructed and operated.

5.0 NITRATE AND NITRITE DESTRUCTION TECHNOLOGIES

This section presents technical descriptions of technologies that are being considered by operators of DOE facilities for the destruction of nitrates and nitrites in aqueous low-level mixed waste streams. The general categories of technologies presented are thermal, hydrothermal, chemical reduction, electrochemical reduction.

Preconceptual designs for several of the more promising technologies are also presented. To

¹⁰Telephone communication between Mike Spritzer (General Atomics) and Mike Navetta (RCS), July 30, 1997.

facilitate comparisons of the preconceptual designs for the various technologies, a common design basis was established (refer to Table 5-1).

Table 5-1. Preconceptual Design Basis, Denitration System for Decontaminated Salt Solution at the Savannah River Plant	
Design Parameter	Design Basis
System Availability	70%
System Capacity	4 million gallons per year
Nitrate in Feed	4.5 M
Nitrite in Feed	1.0 M
Nitrate/Nitrite Destruction Efficiency	90% minimum
Plant Operating Life	25 years

5.1 THERMAL PROCESSES

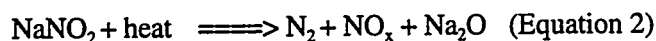
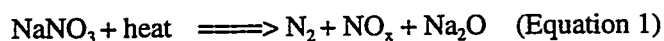
This section of the report discusses the technical and economic aspects of several thermal processes for denitrating aqueous low-level alkaline mixed waste streams.

5.1.1 Process Engineering Description

The basic stoichiometry of the thermal destruction of nitrates and nitrites is described in Section 5.1.1.1. Descriptions of preconceptual designs for several thermal systems for the SRS decontaminated salt solution waste stream are presented in Section 5.1.1.2.

5.1.1.1 Basic Process Chemistry

The thermal process of denitration involves the thermal decomposition of the nitrate and nitrite in the waste solution to nitrogen and oxides of nitrogen. The principal thermal decomposition reactions (stoichiometrically unbalanced) for sodium nitrate and sodium nitrite are as follows:



The relative amounts of nitrogen and NO_x that are formed are largely dependent on the treatment temperature. Sodium nitrate decomposes to nitrogen, NO_x , and sodium oxide in the range of 600 to 900 °C. Calciners that generally operate below 900 °C, therefore, tend to produce large amounts of NO_x . Conversely, plasma furnaces that operate above 2000 °C produce little NO_x .

5.1.1.2 SRS-Specific Configuration

Four types of thermal processors were investigated for adaptability to the treatment of the SRS decontaminated salt solution. These are fluidized bed calciner, plasma furnace, steam reforming, and vitrification.

Preconceptual designs for full-scale processes for thermally treating the decontaminated salt solution at the SRS have not been prepared. To assess the merits of each of the thermal technologies discussed above, RCS developed preconceptual flowsheets and performed crude equipment sizing. The RCS conceptual process descriptions and flowsheets for plants employing calciner, plasma furnace, steam reforming, and vitrification technologies are as follows.

Fluidized Bed Calciner

The preconceptual design discussed below is patterned after the design of the New Waste Calcining Facility (NWCF). The NWCF is an operational calciner for high-level mixed wastes located at the ICPP.

The primary components of a fluidized bed calciner system for low-level SRS mixed waste would be two feed holding tanks, the calciner vessel, the fluidizing system, and the off-gas treatment system. The process flowsheet would be as illustrated in Figure 5-1. It is estimated that an enclosed structure with approximately 40,000 square feet of floor space would be needed to house the calciner system.

In the fluidized bed calciner system, the decontaminated salt solution would be received from the ITP process and stored in two feed tanks. Blending would occur as necessary to prepare a relatively homogeneous waste feed stream for the calciner.

From these tanks, the decontaminated salt solution would be pumped into the bed section of the fluidized bed calciner vessel. The bed section would be a suspension of fine uniform particles, possibly dolomite or a similar substance, that would be fluidized by a stream of heated air (600 to 900 °C). As the waste solution enters the calciner vessel, the liquid would flash into a vapor and the nitrates and nitrites would decompose to nitrous oxide and nitrogen. Water vapor, nitrous oxide, and nitrogen would exit the vessel in the off-gas stream. Metals and radionuclides would preferentially partition to the bed material.

The off-gas would flow from the calciner vessel to a cyclone or other gas-solid separator where entrained bed material would be separated from the process off-gases. The process off-gases would then flow to a wet air pollution control system for NO_x abatement prior to discharge to the atmosphere.

Periodically, excess solids would be withdrawn from the calciner vessel and transferred to the calcined solids storage bins pending incorporation into the final waste form, which, at the SRS, would probably be Saltstone. Solids captured in the cyclone would be managed in the same manner.

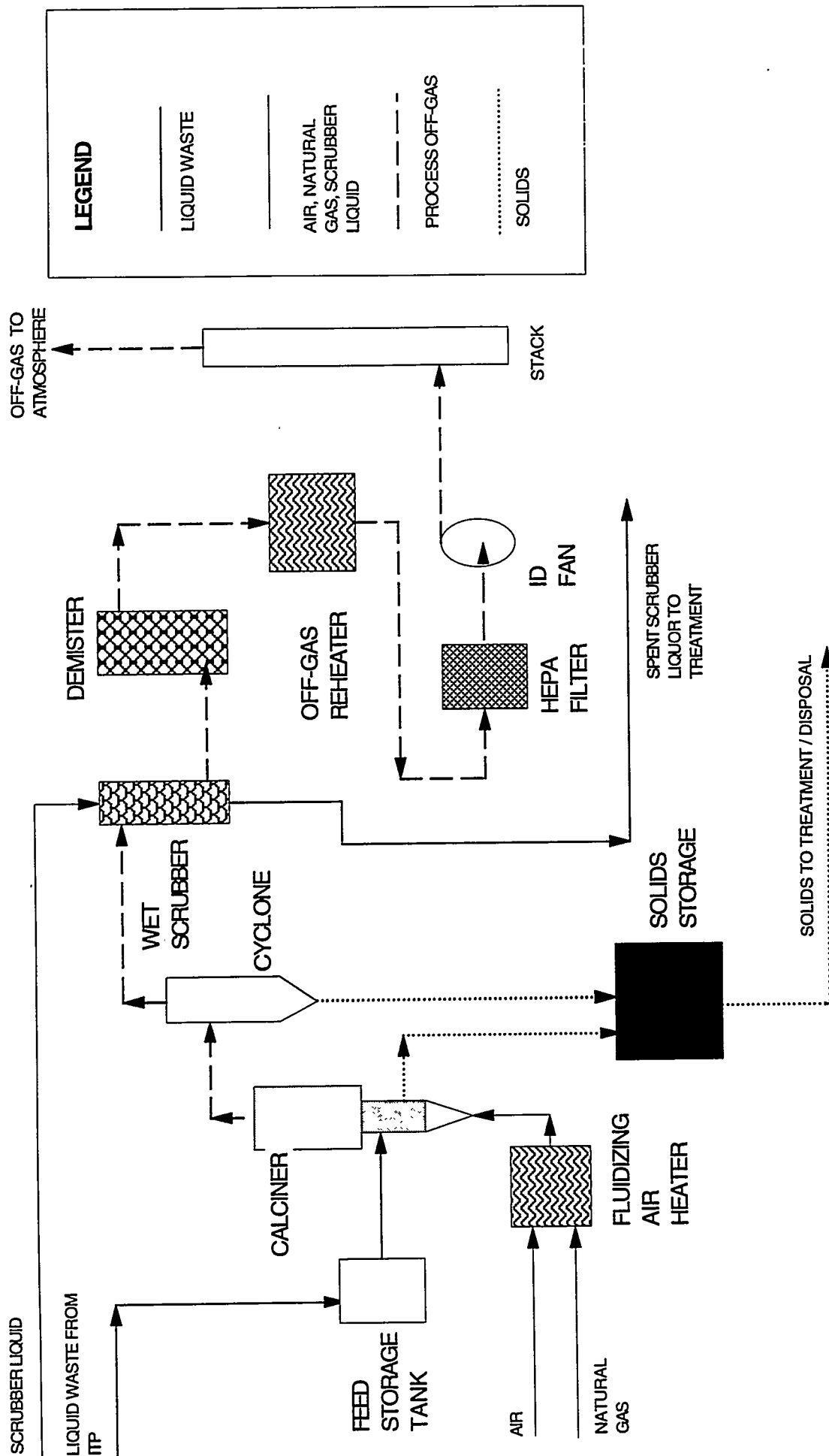


FIGURE 5-1. FLUIDIZED BED CALCINER PROCESS FLOWSHEET

The solids that would be removed from the calciner would be a mixture of granular and powdery fine calcium salt and metal oxide materials with diameters less than 0.2 microns and a bulk density around 1.4 g / cm³.¹¹ The solids should be readily amenable to further processing into a stable, nonleaching solid via the Saltstone, vitrifier, or other process.

Plasma Furnace

Plasma furnaces of many different configurations are being proposed for treating mixed wastes. Westinghouse has conducted testing on DOE mixed wastes with its prototype Marc 3 plasma arc furnace beginning in the early 1990s. A full-scale plasma arc system that is proposed to be constructed by ATG Incorporated near the Hanford site is currently undergoing RCRA permitting. The ATG system will be used to treat liquid and solid mixed wastes.

SAIC has constructed and operated a pilot plant based on its proprietary plasma hearth process (PHP) at a location in California as part of DOE's Technology Deployment Initiative. Proof-of-principle testing on this system has shown it to be capable of processing a wide range of heterogeneous solids (paper, wood, metal, etc.), low heating-value metals and glasses, high water-content inorganic sludges, high heat-value plastics (polyethylene, polyvinyl chloride, polypropylene, etc.), high chloride wastes (trichloroethane and others), and organic sludges.

The preconceptual design envisioned by RCS is an adaptation of SAIC's PHP.¹² The basic flowsheet is provided as Figure 5-2. The major equipment in the preconceptual design includes two agitated waste feed storage tanks, the plasma chamber, the plasma torch, the secondary chamber, and the air pollution control system. An enclosed structure with approximately 60,000 square feet would be needed to house the plasma process.

In the preconceptual design prepared by RCS, the waste feed would be pumped from the holding tanks and injected into the plasma chamber where it would be processed under slightly sub-stoichiometric conditions at temperatures between 1200 and 1400 °C. The inorganic material in the waste would melt at these temperatures and be collected in the fixed hearth crucible where it would separate into two molten phases--slag and metal. All of the process heat would be supplied by the plasma torch that would extend into the plasma chamber.

¹¹Westinghouse Idaho Nuclear Company, Inc., "Leaching Characteristics of Idaho Chemical Processing Plant Calcines," WINCO-1074, February 1990.

¹²Gillins, R.L., Poling, S.D., "Latest Developments in the Plasma Hearth Process Demonstration program for Treatment of Radioactive Mixed Waste," published in the proceedings of the 1996 International Conference on Incineration and Thermal Treatment Technologies.

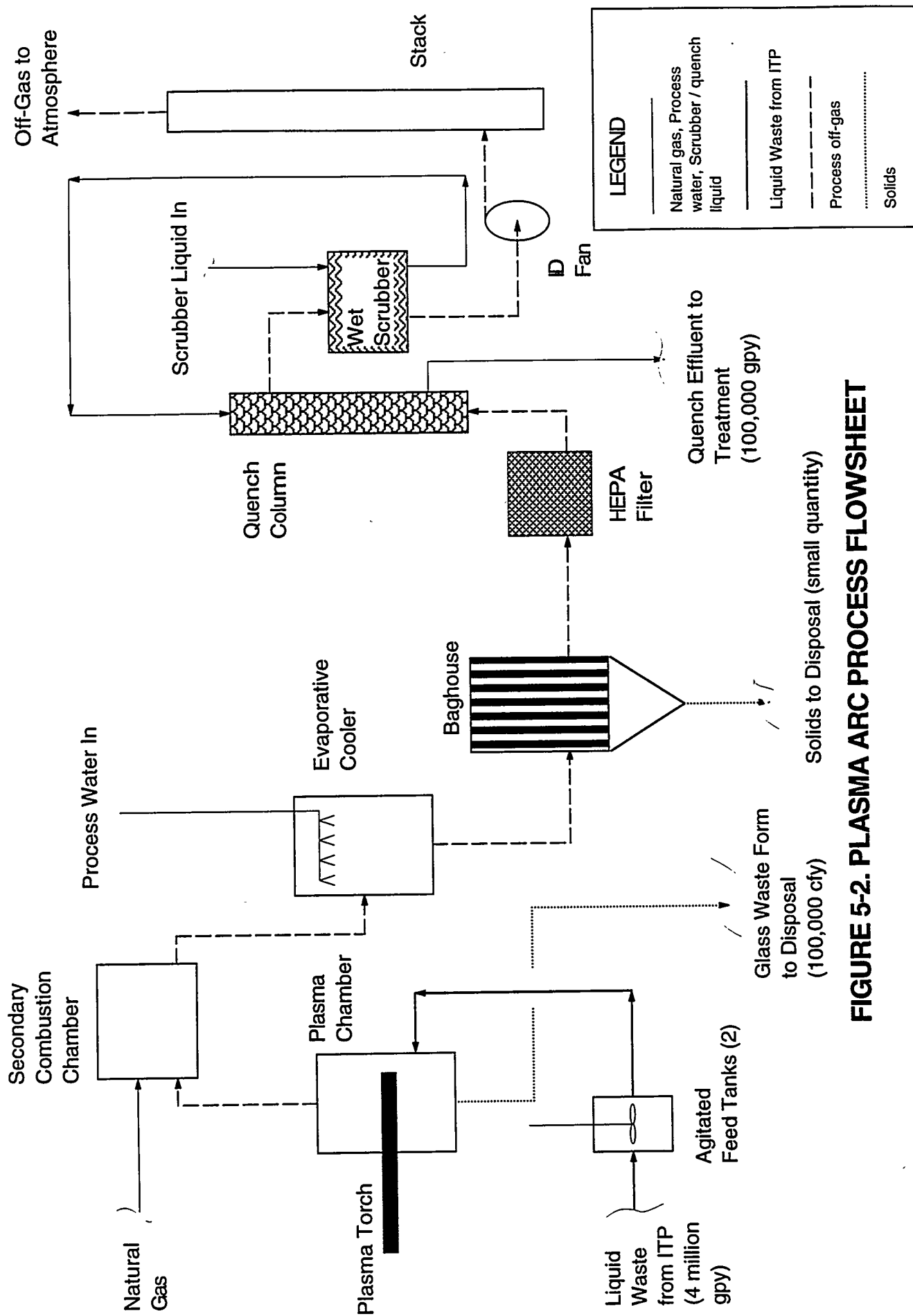


FIGURE 5-2. PLASMA ARC PROCESS FLOWSHEET

Actinides and oxidized metals would tend to partition to the slag phase.¹³ The slag and metal phases would be periodically removed from the crucible, poured into canisters, and allowed to cool and solidify to waste forms suitable for direct land disposal without further treatment.

Organics in the waste feed would be converted to carbon monoxide, carbon dioxide, and hydrogen, which would leave the plasma chamber in the off-gas. Other off-gas constituents would include nitrogen gas with traces of NO_x, HCL, H₂S, and methane.

The off-gas would be ducted to a gas-fired excess air chamber, where it would be retained at temperatures above 1000 °C for 2 seconds to ensure complete destruction of organic constituents. After leaving the secondary chamber, the off-gas would be processed through a water quench and wet scrubber system for particulate and NO_x control before release to the atmosphere. The wet scrubber would produce a liquid waste stream requiring treatment prior to disposal. This waste stream would be processed at the SRS Effluent Treatment Facility.

Steam Reforming

SNL and Synthetica Technologies investigated the use of steam reforming for the destruction of organics and nitrates in liquid mixed wastes for several years in the early 1990s. Since then, GTS Duratek has acquired the rights to the technology and has used it for radioactive waste applications at the ORNL and the Trojan nuclear plant. The principal components of a steam reforming system for decontaminated salt solution would include two feed tanks, an evaporator, a detoxifier reactor, and an air pollution control system. The process flowsheet would be as provided on Figure 5-3.

In the steam reforming process, the waste would be pumped from the feed storage tanks to the evaporator. In the evaporator, the waste would be contacted with live steam and evaporated at a temperature of approximately 300 °C under a slight vacuum.

The vaporized waste would then flow to the electrically heated detoxifier reactor, where it would be heated to approximately 1200 °C and retained for at least one second to affect the destruction of the nitrates and nitrites to NO_x and nitrogen gas.

A slip stream of the off-gas from the detoxifier reactor would be pulled into the air pollution control system to maintain a mass balance in the process. The balance of the off-gas (primarily steam) would be recirculated into the evaporator.

The process should produce little or no solid secondary waste streams. The primary secondary waste stream would be the liquid blowdown from the air pollution control system. This blowdown stream would require treatment prior to disposal, probably at the SRS Effluent Treatment Facility.

¹³Gillins, R.L., Poling S.D., "Latest Developments in the Plasma Hearth process Demonstration Program for Treatment of Radioactive Mixed Waste," from the proceedings of the 1996 International Conference on Incineration and Thermal Treatment Technologies.

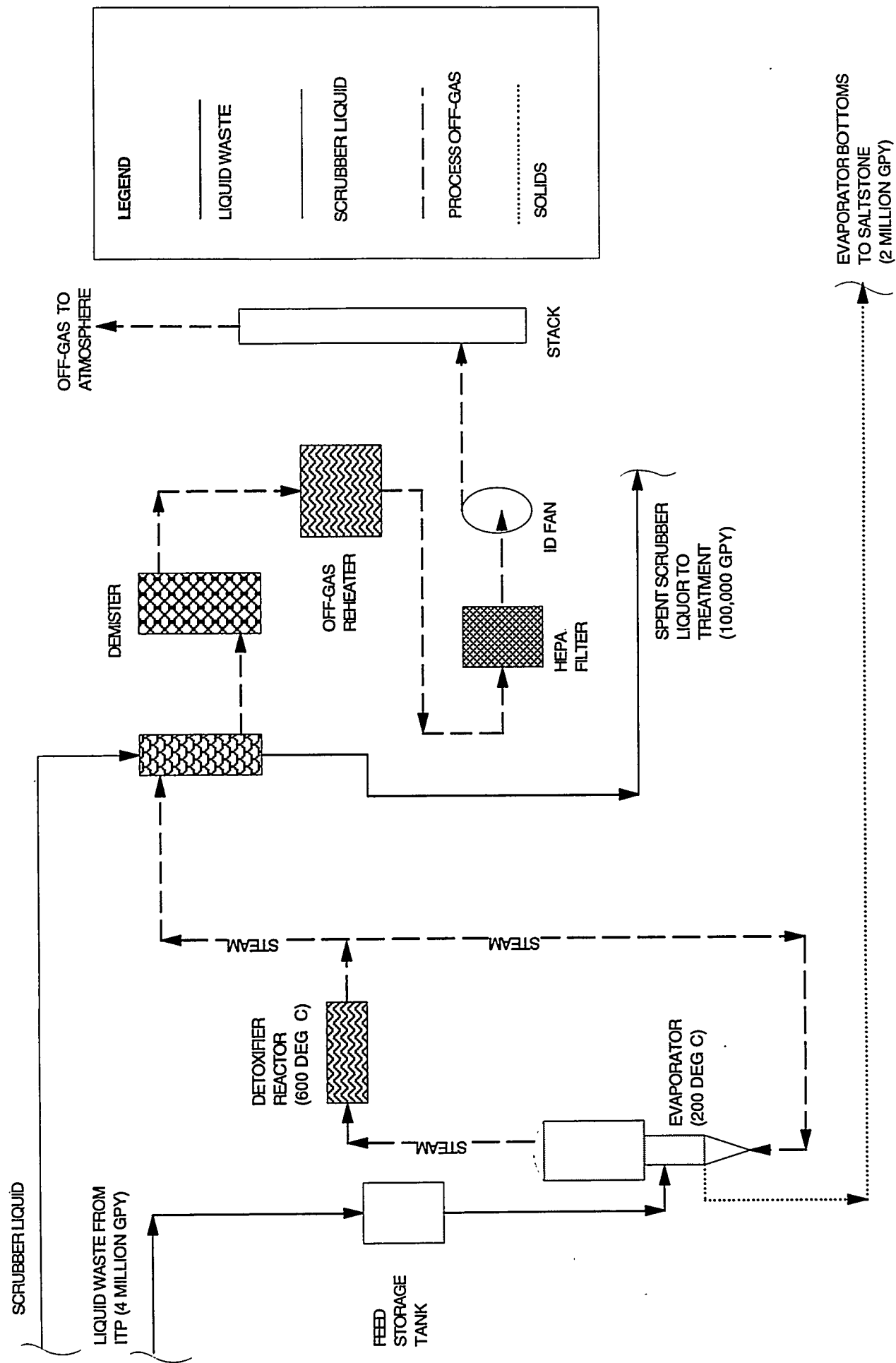


FIGURE 5-3. STEAM REFORMING PROCESS FLOWSHEET

Vitrification

Vitrification is well-established as a treatment process for radioactive wastes. The DWPF at the SRS is an operational high-level waste vitrification system. The GTS Duratek melter at the SRS has been used to vitrify low-level mixed waste for the past year.

The basic process flow diagram envisioned by RCS for the decontaminated salt solution is provided on Figure 5-4. The primary equipment includes two feed storage tanks, the vitrifier, material handling systems, and the off-gas treatment system¹⁴. An enclosed structure with approximately 60,000 square feet would be required to house the vitrification system.

In this preconceptual design, the decontaminated salt solution would be received from the ITP and held in two tanks. From these tanks, the waste would be pumped to the vitrifier, where it would be processed at a temperatures of approximately 1200 °C with the addition of silica and possibly urea. At these temperatures within the vitrifier the inorganics would become a molten glass or slag, organics would readily oxidize to carbon dioxide and water vapor, and nitrates and nitrites would thermally decompose to NO_x.

Unfortunately, the operating conditions of the vitrifier may be conducive to the oxidation of nitrogen to nitrous oxide and other forms of NO_x that would require treatment before being discharged to the atmosphere. Therefore, the process off-gas would be piped to an air pollution control system which would consist of a water quench, wet scrubber system, demisters, reheaters, and HEPA filters.

The molten slag would be decanted from the vitrifier, cooled and formed into spherical-shaped solids, and poured into drums. The glass would be a durable and nonleaching waste form that may be suitable for direct land disposal without further treatment. This waste form may be amenable to delisting under RCRA. If delisted, the waste form could be disposed of as low-level solid waste in an on-site landfill.

The wet scrubber would produce a liquid waste stream that would require treatment prior to disposal. This waste stream would be processed at the SRS Effluent Treatment Facility.

5.1.2 Technical Evaluation

The major advantages and disadvantages associated with the thermal technologies described in Section 5.1.1 are discussed in Sections 5.1.2.1 and 5.1.2.2, respectively. The abilities of the technologies to meet the performance standards discussed in Section 3.4 are summarized in Section 5.1.2.3. The maturity of the technology and outstanding research and development needs are discussed in Section 5.1.2.4.

¹⁴Bowman, B.W., Brandys, M.M., "Development of a Vitrification Process to Solidify Savannah River M Area Waste," presented at the April 1994 meeting of the American Ceramics Society.

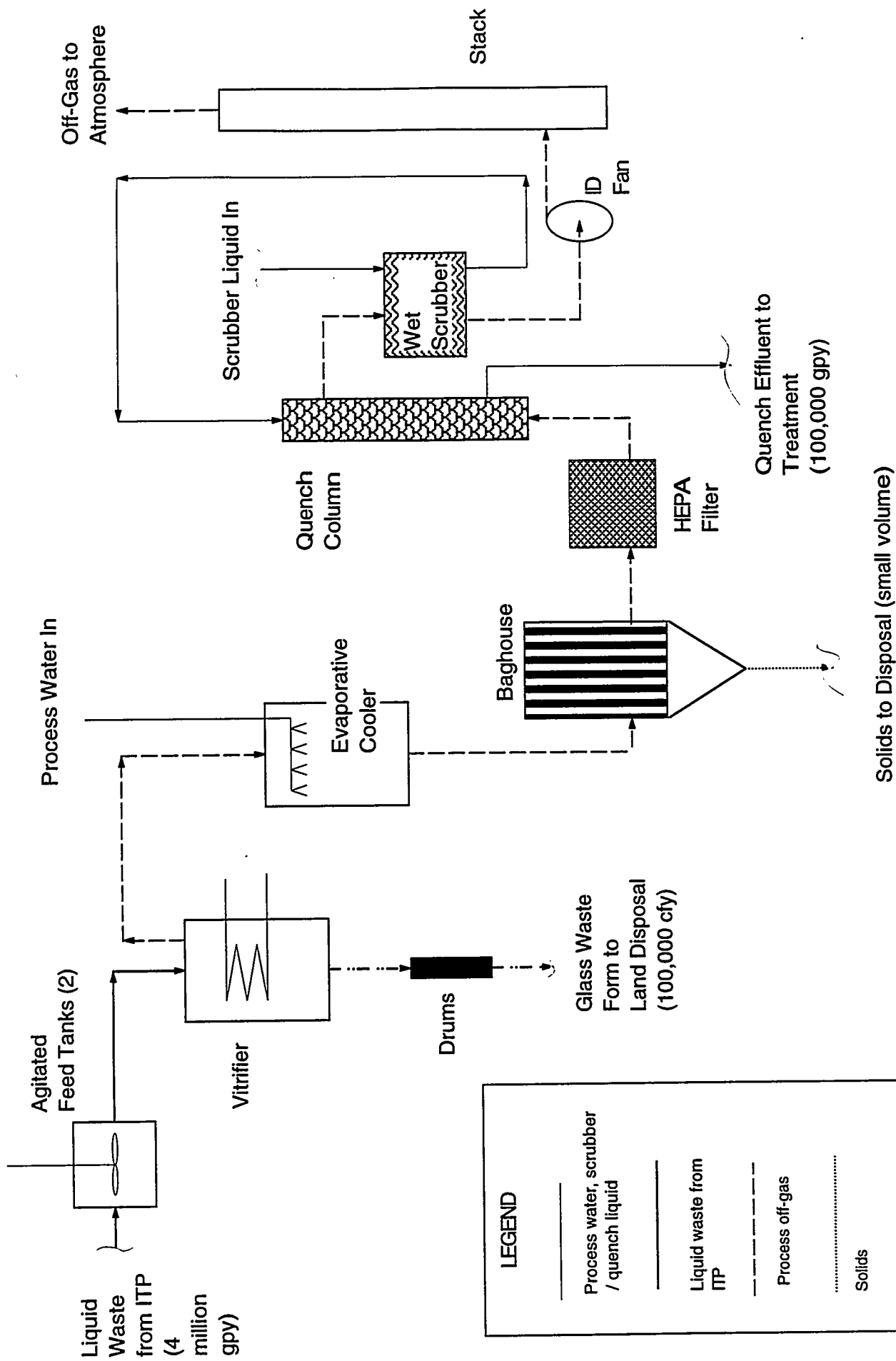


FIGURE 5-4. VITRIFICATION PROCESS FLOWSHEET

5.1.2.1 Major Advantages

The major advantages associated with the thermal technologies are summarized in Table 5-2.

5.1.2.2 Major Disadvantages

The major disadvantages associated with these technologies are described in Table 5-3.

Table 5-2. Advantages of Thermal Treatment Technologies	
Technology	Advantages
Fluidized Bed Calciner	<p>Significant volume reductions (over 70%) are possible.</p> <p>Process has been proven to work at full-scale on low sodium radioactive waste streams.</p> <p>Over 30 years of operational experience with calciners at the INEL.</p>
Plasma Arc Furnace	<p>Significant volume reductions (over 70%) are possible.</p> <p>Product slag is highly resistant to leaching, has a matrix durability similar to engineered glasses, and may be suitable for disposal without further treatment.</p> <p>Nitrates are converted primarily to nitrogen gas.¹⁵</p> <p>The performance of the system is relatively insensitive to waste composition, minimizing the need to conduct extensive waste characterization and segregation prior to treatment.¹⁶</p> <p>The treatment system is versatile and can accept a wide range of solid and liquid wastes.</p>

¹⁵Taylor, P.A., Kurath, D.E., "Evaluation of Nitrate Destruction Methods," DOE/MWIP-10, March 30, 1993, p. 19.

¹⁶Gillins, R.L., Poling, S.D., "Plasma Hearth Waste Treatment Demonstration for Radioactive Mixed Waste," presented at the 1994 Incineration Conference, May 1994.

Table 5-2. Advantages of Thermal Treatment Technologies	
Technology	Advantages
Steam Reforming	<p>Significant volume reductions (over 70%) are possible.</p> <p>The process can destroy organics in addition to nitrates and nitrites.</p>
Vitrification	<p>Significant volume reductions are possible.</p> <p>Product glass or slag may be suitable for disposal without further treatment.</p> <p>Process has been proven to work on other radioactive waste streams.</p> <p>Significant experience with vitrification systems at the SRS, including the DWPF and the GTS Duratek system.</p> <p>The treatment system is versatile and can accept a wide range of solid and liquid wastes.</p>

Table 5-3. Disadvantages of Thermal Treatment Technologies	
Technologies	Disadvantages
Fluidized Bed Calciner	<p>High capital and operating costs.</p> <p>Not useful when the waste contains alkali metals, including sodium. Alkali metals cause sintering of the fluidized solid media.</p> <p>Process off-gas contains high-levels of NO_x which would require treatment before release to the atmosphere.</p> <p>The solid process residue (calcine) would require further treatment prior to disposal.</p>

Table 5-3. Disadvantages of Thermal Treatment Technologies	
Technologies	Disadvantages
Plasma Arc Furnace	<p>High capital and operating costs.</p> <p>Requires extensive development work before a full-scale plant could be built.</p> <p>The economic utility of the plasma arc process chiefly applies to solid or sludge wastes that contain significant quantities of slagging materials.^{17, 18}</p> <p>The process would generate a liquid secondary waste requiring treatment prior to disposal.</p>
Steam Reforming	<p>Process off-gas contains high-levels of NO_x, which would require treatment before release to the atmosphere.</p> <p>The process would generate a liquid secondary waste requiring treatment prior to disposal.</p>
Vitrification	<p>High capital and operating costs.</p> <p>Process off-gas contains high-levels of NO_x, which would require treatment before release to the atmosphere.</p> <p>The process would generate a liquid secondary waste requiring treatment prior to disposal.</p>

5.1.2.3 Potential to Meet Performance Standards

The applicable performance standards were previously described in Section 3.4. Given its inability to process high sodium wastes, the application of fluidized bed calciner technology to the treatment of decontaminated salt solution was not considered to be technically feasible. The fluidized bed calciner technology was, therefore, omitted from further consideration. Evaluations of the remaining technologies' abilities to satisfy these performance standards follow.

¹⁷Science Applications International Corporation, "The Plasma Hearth Process," SAIC-95/1309, 1995.

¹⁸Personal Communication between Ray Geimar (SAIC) and Mike Navetta (RCS), August 11, 1997.

Nitrate/Nitrite Destruction and Separation Efficiency

The plasma arc, steam reforming, and vitrification processes are capable of meeting the performance standard for nitrate and nitrite destruction. Testing of these technologies at the bench-scale has shown that destruction efficiencies in excess of 99% can be achieved for nitrates and nitrites. These destruction efficiencies are greater than the performance criterion of 90%.

Worker Safety Standards

The plasma arc, steam reforming, and vitrification processes do not pose inordinate dangers to workers. The potential worker hazards associated with high equipment temperatures, hazardous off-gases, and radiation can be controlled using engineering and administrative controls.

Process Safety Standards

Facilities housing plasma arc, steam reforming, and vitrification processes would be classified as low or moderate hazard. Under DOE Orders 5480.5 and 5481.1B, detailed safety analysis reports would be required before start-up.

Nothing in the published testing history of these three technologies suggests that the process hazards cannot be effectively controlled with appropriate design features and operating procedures. On the contrary, the experience with vitrifiers at the SRS supports the conclusion that a thermal process using plasma arc, steam reforming, or vitrification technologies can be constructed and operated to meet or exceed all applicable process safety standards.

Radiological Safety Standards

The only full-scale mixed waste treatment system for nitrate-containing mixed wastes are the calciner at the ICPP, the DWPF at the SRS, and the Duratek vitrifier at the SRS. The calciner and the DWPF process high-level aqueous wastes and routinely operate within the limits of applicable radiological safety standards. The Duratek vitrifier processes low-level mixed wastes and has been shown to comply with all applicable radiological safety standards.

Given that the decontaminated salt solution contains much lower levels of radionuclides than the ICPP or DWPF waste feeds and comparable levels to the Duratek waste feed, it is reasonable to conclude that a thermal process based on plasma arc, steam reforming, or vitrification technology can be designed and operated to meet all applicable radiological safety standards, including as-low-as-reasonably-achievable (ALARA) considerations. Shielding may be required around certain process areas.

Environmental Standards

The three viable thermal processes are each capable of meeting all applicable environmental standards. The products of the thermal treatment of decontaminated salt solution will be stable nonleaching solid waste forms and off-gases. It may be possible to dispose of the waste forms

produced by plasma and vitrification systems without further treatment. The process off-gas may require treatment for particulate matter (PM), nitrous oxides, and hazardous air pollutants, but this can probably be accomplished using established technologies.

The treatment of process off-gases from all of the viable thermal technologies may produce wastewater that is not suitable for direct discharge to surface water. Such wastewater could probably be recycled into the waste feed stream. Thus, it is likely that this process will not produce wastewater requiring surface water discharge.

To comply with NEPA, it will be necessary to complete an EA for any thermal process. Given that the current socio-political climate is not favorable to thermal processing, an EIS may be required if one of these alternatives is selected for the denitration mission at SRS.

5.1.2.4 Technology Maturity and Research and Development Needs

Extensive research of the viable thermal treatment technologies has been ongoing at Los Alamos National Laboratory (LANL), INEL, and other sites for a number of years. Testing on mixed wastes that are similar to the decontaminated salt solution at the SRS has generally been limited to the bench-scale and pilot-scale. Extensive research and development work, including the construction and operation of pilot plants, would be necessary before full-scale plants using any of these technologies could be constructed and operated.

5.1.3 Evaluation of Costs

Section 5.1.3.1 discusses the capital costs of the electrochemical waste treatment system. Operations and maintenance (O&M) costs are discussed in Section 5.1.3.2. Decontamination and decommissioning (D&D) costs are estimated in Section 5.1.3.3. Life-cycle costs, computed on the basis of the capital, O&M, and D&D costs, are discussed in Section 5.1.3.4.

5.1.3.1 Capital Cost

Preliminary cost estimates for treatment systems capable of processing 4 million gpy of alkaline nitrate wastes are presented in Table 5-4. The estimated capital cost for these systems range from \$33.3 million (steam reforming) to \$46.6 million (plasma arc and vitrification).

5.1.3.2 Operations and Maintenance

Estimates of O&M costs are summarized in Table 5-5. To the extent possible, these estimates were developed using historical operating data and information obtained from equipment manufacturers. Wherever such information was not available, the Delphi method of cost estimating was used.

The Delphi method, developed during the late 1940s by the Rand Corporation, is useful for

Table 5-4. Thermal Treatment Systems Capital Costs (1997 Dollars)			
Plant Component	Technology		
	Plasma Arc	Steam Reforming	Vitrification
Storage Vessels ^a	170,000	170,000	170,000
Primary Process Chamber	3,500,000	1,650,000 ^b	5,000,000
Secondary Process Chamber	1,500,000	3,250,000 ^c	N/A
Off-Gas Treatment System (quench, wet scrubber, demister, reheater, HEPA filters)	2,500,000 ^d	2,000,000 ^e	2,500,000 ^d
Material Handling Systems (overhead cranes, conveyors, etc.)	2,000,000	750,000	2,000,000
Distributed Control System	1,500,000	1,500,000	1,500,000
Subtotal, Major Equipment	11,170,000	8,320,000	11,170,000
Miscellaneous Equipment @ 30% of Major Equipment	3,350,000	2,500,000	3,350,000
Equipment Installation @ 50% of Major Equipment	5,590,000	4,160,000	5,590,000
Facilities @ \$200 / ft ²	12,000,000	8,000,000	12,000,000
Subtotal, Installed Equipment and Facilities	32,110,000	22,980,000	32,110,000
Engineering @ 15%	4,820,000	3,450,000	4,820,000
Management Reserve @ 30%	9,630,000	6,890,000	9,630,000
TOTAL COST	46,560,000	33,320,000	46,560,000

**Table 5-4. Thermal Treatment Systems Capital Costs
(1997 Dollars)**

Notes:

- a Based on verbal quotations from John Wood Co., Valley Forge, PA, and Dal-Worth Fabrication, Inc., Grand Prairie, TX.
- b Cost of evaporator, scaled up from cost reported by SNL in "Steam Reforming," September 18, 1994.
- c Cost of detoxifier reactor, scaled up from cost reported by SNL in "Steam Reforming," September 18, 1994.
- d Quench, wet scrubber, demister, reheater, HEPA filter.
- e Wet scrubber, demister, reheater, HEPA filter.

**Table 5-5. Annual Operating and Maintenance Costs,
Thermal Treatment Systems**

O&M Item	Units	Unit Cost, \$	Extension, \$
Plasma Arc System			
Direct Labor, Operators (Fully Burdened)	12	60,000	720,000
Direct Labor, Supervisors (Fully Burdened)	4	75,000	300,000
Electricity ^{a,b}	120 million kWh	0.057	6,840,000
Other Utilities	1 lot	60,000	60,000
Maintenance @5% of Capital Cost	1 lot	2,300,000	2,300,000
TOTAL COST			10,220,000
Steam Reforming System			
Direct Labor, Operators (Fully Burdened)	8	60,000	480,000
Direct Labor, Supervisors (Fully Burdened)	4	75,000	300,000
Electricity ^{b,c}	21 million kWh	0.057	1,200,000
Other Utilities	1 lot	60,000	60,000

Table 5-5. Annual Operating and Maintenance Costs, Thermal Treatment Systems			
O&M Item	Units	Unit Cost, \$	Extension, \$
Maintenance @5% of Capital Cost	1 lot	1,670,000	1,480,000
TOTAL COST			3,520,00
Vitrification			
Direct Labor, Operators (Fully Burdened)	12	60,000	720,000
Direct Labor, Supervisors (Fully Burdened)	4	75,000	300,000
Electricity ^{b,d}	145.6 million kWh	0.057	8,300,000
Other Utilities	1 lot	60,000	60,000
Maintenance @5% of Capital Cost	1 lot	2,300,000	2,300,000
TOTAL COST			11,680,000
Notes a Assumes 30 kWh per gallon of waste feed. b Unit cost of \$0.057 per kWh, from telephone conversation with Tony Vovides, SRS, July 14, 1997. c Assumes 5.25 kWh per gallon of waste feed. d Assumes 36.4 kWh per gallon of waste feed.			

developing forecasts of manpower and other O&M costs in the absence of reliable work standards or historical data. The method uses an intermediary as a control center to guide the opinions of several subject experts toward convergence.

5.1.3.3 Decontamination and Decommissioning Costs

RCS estimates the D&D costs at the end of the operational life of each of these facilities to be \$500 per square foot of process facility. The plasma arc and vitrification systems would each require 60,000 square feet of structure. The estimated D&D costs for plasma and vitrification, therefore, would be \$30 million. The steam reforming system would require 40,000 square feet of structure. The associated D&D cost would be \$20 million.

5.1.3.4 Life-Cycle Costs

For the purpose of estimating the present value of the total life-cycle cost for the various thermal

systems, the following assumptions were made:

- Construction, O&M, and D&D costs will increase uniformly at 4% per year over the study period.
- RCRA and NEPA documentation will be prepared and all associated cost incurred in Year 0.
- Construction will begin in Year 0, and all capital costs will be incurred in that year.
- Operations will begin in Year 1 and continue for 25 years.
- D&D will commence immediately following the 25-year service life and be completed in a 3-year period. D&D costs will be uniformly distributed over this 3-year period.
- The time value of money is 8%.
- Process residuals from the steam reforming system will be stabilized in Saltstone and disposed of in on-site vaults at a unit cost of \$4.86 per gallon.¹⁹
- Process residuals from the vitrification and plasma systems will be delisted and disposed of as low-level radioactive waste at a unit cost of \$52 per cubic foot.²⁰

Given the above assumptions, the present values of the life-cycle costs range from \$289 million for the plasma arc technology to \$312 million for the vitrification technology, as listed in Table 5-6.

5.1.4 Other Considerations

Several other considerations impact the viability of the thermal technologies. These include the implementation schedule, secondary waste streams, pollution prevention, public acceptance, regulatory permitting, and versatility. Each is discussed in the ensuing sections of this report.

¹⁹Telephone conversation between A. Whittenburg (WSRC) and Mike Navetta (RCS), August 26, 1997.

²⁰Telephone conversation between James Blankenhorn (SRS) and Mike Navetta (RCS), August 28, 1997.

Table 5-6. Present Value, Thermal Treatment Systems Life-Cycle Costs		
Cost Item	Cost, \$	Present Value, \$
Plasma Arc System		
Capital Cost	46,560,000	46,560,000
RCRA Permits and Tests	1,500,000	1,500,000
NEPA Documentation	100,000	100,000
O&M Cost		
Year 1	10,220,000	
Total, Years 1-25	425,620,000	156,040,000
Residual Disposal ^{a,c}		
Year 1	5,325,000	
Total, Years 1-25	221,765,000	81,303,000
D&D Cost	30,000,000	3,760,000
TOTAL COST	725,545,000	289,263,000
Steam Reforming System		
Capital Cost	29,670,000	29,670,000
RCRA Permits and Tests	500,000	500,000
NEPA Documentation	100,000	100,000
O&M Cost		
Year 1	3,520,000	
Total, Years 1-20	146,590,000	53,740,000
Residual Disposal ^{b,c}		
Year 1	13,976,000	
Total, Years 1-25	582,043,000	213,388,000
D&D Cost	20,000,000	2,510,000
TOTAL COST	778,903,000	299,908,000

Table 5-6. Present Value, Thermal Treatment Systems Life-Cycle Costs		
Cost Item	Cost, \$	Present Value, \$
Vitrification System		
Capital Cost	46,560,000	46,560,000
RCRA Permits and Tests	1,500,000	1,500,000
NEPA Documentation	100,000	100,000
O&M Cost		
Year 1	11,680,000	
Total, Years 1-20	486,420,000	178,330,000
Residual Disposal ^{a,c}		
Year 1	5,325,000	
Total, Years 1-25	221,764,000	81,303,000
D&D Cost	30,000,000	3,760,000
TOTAL COST	786,344,000	311,553,000
Notes ^a Assumes 70% overall volume reduction and disposal of residue as low-level waste at 52 per cubic foot. ^b Assumes 30% overall volume reduction and disposal of residue in Saltstone at unit cost of \$4.86 per gallon. ^c Assumes wet scrubber blowdown is disposed at SRS Effluent Treatment Facility at a unit cost of \$1.25 per gallon.		

5.1.4.1 Implementation Schedule

The requirement to denitrate the alkaline wastes is short-term. To be viable for this application, the technology should be capable of (1) being implemented in a reasonably short period of time (i.e., less than 5 years) and (2) eliminating the anticipated inventory of 92 million gallons of alkaline waste at the SRS in 25 years or less.

RCS believes that full-scale thermal processes based on any of the three viable technologies cannot be made operational in less than 5 years if traditional DOE technology development and procurement methods are used. Approximately 4 years would be needed to design, permit, construct, and operate the pilot plants that will be needed to develop scaling factors and other design parameters for the full-scale systems. Thereafter, the full-scale systems could be designed, permitted, and constructed in 4 to 5 additional years. None of the technologies are capable of

being implemented at full-scale using DOE's traditional technology development and procurement approaches within 5 years.

However, the recent experience with the GTS Duratek vitrification contract at SRS indicates that a procurement approach based on privatization may be capable of bringing thermal technologies on-line in less than 5 years. In the GTS Duratek case, a vendor forum was conducted by DOE and WSRC in the Spring of 1994. Based on a proposal submitted by GTS Duratek as a follow-up to the vendor forum, DOE awarded the contract to GTS Duratek in November 1994. GTS Duratek mobilized to the field in March 1995. The vitrification was operational on radioactive feed in October 1996. The elapsed time from the contract award to full-scale field operations was less than 24 months.

5.1.4.2 Secondary Waste Streams

All three of the thermal processes produce relatively large amounts of secondary waste streams. The process off-gases could contain significant amounts of NO_x. These gases would require treatment prior to atmospheric discharge, probably in some sort of wet scrubber system, which, in turn, would generate a wastewater requiring treatment prior to disposal.

5.1.4.3 Pollution Prevention

It is conceivable that greater than 70% reductions in the volume of mixed waste requiring land disposal can be realized using any of the thermal processes. This volume reduction will obviously result in substantial savings in disposal costs and will be very attractive from a pollution prevention standpoint.

5.1.4.4 Public Acceptance

Non-incineration thermal processes generally receive much less publicity and public opposition than their incineration counterparts. Within the DOE community, for example, vitrification programs at radioactive waste sites have been virtually unopposed. The RCRA permitting of the plasma arc system at the ATG facility in Hanford has thus far been received favorably by the local population. There was little public opposition to the GTS Duratek vitrification project at SRS. There is generally no significant organized opposition to non-incineration thermal technologies.

5.1.4.5 Regulatory Permitting

All of the thermal processes will require a RCRA Part B permit and an air pollution permit from the South Carolina Department of Health and Environmental Control (SCDHEC). These permits will be similar in complexity to those acquired by DOE for the Consolidated Incineration Facility (CIF) at the SRS. RCS believes that the permitting process could require upwards of 24 months to complete. DOE should expect to be required by SCDHEC to complete a trial burn or similar demonstration test, if any type of thermal treatment system is constructed and operated.

5.1.4.6 Versatility

The thermal processes described in this section of the report are very robust and, with only minor modifications, could be used to treat a variety of radioactive, mixed, and hazardous waste generated at the SRS.

5.2 HYDROTHERMAL PROCESS

This section of the report discusses the technical and economic aspects of the hydrothermal process for denitrating aqueous low-level alkaline mixed waste streams.

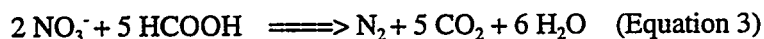
5.2.1 Process Engineering Descriptions

The basic stoichiometry of the hydrothermal destruction of nitrates and nitrites is described in Section 5.2.1.1. A description of a preconceptual design for a hydrothermal system for the SRS decontaminated salt solution waste stream is presented in Section 5.2.1.2.

5.2.1.1 Basic Process Chemistry

The hydrothermal process of denitration is a variation of chemical reduction that occurs in waste solutions under supercritical or near supercritical conditions. Supercritical conditions are broadly defined as combinations of elevated temperatures between 350 °C and 525 °C and pressures between 19 and 30 MPa.

In the hydrothermal treatment system, the aqueous waste containing nitrates and nitrites is contacted with a reducing agent in a pressurized vessel under the supercritical conditions described above for a period of several hours. The basic chemical reaction, with formic acid being the reductant, is as follows:



Other reducing agents that have been tested on low-level mixed waste streams containing nitrates with varying degrees of effectiveness include ammonia, urea, methane, hydrogen, and potassium ferrocyanide.^{21, 22}

Laboratory- and pilot-scale tests have shown that the process has the potential to destroy nitrates in both acidic and alkaline waste streams. The nitrates are converted almost entirely to nitrogen gas

²¹Taylor, P.A., Kurath, D.E., "Evaluation of Nitrate Destruction Methods," DOE/MWIP-10, March 30, 1993, pp. 17-18.

²²Kapline Enterprises, Inc. "Aqueous Nitrate Waste Treatment: Technology Comparison, Cost / Benefit, and Market Analysis," DOE/OR 2013, January 1994, pp. 66-67.

with small quantities of nitrous oxides also being produced. The organic reductants are converted to carbon dioxide.

5.2.1.2 SRS-Specific Configuration

A conceptual design for a full-scale hydrothermal process for treating decontaminated salt solution at the SRS has not heretofore been prepared. RCS speculates that the process flowsheet for such a plant would be similar to that presented on Figure 5-5.

In the RCS design, the decontaminated salt solution would be received from the ITP process and stored in two feed tanks. From these tanks, the decontaminated salt solution would be pumped under high pressure (>20 MPa) into the heated reactor vessel, where it would be contacted with a reducing agent for several minutes at temperatures above 350 °C.

The decontaminated salt solution does not contain organics in sufficient concentrations to function as effective reducing agents. Therefore, organic reductant (formic acid, kerosene, or other) would have to be added to the process, as illustrated on Figure 5-5.

Process off-gas would be piped to an air pollution control system, which would consist of a conventional NO_x scrubber system, demisters, reheaters, and HEPA filters.

Treated liquid would flow from the reactor to a steam-heated evaporator, where the dilute salt stream would be volume-reduced by approximately 70%. The evaporated solution would then be pumped to the existing Z-Area Saltstone Facility for solidification and final disposal.

5.2.2 Technical Evaluation

The major advantages and disadvantages associated with this technology are discussed in Sections 5.2.2.1 and 5.2.2.2, respectively. The ability of the technology to meet the performance standards discussed in Section 3.4 is summarized in Section 5.2.2.3. The maturity of the technology and outstanding research and development needs are discussed in Section 5.2.2.4.

5.2.2.1 Major Advantages

Several major advantages are associated with the hydrothermal technology, including:

- The process works on both acidic and alkaline solutions.
- Organics in the waste are destroyed along with the nitrates and nitrites.
- It may be possible to separate and remove the salts and some radionuclides present in the treated liquid waste as solids, thereby facilitating the subsequent evaporation of the dilute liquid before solidification and final disposal.

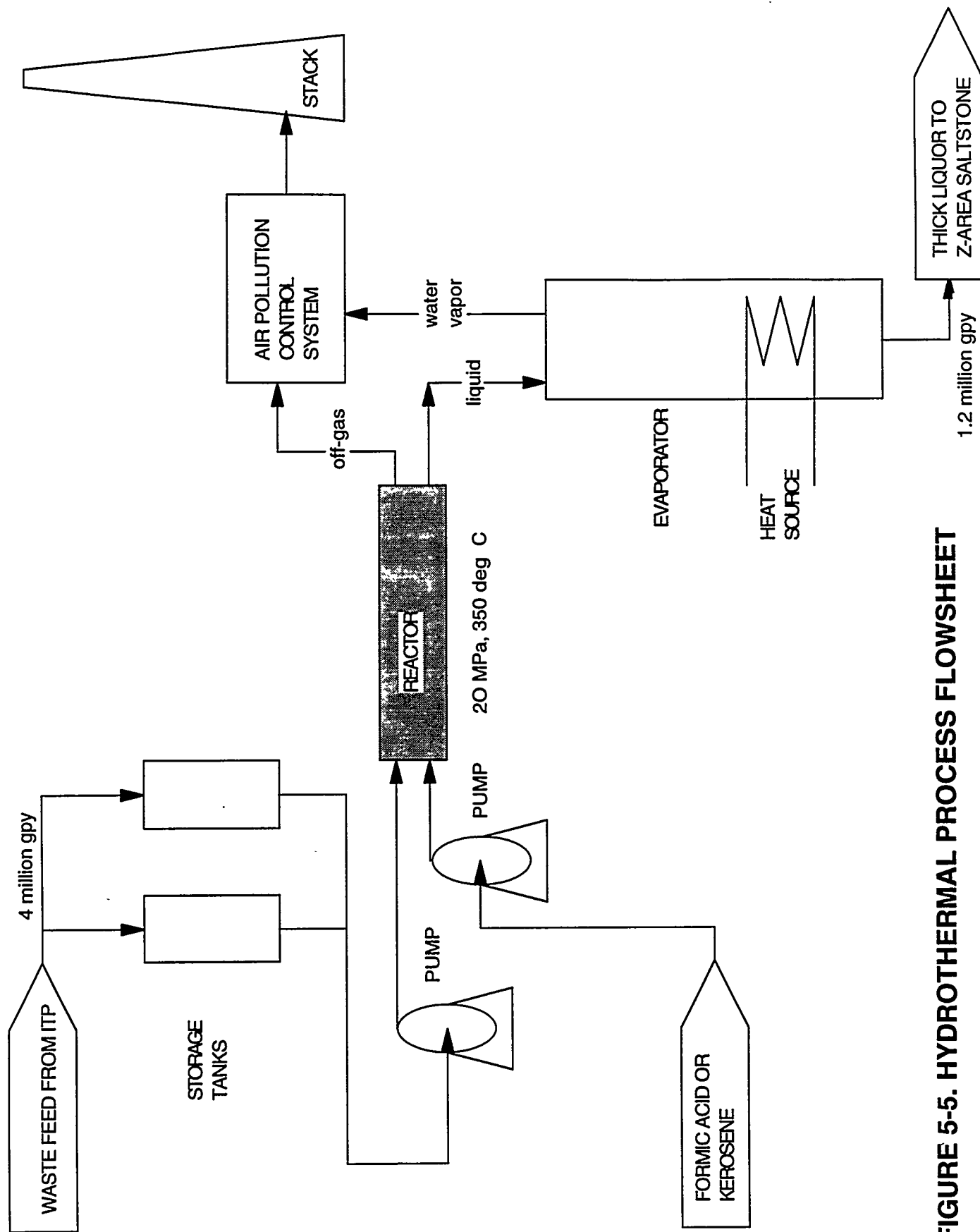


FIGURE 5-5. HYDROTHERMAL PROCESS FLOWSHEET

5.2.2.2 Major Disadvantages

The major disadvantages associated with this technology include the following:

- Plugging of the piping to and from the reactor is a concern because of the limited solubility of salts in supercritical solutions.
- The high temperatures and pressures within the reactor lead to high corrosion rates.
- Further processing of the off-gas may be needed to abate the nitrous oxides produced in the reactor.

5.2.2.3 Potential to Meet Performance Standards

The applicable performance standards were previously described in Section 3.4. An evaluation of this technology's ability to satisfy these performance standards follows.

Nitrate/Nitrite Destruction and Separation Efficiency

The hydrothermal process is capable of meeting the performance standard for nitrate and nitrite destruction. Testing at LANL has shown that destruction efficiencies in excess of 99% can be achieved for nitrates and nitrites.²³ This destruction efficiency is greater than the performance criterion of 90%.

Worker Safety Standards

The hydrothermal process does not pose inordinate dangers to workers. The potential worker hazards associated with high vessel pressures, hazardous off-gases, and radiation can be controlled using engineering and administrative controls.

Process Safety Standards

The hydrothermal facility would be classified as a low or moderate hazard facility. Under DOE Orders 5480.5 and 5481.1B, detailed safety analysis reports would be required before start-up.

Nothing in the published testing history of the hydrothermal process suggests that the process hazards associated with the high vessel pressures and elevated temperatures cannot be effectively controlled with appropriate design features and operating procedures. It is thus reasonable to conclude that a hydrothermal process can be constructed and operated to meet or exceed all applicable process safety standards.

²³Robinson, J.M., et al, "Destruction of Nitrates, Organics, and Ferrocyanides by Hydrothermal Processing," LA-UR-93-456, 1993.

Radiological Safety Standards

The only full-scale treatment systems for mixed wastes containing nitrates are the calciner at the ICPP and the DWPF and Duratek vitrifier at the SRS. The calciner and DWPF facilities process high-level aqueous wastes and routinely operate within the limits of applicable radiological safety standards. The Duratek vitrifier processes low-level mixed wastes and has operated for over a year within the limits of applicable radiological safety standards.

Given that the decontaminated salt solution contains much lower levels of radionuclides than the calciner and DWPF waste feeds and involves processing in enclosed pressure vessels, it is reasonable to conclude that a hydrothermal process can be designed and operated to meet all applicable radiological safety standards, including ALARA considerations. Shielding may be required around certain process areas.

Environmental Standards

The hydrothermal process is capable of meeting all applicable environmental standards. The product of hydrothermal treatment of decontaminated salt solution will be a dilute aqueous solution of sodium salts and radionuclides that should be amenable to solidification to a nonleaching Saltstone waste form. The process off-gas may require treatment for nitrous oxides, but this can probably be accomplished using established technologies. No wastewater will be produced in this process requiring surface water discharge.

5.2.2.4 Technology Maturity and Research and Development Needs

Extensive research of the hydrothermal treatment of mixed wastes has been ongoing at LANL, INEL, and other sites for 15 years. The hydrothermal process has been tested on a bench-scale at LANL.

A pilot plant that was to be located at the INEL was canceled 2 years ago. This pilot plant was going to be used to develop the data on scaling factors, materials, corrosion, thermodynamics, reaction kinetics, and operational hazards needed to design a full-scale plant. A full-scale hydrothermal treatment process for aqueous mixed wastes has not yet been designed or constructed.

Within the DOE complex, the research into hydrothermal processing has slowed considerably in recent years due to funding shortages and a paradigm shift toward privatization. However, R&D in the private sector continues. General Atomics Corporation, Foster Wheeler, and others are presently involved in pilot-scale work related to the destruction of chemical agents (mustard, VX, GB, and others). General Atomics, for example, recently treated 500 pounds of hydrolysate from the neutralization of VX with sodium hydroxide.²⁴

²⁴Telephone conversation between Mike Spritzer (General Atomics Corp.) And Mike Navetta (RCS Corp.), July 28, 1997.

5.2.3 Evaluation of Costs

Section 5.2.3.1 discusses the capital costs of the hydrothermal waste treatment system. O&M costs are discussed in Section 5.2.3.2. D&D costs are estimated in Section 5.2.3.3. Life-cycle costs, computed on the basis of the capital, O&M, and D&D costs, are discussed in Section 5.2.3.4.

5.2.3.1 Capital Cost

A preliminary cost estimate for a hydrothermal system capable of processing 4 million gpy of alkaline nitrate wastes was prepared by RCS. The estimated capital cost for this system was \$29 million, as shown in Table 5-7.

5.2.3.2 Operations and Maintenance

LANL reports that it has achieved incineration-like destruction removal using hydrothermal processing at a unit treatment cost of \$0.05 to \$1.00 per gallon. RCS believes these costs are overly optimistic and has estimated the O&M cost of a nominal 4 million gpy hydrothermal plant, using the Delhi approach, to be \$2.98 million. This equates to a unit cost of \$0.75 per gallon. The estimates prepared by RCS are summarized in Table 5-8.

5.2.3.3 Decontamination and Decommissioning Costs

The D&D costs for the denitration system have not been previously estimated. RCS estimates the D&D costs at the end of the operational life of the facility to be \$500 per square foot of process facility. Estimated D&D costs, therefore, are \$30 million.

Table 5-7. Hydrothermal Plant Capital Cost Estimate (1997 Dollars)		
Item	Size	Cost, \$
Feed Tanks (2)	15,000 gallons each	170,000 ^a
Reactor Vessel	2,500 gallons, 3,000 psig working pressure	1,500,000 ^b
Process Feed Pumps (2)	75 gpm, 3500 psig discharge pressure	750,000
Process Withdrawal Pumps (2)	150 gpm, 15 psig discharge pressure	150,000
Air Pollution Control System (wet scrubber, demister, reheater, HEPA filters)	50,000 cfm	1,000,000
Distributed Control System		1,000,000
Subtotal, Major Equipment		4,570,000
Miscellaneous Equipment @ 30% of Major Equipment		1,370,000
Equipment Installation, 50% of Major Equipment		2,290,000
Facilities @ \$200 / ft ²	60,000 ft ²	12,000,000
Subtotal, Installed Equipment and Facilities		20,230,000
Engineering, 15%		3,030,000
Management Reserve, 30%		6,070,000
Total		29,330,000
Notes a Verbal quotations by John Wood Co., Valley Forge, PA, and Dal-Worth Fabrication, Inc.. Grand Prairie, TX. b Verbal quotation by Nooter Corp., St Louis, MO.		

Table 5 - 8. Annual O&M Costs, Hydrothermal System			
O&M Item	Units	Unit Cost, \$	Extension, \$
Direct Labor (Fully Burdened) - Operators	8	60,000	480,000
Direct Labor (Fully Burdened) - Shift Supervisors	4	75,000	300,000
Process and Support Utilities - electricity, HVAC, lighting, potable water, sewer	1 lot	1,000,000	1,000,000
Process Maintenance (5% of Capital Cost)	1 lot	1,000,000	1,200,000
Total			2,980,000

5.2.3.4 Life-Cycle Costs

For the purpose of estimating the present value of the total life-cycle cost for the denitration system, the following assumptions were made:

- Construction, O&M, and D&D costs will increase uniformly at 4% per year over the study period.
- RCRA and NEPA documentation will be prepared and all associated costs will be incurred in Year 0.
- Construction will begin in Year 0, and all capital costs will be incurred in that year.
- Operations will begin in Year 1 and continue for 25 years.
- D&D will commence immediately following the 25-year service life and be completed in a 3-year period. D&D costs will be evenly distributed across this 3-year period.
- The time value of money will be 8%.
- The solid process residue will be stabilized in Saltstone at a unit cost of \$4.86 per gallon.

Given the above assumptions, the present value of the life-cycle costs is \$168,230,000, as listed in Table 5-9.

Table 5-9. Present Value, Hydrothermal System Life-Cycle Costs		
Cost Item	Cost, \$	Present Value, \$
Capital Cost	29,330,000	29,330,000
RCRA Permits and Tests	500,000	500,000
NEPA Documentation	100,000	100,000
O&M Cost		
Year 1	2,980,000	
Total, Years 1-25	124,100,000	45,500,000
Residual Disposal		
Year 1 ^{a,b}	5,832,000	
Total, Years 1-25	242,879,000	89,044,000
D&D Cost	30,000,000	3,760,000
Total	396,909,000	168,234,000
Notes a Assumes disposal of 1.2 million gallons per year of liquid in Saltstone at a unit cost of \$4.86 per gallon. b Assumes wet scrubber blowdown is disposed at SRS Effluent Treatment Facility at a unit cost of \$1.25 per gallon.		

5.2.4 Other Considerations

Several other considerations impact the viability of the technology. These include the implementation schedule, secondary waste streams, pollution prevention, public acceptance, and regulatory permitting. Each is discussed in the ensuing sections of this report.

5.2.4.1 Implementation Schedule

The requirement to denitrate the alkaline wastes is short-term. To be viable for this application, the technology should be capable of (1) being implemented in a reasonably short period of time (i.e., less than 5 years) and (2) eliminating the anticipated inventory of 92 million gallons of alkaline waste at the SRS in 25 years or less.

Assuming that conventional DOE technology development and procurement methods are used, RCS believes that the full-scale hydrothermal process cannot be made operational in less than 5 years. Approximately 2 years of operations at the existing General Atomics or other pilot plant

would be needed to develop design parameters for a full-scale plant. Thereafter, the time required to complete the design, construction, systemization, and permitting of the full-scale system would be approximately 4 to 6 years. At a minimum, 6 years would be needed to make a full-scale plant operational.

The experience with the Duratek vitrifier at the SRS indicates that it may be possible to substantially reduce the lead time discussed above by using the privatization approach.

5.2.4.2 Secondary Waste Streams

The hydrothermal process should not produce large amounts of secondary waste streams. The only secondary waste stream of concern is the process off-gas, which could contain significant amounts of NO_x. This gas would require treatment using conventional abatement technologies prior to atmospheric discharge.

5.2.4.3 Pollution Prevention

The possibility of removing sodium salts and radionuclides as solids from the reactor provides an opportunity to reduce the volume of the treated liquid using evaporation. It is conceivable that 70% reductions in the volume of mixed waste requiring land disposal can be realized using post-treatment evaporation in conjunction with the hydrothermal process. This will result in substantial savings in disposal costs and is very attractive from a pollution prevention standpoint.

5.2.4.4 Public Acceptance

Heretofore, the hydrothermal process has not been widely publicized. There is no organized opposition to the technology from environmental or citizens groups. All indications are that the public would be supportive of the use of hydrothermal technology to treat the decontaminated salt solution.

5.2.4.5 Regulatory Permitting

The hydrothermal process will require a RCRA Part B permit and an air pollution permit from the South Carolina Department of Health and Environmental Control. These permits will be similar in complexity to those acquired by DOE for the Consolidated Incineration Facility (CIF) at the SRS. RCS believes that the permitting process could require upwards of 24 months to complete.

5.2.4.6 Versatility

The hydrothermal process could be used to treat radioactive, mixed, and hazardous wastes that contain organics. Numerous waste streams generated at the SRS could be treated in a hydrothermal plant.

5.3 CHEMICAL REDUCTION PROCESSES

This section of the report discusses the technical and economic aspects of the chemical denitration of low-level alkaline mixed waste streams.

5.3.1 Process Engineering Description

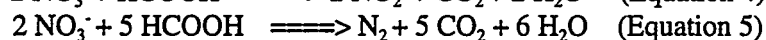
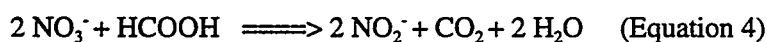
The basic stoichiometry of the chemical denitration (i.e., reduction) of nitrates and nitrites is described in Section 5.3.1.1. A description of a preconceptual design for a chemical reduction system for SRS waste streams based on the nitrate to ammonia and ceramic (NAC) process of chemical reduction is presented in Section 5.3.1.2.

5.3.1.1 Basic Process Chemistry

The chemical reduction of nitrates and nitrites involves the use of reducing agents, such as ascorbic acid, formaldehyde, formic acid, or aluminum, to convert the nitrates and nitrites to simpler oxides of nitrogen (NO_x), ammonia, and nitrogen gas. In general, the processes that use organic reductants have been in use by the chemical industry for over a century. The processes that use metal reductants are more contemporary.

Numerous parallel and sequential reduction reactions occur in solutions of nitrates and nitrites during chemical reduction. Examples of these reactions, using formic acid and aluminum as reducing agents, are as follows:

Formic Acid



Aluminum



Formaldehyde and formic acid have been used in France and Japan for many years to denitrate high-level wastes containing high concentrations of nitric acid. The French and Japanese applications of chemical reduction technology have been geared primarily toward neutralizing strong nitric acid solutions rather than destroying nitrates. No experience in France and Japan has applied this technology to the destruction of nitrates in alkaline mixed waste streams.

The experience in Japan and France shows that chemical reduction using organic reductants does not destroy a high fraction of the nitrate in solution and does not work on alkaline wastes.²⁵

²⁵Kapline Enterprises, Inc., "Aqueous Nitrate Waste Treatment: Technology Comparison, Cost/Benefit, and Market Analysis," DOE/OR 2013, January 1994, p. 44.

Conventional chemical reduction technology using organic reductants is, therefore, not further considered in this report. All further discussions of chemical reduction focus on processes that use metal reductants.

In the U.S., researchers at the ORNL and Florida International University have been developing the innovative NAC chemical reduction process for several years. The NAC process uses aluminum as the reductant. The basic process flow diagram is provided on Figure 5-6.

The NAC process, which is highly exothermic, occurs in alkaline solutions at temperatures above 50 °C with the addition of aluminum, water, and silica. The reaction of nitrate and aluminum in solution produces a granular, sand-like product slurry, and an off-gas stream containing ammonia and hydrogen. The sand-like product can be dried in a calciner, pressed, and sintered at 600 to 800 °C in a furnace to a ceramic waste form with a high bulk density ($>2 \text{ g/cm}^3$), very small pore size, and low leachability. Leach testing on sintered material produced from ORNL wastes have shown that the matrix passes the EPA Toxicity Characteristic Leaching Procedure (TCLP) test and has a leach index for radionuclides comparable to that of glass waste forms.²⁶ The ammonia off-gas from the NAC reactor can be catalytically oxidized to nitrogen and water.

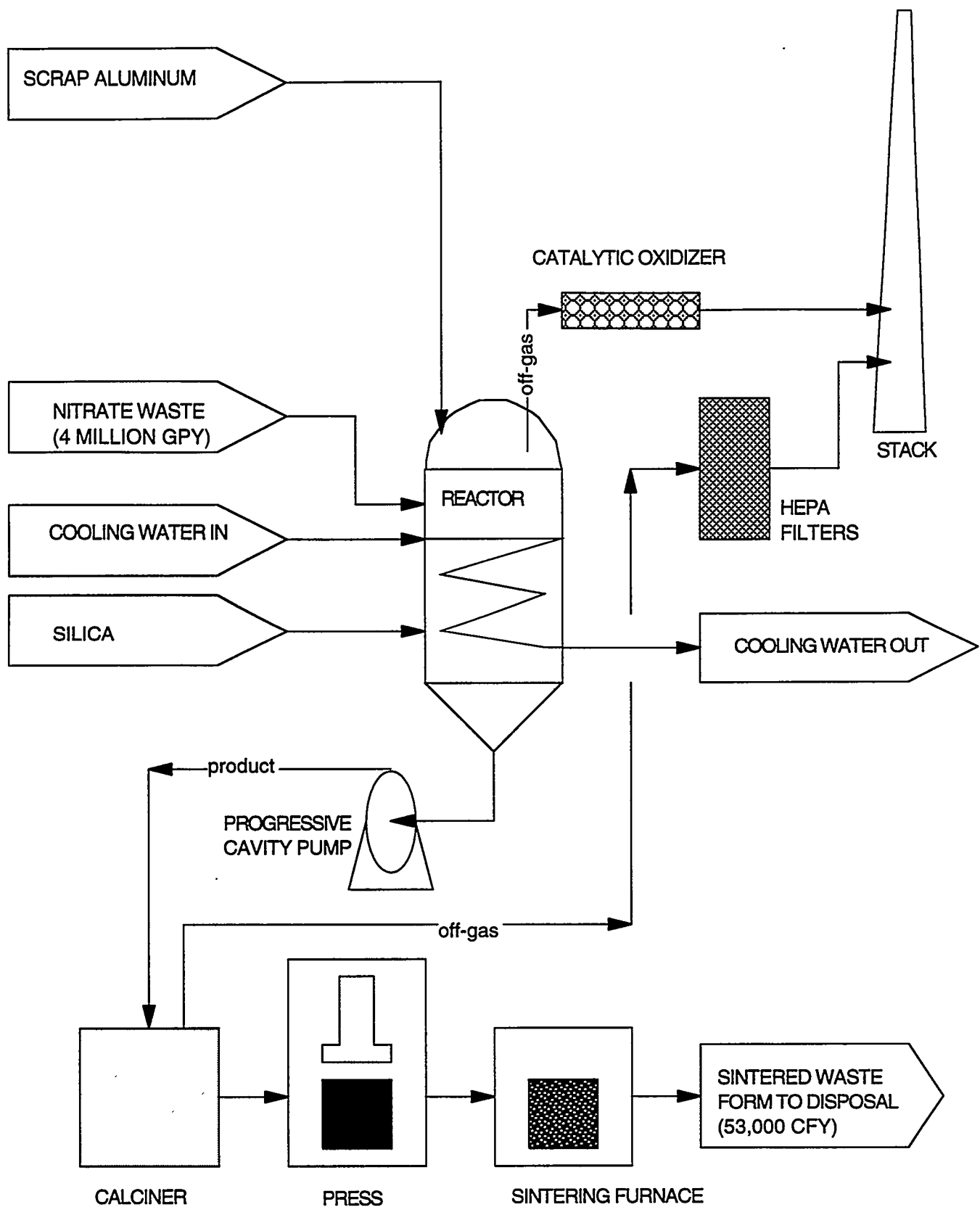
Experiments with ORNL and Hanford wastes indicate that a waste volume reduction of 70% can be achieved using the NAC process. These experiments also indicate that ⁹⁰Sr and other heavy metals will precipitate in the NAC reactor and become chemically bound in the ceramic product, as evidenced by the leach tests described above.

With slight process modifications, the sand-like product can be immobilized in portland cement or vitrified to glass. A variation of the NAC process is the nitrate to ammonia and glass (NAG) process. In the NAG process, the sintering furnace is replaced with a high temperature vitrifier. The product is a glass waste form, instead of a ceramic.

5.3.1.2 SRS-Specific Configuration

The decontaminated salt solution waste stream at the SRS is a dilute solution of sodium nitrate, nitrite, and hydroxide, as stated in Section 3.1 of this report. The results of testing performed on similar wastes at Hanford and ORNL indicate that a process with the same basic configuration shown on Figure 5-6 could probably be used to denitrate the SRS waste using NAC technology.

²⁶Kapline Enterprises, Inc., "Aqueous Nitrate Waste Treatment: Technology Comparison, Cost/Benefit, and Market Analysis," DOE/OR 2013, January 1994, p. 59.



**FIGURE 5-6. NITRATE TO AMMONIA
AND CERAMIC PROCESS FLOWSHEET**

Assuming a reactor residence time of 2 hours, a nominal capacity of 4 million gpy, and a design availability of 70%, the SRS plant would consist of the following major equipment housed in a 60,000-square-foot building:

- Reactor, 5000 gallons
- Waste Feed Tanks (2), 15,000 gallons each
- Liquid Product Storage Tanks (2), 15,000 gallons each
- Slurry Product Storage Tanks (2), 5,000 gallons each
- Calciner, 6 million BTU/hr
- Hydrostatic Press
- Sintering Furnace, 1 million BTU/hr

5.3.2 Technical Evaluation

The major advantages and disadvantages associated with this technology are discussed in Sections 5.3.2.1 and 5.3.2.2, respectively. The ability of the technology to meet the performance standards discussed in Section 3.4 is summarized in Section 5.3.2.3. The maturity of the technology and outstanding research and development needs are discussed in Section 5.3.2.4.

5.3.2.1 Major Advantages

Several major advantages are associated with the NAC technology, including:

- Waste feed streams would not require pretreatment.
- The NAC process would yield an insoluble solid waste form that may be suitable for land disposal without further treatment.
- The NAC process could use radioactively-contaminated scrap aluminum as a feed material, thereby reducing the decontamination and disposal requirements for that material.
- The NAC process would operate at low temperatures.

5.3.2.2 Major Disadvantages

The major disadvantages associated with this technology include the following:

- The chemical reduction of nitrates is highly exothermic and would require strict

engineering controls to prevent runaway reaction.

- Process off-gases containing hydrogen, ammonia, and NO_x would be produced and would require treatment prior to atmospheric discharge.

5.3.2.3 Potential to Meet Performance Standards

The applicable performance standards were previously described in Section 3.4. An evaluation of this technology's ability to satisfy these performance standards is presented below.

Nitrate/Nitrite Destruction and Separation Efficiency

The NAC process is capable of meeting the performance standard for nitrate and nitrite destruction. Testing on ORNL and Hanford waste streams has shown that destruction efficiencies in excess of 99% can be achieved for nitrates and nitrites. This destruction efficiency is greater than the performance criterion of 90%.

Worker Safety Standards

The NAC process is a low temperature process that does not pose inordinate dangers to workers. The potential worker hazards associated with exothermic reactions, hazardous off-gases, and radiation could be controlled using engineering and administrative controls.

Process Safety Standards

The NAC facility would be classified as a low or moderate hazard facility. Under DOE Orders 5480.5 and 5481.1B, detailed safety analysis reports would be required before start-up.

The NAC chemical reduction process is highly exothermic. The literature suggests that in the absence of reactor cooling, runaway reactions are possible. Nothing in the NAC testing history, however, suggests that the process hazards associated with the exothermic nature of the chemical reactions could not be effectively controlled with appropriate design features and operating procedures.

Considering the facts discussed above, the NAC process design would have to include a highly reliable, or perhaps redundant, reactor cooling system. Cooling systems of this type are common in both the chemical and nuclear industries. Thus, it is reasonable to conclude that a NAC process can be constructed and operated to meet or exceed all applicable process safety standards.

Radiological Safety Standards

The only full-scale mixed waste treatment system for nitrates is the calciner at the ICPP. This facility processes high-level aqueous wastes and routinely operates within the limits of applicable radiological safety standards.

Given that the decontaminated salt solution contains much lower levels of radionuclides than the ICPP waste feed, it is reasonable to conclude that a NAC process could be designed and operated to meet all applicable radiological safety standards, including ALARA considerations. To achieve full compliance, the reactor and cooling systems would have to be designed to control the highly exothermic reactions and minimize exposures to O&M personnel. Shielding may also be required around certain process areas.

Environmental Standards

The NAC process is capable of meeting all applicable environmental standards. The treatment process solid residual is reported to be nonleaching and thus may be suited for land disposal without further treatment. The treatment process off-gas may contain high-levels of hydrogen, ammonia, and NO_x that could be effectively abated using commercially available air pollution control equipment. The NAC process would not generate significant quantities of wastewater and would not directly affect surface waters.

5.3.2.4 Technology Maturity and Research and Development Needs

The NAC process has been tested on a bench-scale at ORNL. Engineering plans for a pilot-scale NAC process were completed in 1995, but the construction has been indefinitely deferred because of DOE funding shortages.²⁷ Pilot-scale testing, therefore, remains to be completed.

5.3.3 Evaluation of Costs

Section 5.3.3.1 discusses the capital costs of the electrochemical waste treatment system. O&M costs are discussed in Section 5.3.3.2. D&D costs are estimated in Section 5.3.3.3. Life-cycle costs, computed on the basis of the capital, O&M, and D&D costs, are discussed in Section 5.3.3.4.

5.3.3.1 Capital Cost

The Central Engineering Department at ORNL prepared a preliminary cost estimate in 1992 for a NAC system capable of processing 24,000 gallons per day (gpd) of alkaline nitrate wastes (6.1 million gpy @ 70% availability). The estimated capital cost for this system was \$20 million.

As shown in Table 5-8, it is estimated that a 4 million gpy NAC system would cost approximately \$21.8 million (1997 dollars) to construct at the present time.

²⁷Personal communication between A.J. Mattus (ORNL) and Mike Navetta (RCS), July 18, 1997.

Table 5-8: NAC Capital Cost Estimate (1997 Dollars)		
Item	Size	Cost, \$
Feed Tanks (2)	15,000 gallons each	170,000 ^a
Liquid Product Tanks (2)	15,000 gallons each	120,000 ^a
Slurry Product Tanks (2)	5,000 gallons each	70,000 ^a
Reactor Vessel	5,000 gallons, atmospheric working pressure, glycol-cooled	160,000 ^b
Reactor Cooling System	400 tons	400,000
Slurry Feed Pumps (2)	100 gpm	50,000
Reactor Discharge Pumps (2)	25 gpm	30,000
Aluminum Feed System	2000 lb/hr	150,000
Sludge Dryer	5,000 lb/hr	100,000
Calciner	6 million BTU/hr	350,000
Ammonia Burner	1000 cfm	100,000
Subtotal, Major Equipment		1,700,000
Miscellaneous Equipment @ 30% of Major Equipment		510,000
Equipment Installation, 50% of Major Equipment		850,000
Facilities @ \$200 / ft ²	60,000 ft ²	12,000,000
Subtotal, Installed Equipment and Facilities		15,060,000
Engineering, 15%		2,260,000
Management Reserve, 30%		4,520,000
TOTAL COST		21,840,000
Notes a Verbal quotations from John Wood Co. of Valley Forge, PA and Dal-Worth Fabrication Inc., Grand Prairie, TX. b Verbal quotation from Dan Leonard of Paul Mueller Co., Springfield, MO.		

5.3.3.2 Operations and Maintenance

ORNL's Central Engineering Department estimated the O&M costs for a NAC plant to be \$2 to \$3 per kg of nitrate destroyed. The SRS wastes could contain nitrates in concentrations up to 6M. Assuming the ORNL estimates are accurate, the O&M costs for a NAC plant at the SRS should be upward of \$1 per gallon or \$4 million annually.

Independent estimates of O&M costs for a nominal 4 million gpy NAC plant were prepared by RCS using a Delphi approach. These estimates, provided in Table 5-9, total \$2.87 million annually. These O&M costs, which are slightly lower than the ORNL figures, correspond to a unit treatment cost of \$0.72 per gallon.

Table 5-9. Annual O&M Costs, NAC Denitration System			
O&M Item	Units	Unit Cost, \$	Extension, \$
Direct Labor (Fully Burdened) - Operators	8	60,000	480,000
Direct Labor (Fully Burdened) - Shift Supervisors	4	75,000	300,000
Process and Support Utilities - electricity, HVAC, lighting, potable water, sewer	1 lot	1,000,000	1,000,000
Process Maintenance (5% of Capital Cost)	1 lot	1,100,000	1,090,000
Total			2,870,000

5.3.3.3 Decontamination and Decommissioning Costs

An estimate of the D&D costs for the NAC denitration system has not been prepared. RCS estimates the D&D costs at the end of the operational life of the facility to be \$500 per square foot of process facility. Estimated D&D costs, therefore, are \$30 million.

5.3.3.4 Life-Cycle Costs

For the purpose of estimating the present value of the total life-cycle cost for the denitration system, the following assumptions were made:

- Construction, O&M, and D&D costs will increase uniformly at 4% per year over the study period.

- RCRA and NEPA documents will be prepared and associated costs will be incurred in Year 0.
- Construction will begin in Year 0, and all capital costs will be incurred in that year.
- Operations will begin in Year 1 and continue for 25 years.
- D&D will commence immediately following the 25-year service life and will be completed in a 3-year period. D&D costs will be evenly distributed across the 3-year period.
- The time value of money will be 8%.
- The solid NAC process residue will be delisted and disposed of as low-level radioactive waste at a unit cost of \$52 per cubic foot.

Given the above assumptions, the present value of the life-cycle costs is \$112 million, as listed in Table 5-10.

5.3.4 Other Considerations

Several other considerations may impact the viability of the technology. These include the implementation schedule, secondary waste streams, pollution prevention, public acceptance, and regulatory permitting. Each is discussed in the ensuing sections of this report.

5.3.4.1 Implementation Schedule

The requirement to denitrate the alkaline wastes is short-term. To be viable for this application, the technology should be capable of (1) being implemented in a reasonably short period of time (i.e., less than 5 years) and (2) eliminating the anticipated inventory of 92 million gallons of alkaline waste at the SRS in 25 years or less.

In the event that the conventional DOE technology development and procurement process is followed, RCS believes that the full-scale NAC process could not be made operational in less than 5 years. RCS estimates that a full-scale chemical reduction process using NAC technology would require at least 6 years to become operational. Assuming the availability of funding, approximately 2 years would be needed to construct a pilot plant. Another year of pilot-scale testing would follow to refine the process flowsheet and establish operational settings. Thereafter, the design, construction, systemization, and permitting of the full-scale system could be completed in 4 years.

As stated previously, the experience with privatization at the SRS suggests that the lead time could be reduced to 5 years or less if the privatization approach were used.

Table 5-10. Present Value, NAC System Life-Cycle Costs		
Cost Item	Cost, \$	Present Value, \$
Capital Cost	21,840,000	21,840,000
RCRA Permit and Tests	500,000	500,000
NEPA Documents	100,000	100,000
O&M Cost		
Year 1	2,870,000	
Total, Years 1-25	119,520,000	43,820,000
Residue Disposal ^{a,b}		
Year 1	2,756,000	
Total, Years 1-25	114,776,000	42,079,000
D&D Cost	30,000,000	3,760,000
Total	286,736,000	112,099,000
Notes a Assumes overall volume reduction of 70% and disposal of process residuals as low-level waste at a unit cost of \$52 per cubic foot. b Assumes wet scrubber blowdown is disposed at SRS Effluent Treatment Facility at a unit cost of \$1.25 per gallon.		

5.3.4.2 Secondary Waste Streams

The NAC process should not produce large amounts of secondary waste streams. The only secondary waste stream of concern is the process off-gas, which could contain significant amounts of hydrogen, ammonia, and NO_x. These gases would require treatment using conventional abatement technologies prior to atmospheric discharge.

5.3.4.3 Pollution Prevention

Bench-scale testing indicates that 70% reductions in the volume of mixed waste requiring land disposal could be realized using the NAC process. This would result in substantial savings in disposal costs and would be very attractive from a pollution prevention standpoint.

5.3.4.4 Public Acceptance

Heretofore, the NAC process has not been widely publicized. There is no organized opposition to

the technology from environmental or citizens groups. All indications are that the public would be supportive of the use of NAC technology to treat the decontaminated salt solution.

5.3.4.5 Regulatory Permitting

The NAC process would require a RCRA Part B permit and an air pollution permit from the South Carolina Department of Health and Environmental Control. These permits would be relatively easy to acquire and would be much less expensive than the permits acquired by DOE for the Consolidated Incineration Facility (CIF) at the SRS. RCS believes that the permitting process could be completed in 12 to 24 months.

5.3.4.6 Versatility

The applicability of the NAC process is limited primarily to radioactive, mixed, and hazardous wastes that contain nitrates. The process is less versatile than the thermal and hydrothermal alternatives.

5.4 ELECTROCHEMICAL REDUCTION PROCESS

This section of the report discusses the technical and economic aspects of the electrochemical process of denitrating low-level alkaline mixed waste streams.

5.4.1 Process Engineering Description

The basic process stoichiometry is described in Section 5.4.1.1. A description of a preconceptual design for an electrolysis system for SRS waste streams is presented in Section 5.4.1.2.

5.4.1.1 Basic Process Chemistry

The electrochemical process of liquid waste treatment is conducted in an electrolytic cell (electrolyser) consisting of an electrolyte reservoir, the electrolyte (untreated liquid waste), an anode, and a cathode (refer to Figure 5-7).

Within the electrolytic cell, an electric potential is maintained across the anode and cathode to provide the driving force for oxidation reactions that occur at the anode and reduction reactions that occur at the cathode. At the cathode, electrons are supplied to reduce electroactive species in the electrolyte. At the anode, electroactive species release electrons and are oxidized.

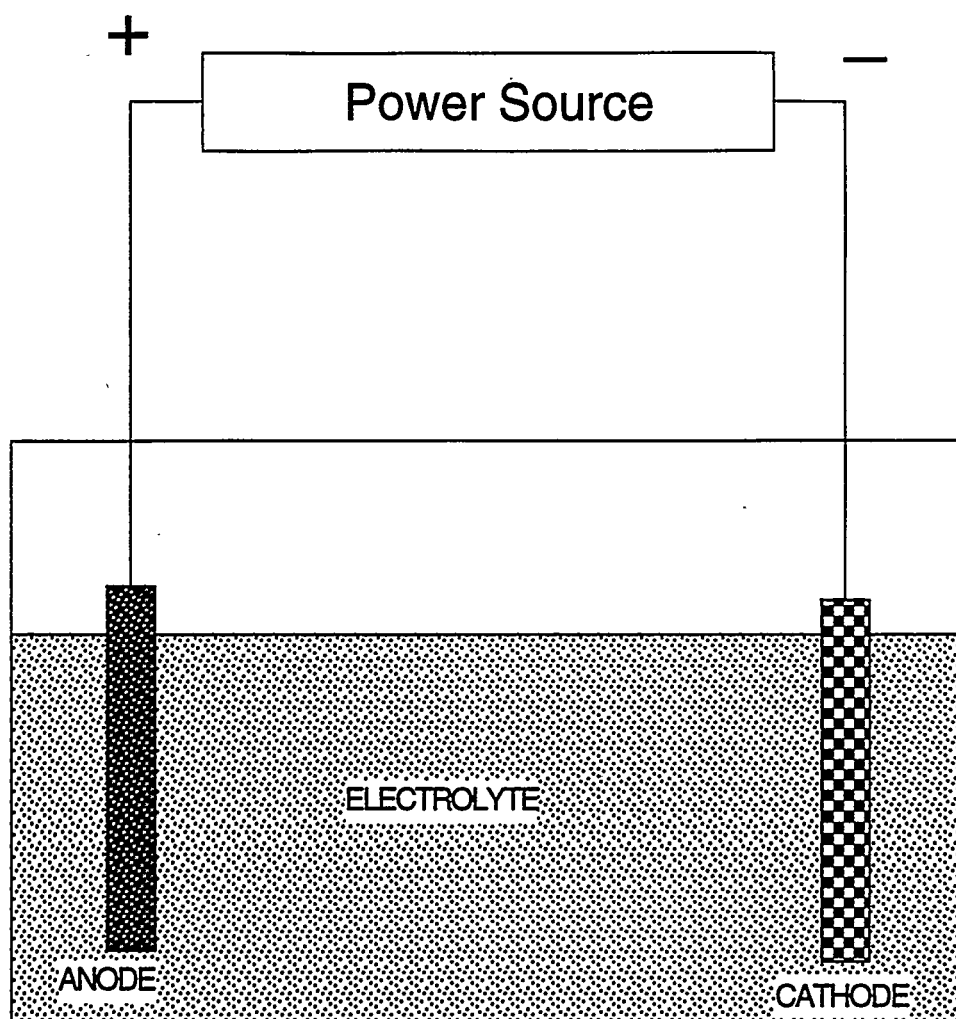
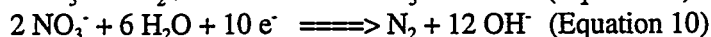
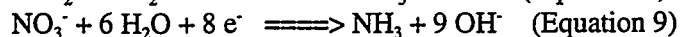
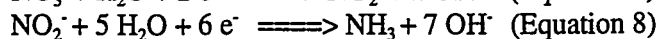


FIGURE 5-7. TYPICAL ELECTROCHEMICAL CELL

The electrochemical destruction of nitrates in an electrolyte solution is brought about by the reduction of the nitrate and nitrite at the cathode to nitrogen and ammonia, as shown on Figure 5-8. Numerous parallel and sequential reduction reactions occur at the cathode, including but not limited to, the following:



At the anode, organic species dispersed in the electrolyte are oxidized, primarily to carbon dioxide and water.

In the case of aqueous electrolytes, competing electrolysis reactions are the oxidation and reduction of water to oxygen and hydrogen.

Metal cations in the electrolyte may be reduced at the cathode and plate out as insoluble salts or pure metal on the cathode.

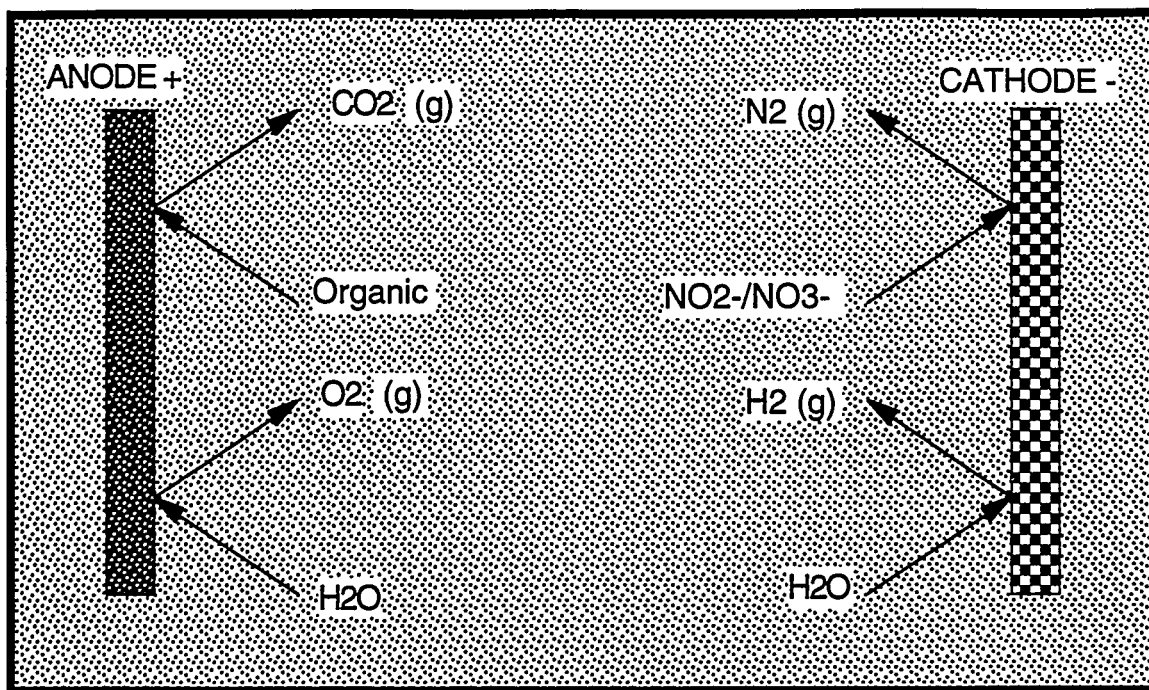
The kinetics of typical electrolysis reactions in electrochemical cells are governed by both mass transport (electroactive species diffusion through the electrolyte solution to the electrodes) and surface phenomena. Due to the latter, the presence of significant concentrations of metals in the electrolyte that reduce to insoluble salts at the cathode can lead to poisoning of the cathode and greatly reduce the electrolysis efficiency. This effect is, according to the literature, especially pronounced when chromates are present in the waste.

The reduction of chromate at the cathode forms insoluble chromium hydroxide films that are impermeable to some electronegative species, including nitrates.^{28, 29, 30} In experiments conducted using actual and simulated wastes, the electrolysis efficiency has been shown to decrease from over 90% to less than 40% in the presence of chromium at a concentration of 16 mg/L. At a chromium concentration of 318 mg/L, the electrolysis efficiency was observed to drop to less than

²⁸Chai, D., Hartsough, D., Genders, D., "Electrochemical Processing of Hanford and SRS Waste Simulants using an ICI FM21-SP Pilot Scale Flow Cell," Electrosynthesis Co., Inc., September 14, 1995.

²⁹Hobbs, D. T., "Electrolytic Denitration of Radioactive Savannah River Site Waste," WSRC-TR-95-0176, April 26, 1995.

³⁰Hobbs, D. T., "Summary Technical Report on the Electrochemical Treatment of Alkaline Nuclear Wastes," WSRC-TR-94-0287, July 30, 1994.



**FIGURE 5-8. REDUCTION OF NITRATE/NITRITE
IN ELECTROLYSER**

10%.^{31, 32}

The designs of electrochemical cells are various and incorporate numerous combinations of divided, undivided, batch, and flow-through cell configurations. A schematic of a typical undivided flow-through electrochemical cell is provided on Figure 5-9.

5.4.1.2 SRS-Specific Configuration

The alkaline nitrate-bearing waste streams at the SRS are dilute solutions of sodium nitrate, nitrite, and hydroxide. During experiments conducted at the SRS and other locations in recent years, the nitrates and nitrites in these wastes were essentially completely destroyed in an industrial flow-through electrolyser. The reduction and oxidation products included nitrogen, ammonia, sodium hydroxide (NaOH), oxygen, and hydrogen.³³

In 1996, Bechtel Savannah River, Inc., completed the preconceptual design of an electrochemical denitration system for the alkaline nitrate-bearing wastes at the SRS. The design capacity of the process is approximately 2 million gpy. This capacity is significantly below the design basis of 4 million gpy. WSRC personnel report, however, that with the addition of extra electrolyser cells and the replacement of electrolyte pumps with larger units, the design prepared by Bechtel could be easily upgraded to 4 million gpy.

The principal components of the upgraded process would be two parallel banks of five electrolyzers in series, two 20,000-gallon liquid storage tanks, liquid waste feed pumps, and an off-gas treatment system. The simplified process flow diagram is provided on Figure 5-10.³⁴ The design calls for the process to be located in a 60,000-square-foot steel building.

In the upgraded preconceptual design, the alkaline wastes would be received in discrete batches in Tank TK-1. The batch processing time would be 50 hours. From Tank TK-1, the wastes would be

³¹Hobbs, D. T., Ebra, M. A., "Electrochemical Processing of Nitrate and Nitrite Solutions," AIChE Symposium Ser. 83(254), pp. 149-155, 1987.

³²Taylor, P. A., Kurath, D. E., "Evaluation of Nitrate Destruction Methods," DOE/MWIP-10, March 30, 1993.

³³Chai, D., Hartsough, D., Genders, D., "Electrochemical Processing of Hanford and SRS Waste Simulants using an ICI FM21-SP Pilot Scale Flow Cell," Electrosynthesis Co., Inc., September 14, 1995.

³⁴Bechtel Savannah River, Inc., "Preconceptual Design Study for the Salt Solution Electrochemical Denitration and Caustic Recovery Facility," WAD # LIW2EE002, Rev. C, September 5, 1996.

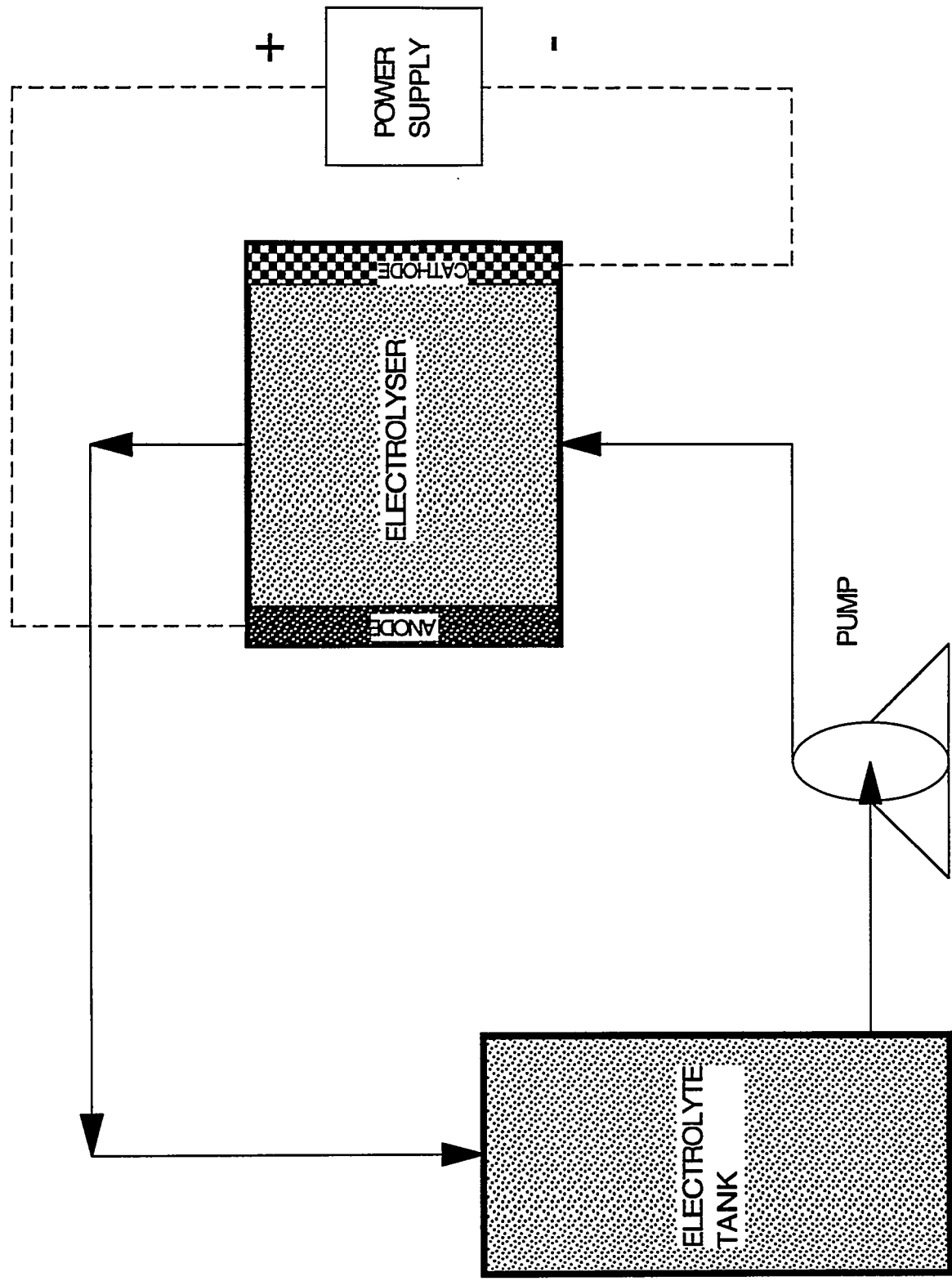


FIGURE 5-9. SCHEMATIC OF FLOW-THROUGH ELECTROLYSER

SOURCE: PIPING & INSTRUMENTATION DIAGRAM, SK-M-001,
ELECTROLYTIC DENTRATION OF RADIOACTIVE WASTE, UNDIVIDED CELL PROCESS

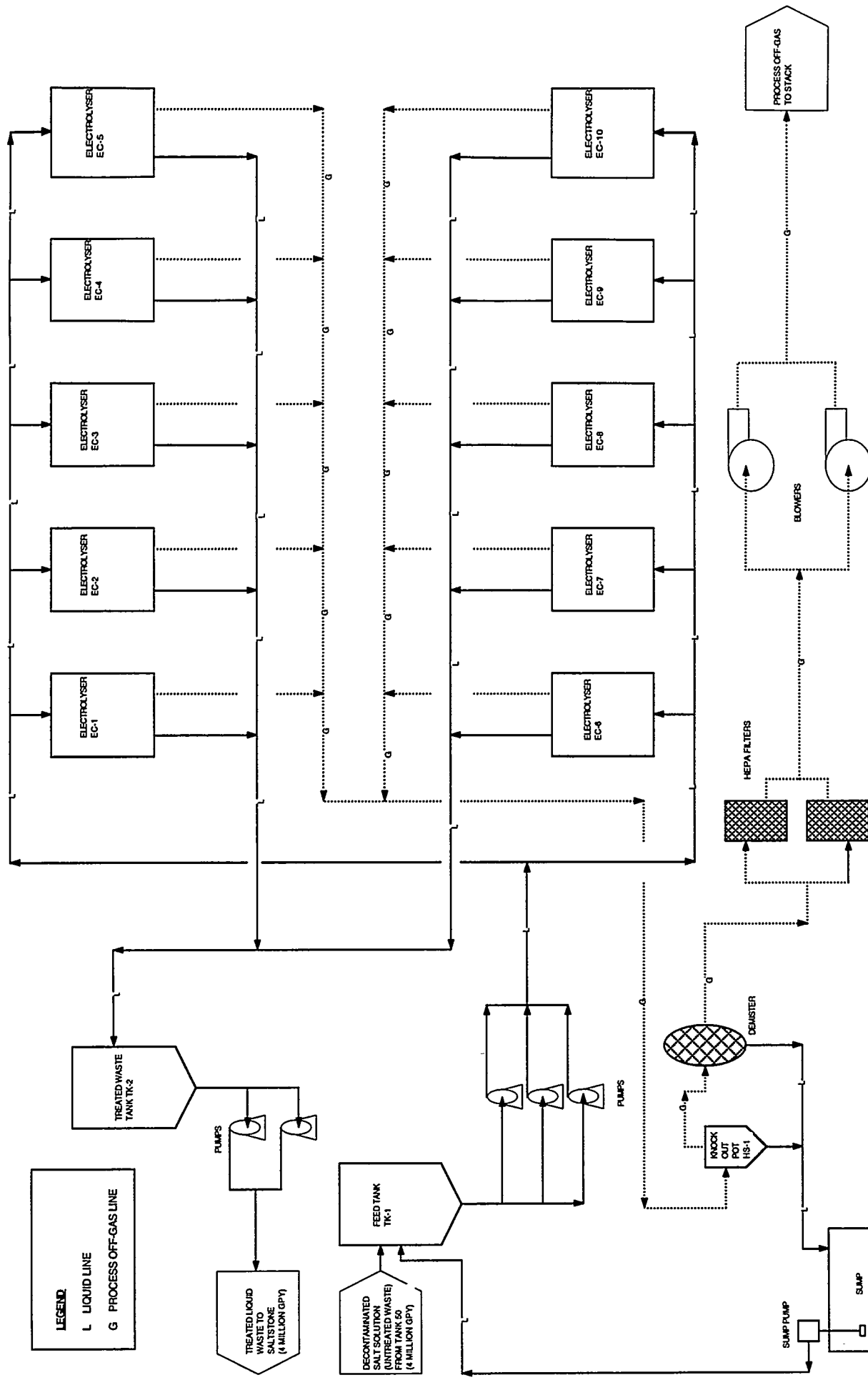


FIGURE 5-10. CONCEPTUAL PROCESS FLOWSHEET, 2 MILLION GPY ELECTROCHEMICAL DENTRATION SYSTEM

pumped through the electrolyzers at a rate of 300 gpm per electrolyzer for processing. Separation of the gases from the liquid would be facilitated by oversized piping on the electrolyzer outlets and a knock-out pot (HS-1).

The electrolyte that exits the electrolyzers would be piped directly to Tank TK-2, where it would be sampled and held pending analysis. If the analysis shows that nitrate levels have been reduced to acceptable levels, the treated waste would be pumped from Tank TK-2 to the existing Saltstone Processing Facility for solidification and disposed of in on-site vaults.

During electrochemical processing, one mole of sodium hydroxide would be produced at the anode for each mole of nitrate that is destroyed at the cathode. In cases where the nitrate feed is concentrated, the hydroxide concentration in the treated liquid would exceed the Saltstone waste acceptance criterion of 4 M. To address this issue, the preconceptual design prepared by Bechtel must be modified to include a sodium hydroxide recovery step, as shown on Figure 5-11. The recovered sodium hydroxide could then be either reused on-site as a chemical reagent or sold as a commodity chemical to off-site consumers.

In the upgraded preconceptual design, the process off-gas would flow from the knock-out pot through a bank of HEPA filters and blowers before being discharged to the atmosphere through the process exhaust stack.

The process flowsheet prepared by Bechtel shows the off-gas system to consist primarily of a demister and HEPA filters. This aspect of the preconceptual design probably would not comply with air emission restrictions because it provides no abatement for discharges of ammonia gas. It is likely that a more rigorous off-gas treatment system that includes an ammonia burner or dissociator would be required if the electrochemical process is constructed at the SRS. This modification is also shown on Figure 5-11.

5.4.2 Technical Evaluation

The major advantages and disadvantages associated with this technology are discussed in Sections 5.4.2.1 and 5.4.2.2, respectively. The ability of the technology to meet the performance standards discussed in Section 3.4 is summarized in Section 5.4.2.3. The maturity of the technology and outstanding research and development needs are discussed in Section 5.4.2.4.

5.4.2.1 Major Advantages

Several major advantages associated with this technology include:

- The electrolysis of the nitrate-bearing alkaline waste streams could be accomplished without the addition of chemicals or other pretreatment.
- The process could be used on both alkaline and acidic waste streams.
- The potential exists to simultaneously destroy organic compounds in the waste streams at

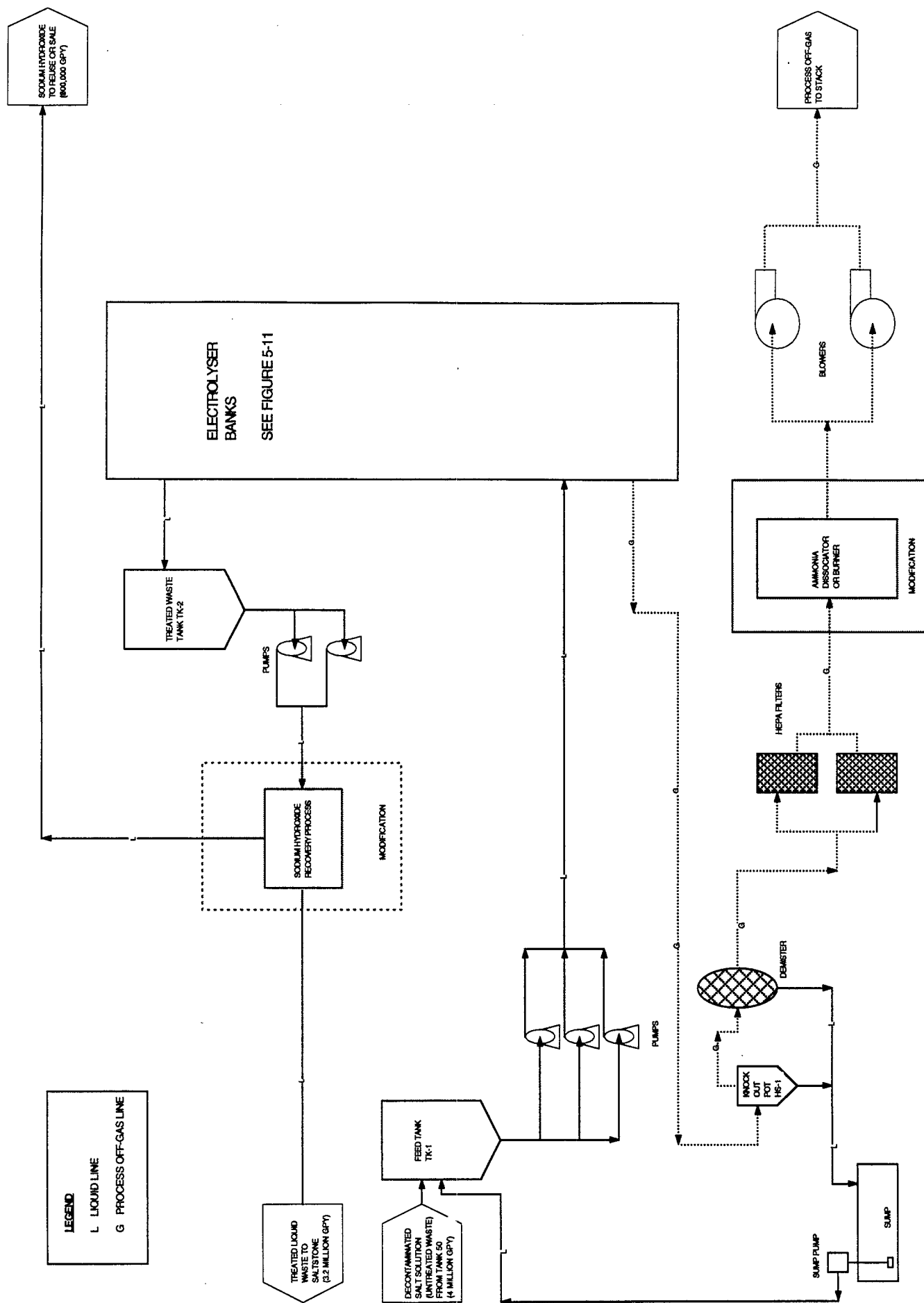


FIGURE 5-11. MODIFIED PROCESS FLOWSHEET, 2 MILLION GPY ELECTROCHEMICAL DENITRATION SYSTEM

the anode while nitrates are being destroyed at the cathode.

5.4.2.2 Major Disadvantages

The major disadvantages associated with this technology include the following:

- The electrolysis of nitrates would produce flammable and toxic ammonia gas that would require treatment prior to atmospheric discharge.
- Hydrogen produced at the cathode would present an explosion hazard.
- Sodium hydroxide would be produced at the anode. In cases where high concentrations of sodium hydroxide are produced, separation of the sodium hydroxide from the liquid stream may be needed to ensure the integrity of the final waste form. The waste acceptance criteria for the Saltstone facility would restrict the hydroxide content of feed streams to 4M.³⁵
- Metals, including some radionuclides, dispersed in the wastes to be treated may plate out on the electrodes and reduce the electrolysis efficiency.
- Because of the metal and radionuclide plating problem, some criticality concerns may be associated with this technology.
- The product of electrolysis (treated liquid waste) would not be suitable for direct disposal and would have to be treated further (i.e., solidified in Saltstone). The use of Saltstone would increase the overall waste volume and final disposal costs by approximately 40%.

5.4.2.3 Potential to Meet Performance Standards

The applicable performance standards were previously described in Section 3.4. An evaluation of this technology's ability to satisfy these performance standards is presented below.

Nitrate/Nitrite Destruction and Separation Efficiency

The electrochemical process would be capable of meeting the performance standard for nitrate and nitrite destruction. Testing on SRS waste streams has shown that destruction efficiencies in excess of 99% can be achieved for nitrates and nitrites. Final catholyte concentrations of nitrate below

³⁵Westinghouse Savannah River Corporation, "WSRC 1S Waste Acceptance Criteria Manual, Procedure 4.01, Acceptance Criteria for Aqueous Waste Sent to the Z-Area Saltstone Production Facility," Rev. No. 1, May 30, 1997.

0.1 M have been achieved.³⁶

Worker Safety Standards

Electrolysis has been used safely by industry in other applications for over a century. All applicable worker safety standards, including those specified in DOE Order 5480.1A, could be satisfied. The electrochemical process would use large amounts of electricity and pose significant electrical hazards to personnel. Electrical hazards could be effectively mitigated, however, by proper design and adherence to standard operating procedures.

Process Safety Standards

An electrochemical process for treating the decontaminated salt solution would probably be classified as a low or moderate hazard facility. A safety analysis report would be required before start-up. It is reasonable to conclude that an electrochemical process can be constructed and operated to meet or exceed all applicable process safety standards.

Electrolysis would require rigorous engineering controls to mitigate process hazards. The electrochemical treatment of nitrates would result in the evolution of significant quantities of ammonia and hydrogen gases. Ammonia gas is both flammable and toxic. Hydrogen gas is flammable.

Radiological Safety Standards

The electrochemical process could be designed and operated to meet all applicable radiological safety standards, including ALARA considerations. Process equipment would have to be designed to minimize exposures to O&M personnel. Shielding may be required around certain process areas (i.e., electrolyzers).

Environmental Standards

The electrochemical process would be capable of meeting all applicable environmental standards. The treatment process liquid residuals would be solidified in Saltstone and would meet applicable environmental standards, including the Saltstone waste acceptance criteria and the land disposal restrictions of RCRA. The treatment process gaseous emissions would contain high-levels of ammonia that could probably be effectively abated using commercially available air pollution control equipment. The electrochemical process would not produce liquid wastes that must be discharged to surface waters and, therefore, would not directly affect surface water quality.

³⁶Hobbs, D. T., "Electrolytic Denitration of Radioactive Savannah River Site Waste," WSRC-TR-95-0176, April 26, 1995.

5.4.2.4 Technology Maturity and Research and Development Needs

The electrochemical process for treating nitrate and nitrite containing mixed wastes has been studied for many years. Bench-scale and pilot-scale testing using actual and simulated wastes have been completed, as previously described.

The bench- and pilot-scale tests indicate that the electrochemical process may be a viable alternative for treating nitrate- and nitrite-bearing mixed waste streams at the SRS, achieving nearly complete nitrate/nitrite destruction and high electrolysis efficiencies.

There remain, however, substantial research and development needs. In particular, the generation and abatement of ammonia gas would require additional research to baseline the ammonia production rates in an industrial-scale process and to develop an effective ammonia abatement system. The process flowsheet prepared by Bechtel is believed to be deficient in these regards.³⁷

Also, given the uncertainties regarding the production and abatement of ammonia gas, the capital and O&M costs of an industrial-scale electrochemical process are not completely understood at this time.

5.4.3 Evaluation of Costs

Section 5.4.3.1 discusses the capital costs of the electrochemical waste treatment system. O&M costs are discussed in Section 5.4.3.2. D&D costs are estimated in Section 5.4.3.3. Life-cycle costs, computed on the basis of the capital, O&M, and D&D costs, are discussed in Section 5.4.3.4.

5.4.3.1 Capital Cost

The Westinghouse Savannah River Company (WSRC) Engineering and Construction Services Division has prepared a line-item cost estimate corresponding to the preconceptual design prepared by Bechtel (see Attachment 1). This cost estimate, which includes a 30% management reserve, establishes the capital cost of the 2 million gpy denitration system at \$23,024,000.

The addition of electrolyser cells and the upgrading of pumping systems will increase the capital costs. As shown in Table 5-11, RCS estimates the capital cost for a 4 million gpy electrochemical plant to be \$22.55 million.

5.4.3.2 Operation and Maintenance

WSRC has not performed a formal estimate of the O&M costs for the denitration system. However, the University of South Carolina recently determined that the electrical power

³⁷Personal Communication between David Hobbs, Savannah River Technology Center, and Michael Navetta, RCS, June 30, 1997.

Table 5-11. Electrochemical System Capital Cost Estimate (1997 Dollars)		
Item	Size	Cost, \$
Feed Tanks (2)	20,000 gallons each	170,000 ^a
Chemical Flush Tank	5,000 gallons	55,000 ^b
Knock-out Pot		10,500 ^b
Feed Tank Pumps (2)	3000 gpm, 300 ft. head	180,000
Miscellaneous Pumps		20,000
Demister		7,700 ^b
Electrolysers (10)	ICI FM 21	1,500,000
HEPA Filter (2)		28,000 ^b
Subtotal, Major Equipment		1,970,000
Miscellaneous Equipment @ 30% of Major Equipment		590,000
Equipment Installation, 50% of Major Equipment		990,000
Facilities @ \$200 / ft ²		12,000,000
Subtotal, Installed Equipment and Facilities		15,550,000
Engineering, 15%		2,330,000
Management Reserve, 30%		4,670,000
Total		22,550,000
Notes		
a	Verbal quotations from John Wood Co., Valley Forge, PA, and Dal-Worth Fabrication Inc., Grand Prairie, TX.	
b	Taken from Bechtel preconceptual cost estimate.	

requirements for the 2 million gpy denitration system designed by Bechtel would be 17.2 million

kWh/yr.³⁸ At a power consumption rate of 34.4 million kWh/yr and a unit cost of \$0.057 per kWh, the cost of electricity for a nominal 4 million gpy system would be approximately \$2,000,000 per year.

It is estimated that the operation of the electrochemical process would require two chemical operators and a supervisor on each shift. Corresponding annual labor costs are estimated to be \$780,000.

Total O&M costs have been estimated by RCS to be approximately \$3.97 million per year, as listed in Table 5-12. At a processing rate of 4 million gpy, these costs appportion to \$0.99 per gallon of alkaline waste treated.

Table 5-12. Annual O&M Costs, Electrochemical Denitration System			
O&M Item	Units	Unit Cost, \$	Extension, \$
Direct Labor (Fully Burdened) - Operators	8	60,000	480,000
Direct Labor (Fully Burdened) - Shift Supervisors	4	75,000	300,000
Process Electricity	34.4 million kWh	0.057	2,000,000
Support Utilities - HVAC, lighting, potable water, sewer	1 lot	60,000	60,000
Process Maintenance (5% of Capital Cost)	1 lot		1,130,000
Total			3,970,000

5.4.3.3 Decontamination and Decommissioning Costs

An estimate of the D&D costs has not been prepared by WSRC. Consistent with guidelines used in previous sections of this report, the author estimates the D&D costs to be \$30 million.

5.4.3.4 Life-Cycle Costs

For the purpose of estimating the present value of the total life-cycle cost for the electrochemical

³⁸Letter from John W. Van Zee (University of South Carolina) to David Hobbs (SRTC), December 27, 1996.

denitration system, the same assumptions described in Section 5.1.3.4 of this report were made. The present value of the life-cycle costs is estimated to be approximately \$325 million, as listed in Table 5-13.

Table 5-13. Present Value of Electrochemical Denitration System Life-Cycle Costs		
Cost Item	Cost, \$	Present Value, \$
Capital Cost (2000 dollars)	22,550,000	22,550,000
RCRA Permit	500,000	500,000
NEPA Documents	100,000	100,000
O&M Cost		
Year 1	3,970,000	
Total, Years 1 - 25	165,330,000	60,610,000
Residue Disposal		
Year 1 ^a	15,552,000	
Total, Years 1 - 25	647,700,000	237,451,000
D&D Cost (2023 Dollars)	30,000,000	3,760,000
Total	866,180,000	324,971,000
Notes		
a Assumes disposal of 3.2 million gallon of liquid per year in Saltstone at a unit cost of \$4.86 / gallon.		

5.4.4 Other Considerations

Several other considerations may impact the viability of the technology. These include the implementation schedule, secondary waste streams, pollution prevention, public acceptance, and regulatory permitting. Each is discussed in the ensuing sections of this report.

5.4.4.1 Implementation Schedule

The requirement to denitrate the alkaline wastes is short-term. To be viable for this application, the technology should be capable of (1) being implemented in a reasonably short period of time (i.e., less than 5 years) and (2) eliminating the anticipated inventory of 92 million gallons of alkaline waste at the SRS in 25 years or less.

Assuming a conventional technology development and procurement approach will be used and

funding will be available, it is estimated that a full-scale electrochemical process could be operational in 6 years. Approximately 2 years would be required to prepare the final engineering design. Regulatory permitting would also need to be completed during this 2-year period. Thereafter, the design, construction, and systemization of the electrochemical treatment system could be completed in 3 to 4 years. As stated previously, privatization may afford an opportunity to reduce this lead time below 5 years.

At a processing rate of 4 million gpy, the system should be capable of eliminating the inventory of alkaline nitrate-bearing mixed waste at the SRS in less than 25 years.

5.4.4.2 Secondary Waste Streams

To the extent possible, the treatment system should not produce large quantities of highly toxic secondary waste streams that would require treatment prior to disposal.

Two secondary waste streams are produced during the electrolysis of nitrates. The first is process off-gas containing hydrogen and ammonia. The second is electrode cleaning solution consisting of a mixture of acids, metals, and radionuclides. Both of these waste streams would be produced in substantial volume and would require treatment. The required treatment could probably be affected using conventional technologies, however.

5.4.4.3 Pollution Prevention

By reducing the nitrate content of the treated waste, electrolysis would reduce the toxicity and leachability of the final waste form (Saltstone). The use of Saltstone, however, would have the adverse effect of increasing the overall waste volume and final disposal costs by 40%.

5.4.4.4 Public Acceptance

Electrolysis has not been widely publicized, and there is no organized opposition to electrolysis from environmental or citizens groups. All indications are that the selection of electrochemical processing for the decontaminated salt solution task would receive public support.

5.4.4.5 Regulatory Permitting

The electrochemical process would require a RCRA Part B permit and an air pollution permit from the South Carolina Department of Health and Environmental Control. These permits would be relatively easy to acquire and would be much less expensive than the permits required for the Consolidated Incineration Facility (CIF). The permitting process could be completed in 12 to 24 months.

5.4.4.6 Versatility

The electrochemical process has been demonstrated to be capable of destroying organics in radioactive, mixed, and hazardous wastes. The process is more versatile than NAC but less

versatile than the thermal and hydrothermal alternatives.

6.0 EVALUATION OF ALTERNATIVE TECHNOLOGIES FOR NITRATE AND NITRITE DESTRUCTION AND SEPARATION

Section 5 briefly described the technical and economic merits of several treatment alternatives. Table 6-1 summarizes the information that was presented.

6.1 EVALUATION METHODOLOGY

RCS employed a two-step evaluation process to systematically assess the relative technical and economic merits of the treatment alternatives. In Step 1, technologies that could not reasonably be expected to meet the following performance standards were eliminated. In Step 2, the remaining technologies were ranked on the basis of economic and other considerations. Ranking was based on the assignment of numerical scores using the Delphi technique, as shown in Table 6-2.

6.2 TECHNOLOGY RANKING

Using the evaluation methodology described above, RCS scored and ranked the alternatives as shown in Table 6-3. The NAC process achieved the highest ranking. The ranking hierarchy of the technologies, in descending order of attractiveness, was as follows:

- NAC
- Vitrification
- Electrochemical
- Hydrothermal
- Steam Reforming
- Plasma Arc

6.3 UNCERTAINTY ANALYSIS

Much work remains to be done in developing the denitration technologies investigated for this report. Full-scale flowsheets encompassing both the waste processing and off-gas and residuals treatment systems have not been completed. Accordingly, there remain significant uncertainties with regards to treatment efficacy and mass and energy balances. These technical uncertainties, in turn, impart uncertainties to the cost analyses reported in the previous sections.

The disposal costs for process residues from plasma arc, vitrification, and NAC were predicated on those residues being delisted from RCRA Subtitle C regulation and disposed of as low-level wastes at significant savings over disposal as mixed wastes. The delisting process is highly

Table 6-1. Technology Summary

Technology	Advantages	Disadvantages	Able to Meet Performance Standards?	Maturity and R&D Needs	Costs	Other Considerations
Fluidized Bed Calciner	<p>Significant volume reductions are possible.</p> <p>Process has been proven to work at full-scale on low sodium radioactive waste streams.</p> <p>Over 30 years of operational experience with calciners at the INEL.</p>	<p>High capital and operating costs.</p> <p>Not useful when the waste contains alkali metals, including sodium. Alkali metals cause sintering of the fluidized solid media.</p> <p>Process off-gas contains high levels of NO_x that require treatment before release to the atmosphere.</p> <p>The solid process residue (calcine) will require further treatment prior to disposal.</p>	No	Operational at full-scale.	Not applicable, eliminated from further consideration.	Not applicable, eliminated from further consideration.
Steam Reforming	<p>Significant volume reductions are possible.</p> <p>The process can destroy organics in addition to nitrates and nitrites.</p>	<p>Process off-gas contains NO_x at levels that will require treatment prior to discharge to the atmosphere.</p> <p>The process generates a liquid secondary waste stream.</p>	Yes	Requires pilot-scale testing on nitrate wastes.	<p>Capital, \$33.3 million</p> <p>O&M, \$3.5 million/yr</p> <p>Life-cycle, \$300 million</p>	Volume reductions in excess of 70% are possible.

Table 6-1. Technology Summary

Technology	Advantages	Disadvantages	Able to Meet Performance Standard?	Maturity and R&D Needs	Costs	Other Considerations
Plasma Arc	<p>Significant volume reductions are possible.</p> <p>Product slag is highly resistant to leaching, has a matrix durability similar to engineered glasses, and may be suitable for disposal without further treatment.</p> <p>Nitrates are converted primarily to nitrogen gas.</p> <p>The performance of the system is relatively insensitive to waste composition, minimizing the need to conduct extensive waste characterization and segregation prior to treatment.</p> <p>The treatment system is versatile and can accept a wide range of solid and liquid wastes.</p>	<p>High capital and operating costs.</p> <p>Requires extensive development work before a full-scale plant could be built.</p> <p>The economic utility of the plasma arc process chiefly applies to solid or sludge wastes that contain significant quantities of slagging materials.</p>	Yes	Requires pilot testing on nitrate wastes.	<p>Capital, \$46.6 million</p> <p>O&M, \$10.2 million/yr</p> <p>Life-cycle, \$289 million</p>	<p>Volume reductions in excess of 70% are possible.</p> <p>Process is versatile and could accept other waste streams.</p>

Table 6-1. Technology Summary

Technology	Advantages	Disadvantages	Able to Meet Performance Standards?	Maturity and R&D Needs	Costs	Other Considerations
NAC	<p>Waste feeds would not require pretreatment.</p> <p>The process residual would be an insoluble solid.</p> <p>The process could use scrap aluminum as a feed material.</p> <p>The process operates at low temperatures.</p>	<p>Process is highly exothermic</p> <p>Process off-gases would require treatment</p>	Yes	Pilot-scale testing would be needed.	<p>Capital, \$21.8 million</p> <p>O&M, \$2.9 million/yr</p> <p>Life-cycle, \$112 million</p>	<p>Volume reductions in excess of 70% are possible.</p> <p>Process is not versatile.</p>
Electrochemical	<p>Waste feeds would not require pretreatment.</p> <p>The process could be used on both acidic and alkaline wastes.</p> <p>The potential exists to destroy organics in the waste.</p>	<p>Electrolysis would produce flammable and toxic off-gas that would require treatment.</p> <p>The product of hydrolysis would require stabilization prior to disposal.</p> <p>The electrochemical process would produce sodium hydroxide that may have to be separated from the product stream before stabilization and disposal.</p>	Yes	Some pilot-scale work is needed to refine the process flowsheet.	<p>Capital, \$22.6 million</p> <p>O&M, \$4 million/yr</p> <p>Life-cycle, \$325 million</p>	<p>Electrochemical processing followed by stabilization in Salstone leads to an overall 40% increase in waste volume.</p>

Table 6-1. Technology Summary

Technology	Advantages	Disadvantages	Able to Meet Performance Standards?	Maturity and R&D Needs	Costs	Other Considerations
Vitrification	<p>Significant volume reductions are possible</p> <p>Product glass or slag may be suitable for disposal without further treatment</p> <p>Process has been proven to work on other radioactive waste streams</p> <p>Significant experience with vitrification systems at the SRS, including the DWPF and the GTS Duratek system</p> <p>The treatment system is versatile and can accept a wide range of solid and liquid wastes.</p>	<p>High capital and operating costs</p> <p>Process off-gas contains high levels of NO_x which require treatment before release to the atmosphere</p>	Yes	Requires pilot testing on nitrate wastes	<p>Capital, \$46.6 million</p> <p>O&M, \$111.7 million / yr</p> <p>Life-cycle, \$312 million</p>	<p>Volume reductions in excess of 70% are possible.</p> <p>Process is versatile and could accept other waste streams</p>
Hydrothermal	<p>Process works on both acidic and alkaline wastes.</p> <p>Organics in the waste feed are destroyed.</p> <p>It may be possible to remove salts as solids, thereby facilitating greater volume reduction.</p>	<p>Plugging of the piping systems is a concern.</p> <p>Corrosion of process equipment.</p> <p>Treatment of off-gases may be needed.</p>	Yes	Pilot testing will be needed.	<p>Capital, \$29.3 million</p> <p>O&M, \$3 million/yr</p> <p>Life-cycle, \$168 million</p>	<p>Volume reductions in excess of 70% are possible</p> <p>The process has the flexibility to treat other waste streams.</p>
Conventional Chemical	Not applicable, eliminated from consideration.	Not applicable, eliminated from consideration.	No	Not applicable, eliminated from consideration.	Not applicable, eliminated from consideration.	Not applicable, eliminated from consideration.

Table 6-2. Scoring System	
Consideration	Score
Destruction/Separation Efficiency	If > 90%, score is 1. If <90%, total score is 0 and technology is eliminated.
Worker Protection, Radiological, and Process Safety Standards	If able to meet all, score is 1. If unable to meet any, total score is 0 and technology is eliminated.
Environmental Protection Standards	If able to meet all, score is 1. If unable to meet any, total score is 0 and technology is eliminated.
Technology Maturity	Score is 0 if not tested using nitrate wastes. Score is 1 if bench-scale tested using nitrate wastes. Score is 5 if pilot-scale tested using nitrate wastes. Score is 10 if engineering-scale tested using nitrate wastes. Score is 17 if full-scale facility has treated nitrate wastes.
Cost	If present value of life-cycle cost < \$150 million, score is 30. If present value of life-cycle cost > \$150 million and < \$250 million, score is 20. If present value of life-cycle cost > \$250 million and < \$350 million, score is 10. If present value of life-cycle cost > \$350 million, score is 0.
Implementation Schedule	If < 5 years using conventional approach, score is 5. If privatization can be used to get to <5 years, score is 3. Otherwise, score is 0.
Secondary Waste Streams	If significant quantities are produced, score is 0. Otherwise, score is 5.

Table 6-2. Scoring System	
Consideration	Score
Pollution Prevention	<p>If no volume reduction, score is 0.</p> <p>If volume reduction < 50%, score is 5.</p> <p>If volume reduction > 50%, score is 10.</p>
Public Acceptance	<p>If strong, organized opposition, score is 0.</p> <p>If moderate opposition, score is 3.</p> <p>Otherwise, score is 10.</p>
Regulatory Permitting	<p>If very difficult, score is 0.</p> <p>If moderately difficult, score is 5.</p> <p>If relatively easy, score is 10.</p>
Versatility	<p>If process is adaptable to many waste streams, score is 10.</p> <p>If process is adaptable to a few waste streams, score is 5.</p> <p>If process is limited to nitrates only, score is 0.</p>
Maximum Score is 100	

Table 6-3. Technology Scoring

Consideration	Technology							
	Fluidized Bed Calciner	Steam Reformer	Plasma Arc	Vitrification	Hydrothermal	Conventional Chemical	NAC	Electrochemical
Destruction / Separation Efficiency	0	1	1	1	1	0	1	1
Worker Protection, Radiological, and Process Safety Standards		1	1	1	1		1	1
Environmental Protection Standards		1	1	1	1		1	1
Technology Maturity		0	0	17	1		1	17
Cost		10	10	10	20		30	10
Implementation Schedule		3	3	3	3		3	3
Secondary Waste Streams		5	5	5	0		5	0
Pollution Prevention		10	10	10	5		10	0
Public Acceptance		10	3	3	10		10	10
Regulatory Permitting		10	5	5	10		10	10
Versatility		5	10	10	5		0	5
Total	0	56	49	66	57	0	72	58
Rank	N/A	5	6	2	4	N/A	1	3

uncertain. Consequently, the disposal costs for these residues could increase substantially over those reported if delisting proves to be impracticable.

The ranking of the technologies is particularly sensitive to the life-cycle costs. The technology ranking was most strongly correlated to the O&M and residue disposal costs. Given that the operating experience with these alternatives is limited, there is significant uncertainty in the O&M and residue disposal costs.

To test the effects of this uncertainty on the ranking process, the O&M and residue disposal costs for the top three alternatives were increased by 25% and those of the bottom three alternatives were reduced by 25%. Life-cycle costs were then recomputed and the alternatives were rescored using the same methodology described in Table 6-2. The results, summarized in Table 6-4, indicate a much different selection hierarchy as follows:

- NAC
- Hydrothermal
- Steam Reforming
- Plasma Arc
- Vitrification
- Electrochemical

7.0 CONCLUSIONS AND RECOMMENDATIONS

The following technologies that were investigated by RCS appear to be capable of meeting the technical and procedural performance standards for the nitrate/nitrite treatment system to be constructed at the SRS:

- Electrochemical
- Steam reforming
- NAC
- Hydrothermal
- Vitrification
- Plasma arc

Table 6-4. Uncertainty Analysis Scoring

Consideration	Technology							
	Fluidized Bed Calciner	Steam Reformer	Plasma Arc	Vitrification	Hydrothermal	Conventional Chemical	NAC	Electrochemical
Destruction/Separation Efficiency	0	1	1	1	1	0	1	1
Worker Protection, Radiological, and Process Safety Standards		1	1	1	1		1	1
Environmental Protection Standards		1	1	1	1		1	1
Technology Maturity		0	0	17	1		1	17
Cost		20	20	0	30		30	0
Implementation Schedule		3	3	3	3		3	3
Secondary Waste Streams		5	5	5	0		5	0
Pollution Prevention		10	10	10	5		10	0
Public Acceptance		10	3	3	10		10	10
Regulatory Permitting		10	5	5	10		10	10
Versatility		5	10	10	5		0	5
Total	0	66	59	56	67	0	72	48
Rank	N/A	3	4	5	2	N/A	1	6

The technologies that exhibit the most favorable economics are NAC, hydrothermal, and plasma arc. Considering other factors in addition to economics, such as implementation schedule, pollution prevention, and public acceptance, the ranking performed by RCS indicates the hierarchy of alternatives, in descending order of attractiveness, to be as follows:

- NAC
- Vitrification
- Electrochemical
- Hydrothermal
- Steam Reforming
- Plasma Arc

The ranking performed by RCS is most sensitive to life-cycle costs, especially O&M costs. Increasing the life-cycle costs of the three most attractive alternatives by 25% while reducing the O&M costs of the three least attractive alternatives by that same percentage has the effect of reordering the hierarchy as follows:

- NAC
- Hydrothermal
- Steam Reforming
- Plasma Arc
- Vitrification
- Electrochemical

For this reason, the life-cycle costs of the alternatives should be more rigorously examined before the final technology is selected.

The other principal conclusions of this report are as follows:

- All of the technologies listed above would require extensive development before a full-scale process for treating SRS waste could be constructed and operated.
- The technical and economic feasibility of the NAC, vitrification, and electrochemical processes would be most attractive, relative to the other alternatives investigated.

- More robust treatment technologies, such as plasma arc or vitrification, are more versatile than the electrochemical, steam reforming, hydrothermal, and NAC processes and offer the ability to treat additional waste streams.
- Some type of privatization may be required to expedite the deployment of the selected technology.
- The ranking of the electrochemical is suppressed more than any other by high residue disposal costs. If the cost of Saltstone operations and final disposal could be reduced, the ranking of the electrochemical process would rise.

The electrochemical reduction process has been extensively tested on SRS waste streams and is more mature in this application than the other technologies. There remain significant uncertainties in the development of all of the technologies investigated; however, the uncertainties associated with electrochemical reduction are much smaller than those associated with the other technologies.

**ATTACHMENT 1. PRECONCEPTUAL COST ESTIMATE, ELECTROCHEMICAL
DENITRATION AND CAUSTIC RECOVERY, PHASE I**

ENGINEERING & CONSTRUCTION SERVICES DIVISION
SITE PROJECT ESTIMATING

WESTINGHOUSE SAVANNAH RIVER COMPANY

SUMMARY REPORT PAGE # 1
ESTIMATED BY: WNW/WLK/DM
LOCATION 2: 730-1B / 1080
DESIGN CLASSIFICATION: PS/C
TIME: 12:56:30
DATE: 23-Aug-1996
FILE: NITRREC.V.PWS
REPORT NAME: Sum WBS 9697 G&A signoff box

ESTIMATE SUMMARY LEVEL REPORT

LOG NUMBER: 96-05-06, R/1
PROJECT NAME: ELECTROCHEMICAL DENITRATION & CAUSTIC REC., PHASE I
LOCATION 1: S-AREA
PROJ. MANAGER: D. HOBBS
ESTIMATE TYPE: PRE-CONCEPTUAL
SITE WBS: SITE WBS
PRICING: POST 94 RATES

WBS ELEMENT	DESCRIPTION	HOURS	LABOR	CONST. EQUIP.	MAT'L	ENGR'D EQUIP.	CONTRACT SERVICES	TOTAL COST
1.0	TOTAL ESTIMATED COST (TEC)							
1.1	ENGINEERING	31,818	\$2,033,189					\$2,033,189
1.2	CONSTRUCTION	104,853	\$3,767,923	\$678,897	\$1,910,462	\$2,175,000	\$1,394,748	\$9,927,030
1.4	PROJECT SUPPORT	19,732	\$1,394,033					\$1,394,033
	ESCALATION FOR TOTAL ESTIMATED COST (TEC)		565,199	65,853	185,315	210,975	135,291	1,162,632
	TOTAL ESTIMATED COST (TEC) SUBTOTAL	156,403	\$7,760,344	\$744,750	\$2,095,777	\$2,385,975	\$1,530,039	\$14,516,885

FY 97 G & A RATE @ 22.00% AND APPLIED TO 100.00 % OF ALL TOTALS \$3,193,715

SUBTOTAL WITHOUT CONTINGENCY \$17,710,599

MANAGEMENT RESERVE @ 30.00% \$5,313,000

CONTINGENCY @ 0.00 % \$0

PROJECT TOTAL COST

\$23,024,000

APPROVAL SIGNATURES

TPC PROJECT MANAGER	DATE
CONSTRUCTION	DATE
PROJECT ENGINEERING MANAGER (PEM)	DATE
ESTIMATING MANAGER	DATE
ESTIMATOR	DATE
PEER	DATE
LEAD	DATE

ENGINEERING & CONSTRUCTION SERVICES DIVISION
SITE PROJECT ESTIMATING

ESTIMATE SUMMARY LEVEL REPORT

WESTINGHOUSE SAVANNAH RIVER COMPANY

LINE ITEM:

PROJECT NO:

LOG NUMBER: 96-05-06, R/1

PROJECT NAME: ELECTROCHEMICAL DENITRATION & CAUSTIC REC., PHASE I

LOCATION 1: S-AREA

PROJ. MANAGER: D. HOBBS

ESTIMATE TYPE: PRE-CONCEPTUAL

SITE WBS: SITE WBS

PRICING: POST 94 RATES

SUMMARY REPORT PAGE # 1

ESTIMATED BY: WNW/WLKD/DM

LOCATION 2: 730-1B / 1080

DESIGN CLASSIFICATION: PS/C

TIME: 12:56:37

DATE: 23-Aug-1996

FILE: NITRREC.V.PWS

REPORT NAME: Sum WBS level Indent comp

WBS ELEMENT	DESCRIPTION	HOURS	LABOR	CONST. EQUIP.	MAT'L	ENGR'D EQUIP.	CONTRACT SERVICES	TOTAL COST
1.0	TOTAL ESTIMATED COST (TEC)	156,403	7,195,146	678,897	1,910,462	2,175,000	1,394,748	13,354,253
1.1	ENGINEERING	31,818	2,033,189					2,033,189
1.1.1	DIRECT ENGINEERING	31,818	2,033,189					2,033,189
1.2	CONSTRUCTION	104,853	3,767,923	678,897	1,910,462	2,175,000	1,394,748	9,927,030
1.2.2	SRS CONSTRUCTION	77,621	2,550,379	678,897	1,910,462	2,175,000	1,315,800	8,630,538
1.2.2.1	BUILDING WORK	52,286	1,726,356		1,703,491	2,175,000	1,220,800	6,825,647
1.2.2.1.1	ADMIN. AREA	10,118	335,807		387,064	392,500	371,800	1,487,171
1.2.2.1.1.1	C/S/A WORK - ADMIN. AREA	2,598	77,320		74,061		343,200	494,581
1.2.2.1.1.2	ELECTRICAL WORK - ADMIN. AREA	1,685	60,051		13,842	17,500		91,394
1.2.2.1.1.3	MECHANICAL WORK - ADMIN. AREA	4,244	147,396		117,660		28,600	293,657
1.2.2.1.1.3.1	EQUIPMENT - ADMIN. AREA	3,032	105,197		83,054		28,600	188,251
1.2.2.1.1.3.2	PIPING - ADMIN. AREA	1,213	42,200		34,606			105,406
1.2.2.1.1.4	MISC. ITEMS - ADMIN. AREA	1,590	51,039		181,500	375,000		607,539
1.2.2.1.2	PROCESS AREA	42,168	1,390,549		1,316,427	1,782,500	849,000	5,338,476
1.2.2.1.2.1	C/S/A WORK - PROCESS AREA	21,423	660,777		352,885		839,000	1,852,662
1.2.2.1.2.2	ELECTRICAL WORK - PROCESS AREA	6,138	218,968		81,457	111,250		411,675
1.2.2.1.2.3	MECHANICAL WORK - PROCESS AREA	14,607	510,804		882,085	1,671,250	10,000	3,074,139
1.2.2.1.2.3.1	EQUIPMENT - PROCESS AREA	6,391	224,899		416,313	1,671,250	10,000	2,322,461
1.2.2.1.2.3.2	PIPING - PROCESS AREA	8,216	285,905		465,773			751,678
1.2.2.2	SITEWORK / UTILITIES / U.G. PROCESS	25,335	824,023		206,971		95,000	1,125,993
1.2.2.2.1	CIVIL WORK - SITEWORK/UTILITIES	13,386	408,255		95,772		75,000	579,026
1.2.2.2.2	ELECTRICAL WORK - SITEWORK/UTILITIES	1,120	39,887		62,618			102,504
1.2.2.2.3	MECHANICAL WORK - SITEWORK/UTILITIES	10,737	373,657		42,895		20,000	436,551
1.2.2.2.3.1	EQUIPMENT - SITEWORK/UTILITIES	233	8,113		18,150		20,000	46,263
1.2.2.2.3.2	PIPING - SITEWORK/UTILITIES	10,504	365,544		24,745			390,288

ENGINEERING & CONSTRUCTION SERVICES DIVISION

WESTINGHOUSE SAVANNAH RIVER COMPANY

SUMMARY REPORT PAGE # 2
 ESTIMATED BY: WNW/WLK/DM
 LOCATION 2: 730-1B / 1080
 DESIGN CLASSIFICATION: PS/C
 TIME: 12:56:37
 DATE: 23-Aug-1996
 FILE: NITRRECV.PWS
 REPORT NAME: Sum WBS level Indent comp

SITE PROJECT ESTIMATING ESTIMATE SUMMARY LEVEL REPORT

LOG NUMBER: 96-05-06, R/1
 PROJECT NAME: ELECTROCHEMICAL DENITRATION & CAUSTIC REC., PHASE I
 LOCATION 1: S-AREA
 PROJ. MANAGER: D. HOBBS
 ESTIMATE TYPE: PRE-CONCEPTUAL
 SITE WBS: SITE WBS
 PRICING: POST 94 RATES

WBS ELEMENT	DESCRIPTION	HOURS	LABOR	CONSTR. EQUIP.	MAT'L	ENGR'D EQUIP.	CONTRACT SERVICES	TOTAL COST
1.2.2.2.3.2.1	CORE/JKT. WASTE TRANSFER LINE - SITEWORK	10,320	359,125		18,392			377,517
1.2.2.2.3.2.2	DOMESTIC WATER - SITEWORK	74	2,576		1,906			4,482
1.2.2.2.3.2.3	FIRE PROTECTION PIPING - SITEWORK	110	3,843		4,447			8,290
1.2.2.2.4	MISC. ITEMS - SITEWORK/UTILITIES	91	2,224		5,687			7,911
1.2.2.3	BEMCAP			678,897				678,897
1.2.3	CONTRACT ADMINISTRATION / CRAFT SUPPORT / OTHER	12,419	373,821				78,948	452,769
1.2.3.1	CONTRACT ADMIN. / COST DISTR. / OTHER	12,419	373,821				78,948	78,948
1.2.3.9	CRAFT SUPPORT							373,821
1.2.4	CONSTRUCTION NONMANUAL	14,813	843,723					843,723
1.4	PROJECT SUPPORT	19,732	1,394,033					1,394,033
1.4.1	PROJECT MANAGEMENT	8,216	637,562					637,562
1.4.2	PROJECT CONTROLS PM	4,562	299,661					299,661
1.4.3	PROJECT CONTROLS DESIGN ENGINEERING	1,521	99,887					99,887
1.4.4	PROJECT CONTROLS CONSTRUCTION	5,433	356,923					356,923

ENGINEERING & CONSTRUCTION SERVICES DIVISION

WESTINGHOUSE SAVANNAH RIVER COMPANY

SITE PROJECT ESTIMATING

PAGE # 2
ESTIMATED BY: WNW/WLK/DM
LOCATION 2: 730-1B / 1080
DESIGN CLASSIFICATION: PS/C
TIME: 12:56:08
DATE 23-Aug-1996
FILE: NITRRCV.PWS

DETAIL LINE ITEM REPORT

REPORT NAME: Detail Cost by WBS 9697 by seq

PROJECT NO.:
LINE ITEM:
LOG NUMBER: 96-05-06, R/1
PROJECT NAME: ELECTROCHEMICAL DENITRATION & CAUSTIC REC., PHASE I
LOCATION 1: S-AREA
PROJ. MANAGER: D. HOBBS
ESTIMATE TYPE: PRE-CONCEPTUAL
SITE WBS: SITE WBS

PRICING: POST 94 RATES

WBS SOURCE / TWC	DESCRIPTION	QUANTITY	UOM	CREW SUB	BASE	HOURS ADJUST	LABOR	CONST. EQUIP.	MAT'L	ENGR'D EQUIP.	CONTRACT SERVICES	TOTAL COST
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1.2.2.1.1.1 C/S/A WORK - ADMIN. AREA

TWC CODE:	MISC. FLOOR COVERINGS	700 SY			0.000	0.000	N/A		24.20			24
					1.00				16,940			16,940
TWC CODE:	F&I FORMWORK	5,000 SFCA			0.250	0.265	28.70		1.82			9
					1.06	1,325	38,028		9,075			47,103
TWC CODE:	F&I REBAR	25 TN			1.06	398	13,603		9			13,612
					1.06	1,500	28.30		96.80			142
TWC CODE:	F&I C.I.P. CONCRETE Memo: INCLUDES TRUCK APRON, SIDEWALKS, STOOPS, ETC.	400 CY			1.06	636	18,000		38,720			56,720

C/S/A WORK - ADMIN. AREA SUBTOTAL

					2,598		\$77,320		\$74,061		\$343,200	\$494,581
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1.2.2.1.1.2 ELECTRICAL WORK - ADMIN. AREA

TWC CODE:	MISC. ELECTRICAL WORK Memo: INCLUDES MCC'S AND OTHER REQUIRED WIRING, CONDUIT, AND CABLE FOR CONTROL ROOM, OFFICE AND LAB AREA	5,720 SF			0.250	0.265	35.60		2.42			12
					1.06	1,516	53,962		13,842			67,805
TWC CODE:	DCS W/SOFTWARE	1 LS			1.06	170	6,089					23,589
												23,589

ELECTRICAL WORK - ADMIN. AREA SUBTOTAL

					1,685		\$60,051		\$13,842		\$17,500	\$91,394
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ENGINEERING & CONSTRUCTION SERVICES DIVISION

SITE PROJECT ESTIMATING

WESTINGHOUSE SAVANNAH RIVER COMPANY

PROJECT NO.:

LINE ITEM:

LOG NUMBER: 96-05-06, R/1

PROJECT NAME: ELECTROCHEMICAL DENITRATION & CAUSTIC REC., PHASE I

LOCATION 1: S-AREA

PROJ. MANAGER D. HOBBS

ESTIMATE TYPE: PRE-CONCEPTUAL

SITE WBS: 1

PRICING: POST 94 RATES

DETAIL LINE ITEM REPORT

REPORT NAME: Detail Cost by WBS 9697 by seq

FILE: NITRRECV.PWS

DATE 23-Aug-1996

TIME: 12:56:08

DESIGN CLASSIFICATION: PS/C

LOCATION 2: 730-1B / 1080

ESTIMATED BY: WNW/WLK/DM

PAGE # 3

WBS	SOURCE / TWC	DESCRIPTION	QUANTITY	UOM	CREW	SUB	BASE	HOURS	ADJUST	LABOR	CONST. EQUIP.	MAT'L	ENGR'D EQUIP.	CONTRACT SERVICES	TOTAL COST
-----	--------------	-------------	----------	-----	------	-----	------	-------	--------	-------	---------------	-------	---------------	-------------------	------------

1.2.2.1.1.3.1 EQUIPMENT - ADMIN. AREA

TWC CODE:		HVAC SYSTEM					0.500	0.530		34.70	14.52				33
		Memo:													
		INCLUDES DUCTWORK AND HVAC UNIT AS REQUIRED FOR COOLING/HEATING LOADS.	5,720 SF				1.06	3,032		105,197	83,054				188,251

EQUIPMENT - ADMIN. AREA SUBTOTAL

1.2.2.1.1.3.2 PIPING - ADMIN. AREA

TWC CODE:		FIRE PROTECTION SYSTEM					0.000	0.000		N/A					5
		Memo:													
		INCLUDES DELUGE SYSTEM, STANDPIPES, AND FIRE DETECTION.	5,720 SF				1.00							28,600	28,600

TWC CODE:		PLUMBING					0.200	0.212		34.80	6.05				13
			5,720 SF				1.06	1,213		42,200	34,606				76,806

PIPING - ADMIN. AREA SUBTOTAL

1.2.2.1.1.4 MISC. ITEMS - ADMIN. AREA

TWC CODE:		ANALYTICAL / OFFICE EQUIPMENT / FURNITURE					1500.00	1590.00		32.10	181,500.00	375000			607539
		Memo:													
		INCLUDES FUME HOODS, GLOVEBOXES, PORTAL & CONSTANT AIR MONITORS.	1 LS				1.06	1,590		51,039	181,500	375,000			607,539

MISC. ITEMS - ADMIN. AREA SUBTOTAL

								1,590		\$51,039	\$181,500	\$375,000			\$607,539
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ENGINEERING & CONSTRUCTION SERVICES DIVISION

WESTINGHOUSE SAVANNAH RIVER COMPANY

SITE PROJECT ESTIMATING

PAGE # 4
ESTIMATED BY: WNW/WLK/DM
LOCATION 2: 730-1B / 1080
DESIGN CLASSIFICATION: PS/C
TIME: 12:56:08

PROJECT NO.:
LINE ITEM: 96-05-06, R/I
LOG NUMBER: ELECTOCHEMICAL DENITRATION & CAUSTIC REC., PHASE I
LOCATION 1: S-AREA

PROJ. MANAGER: D. HOBBS
ESTIMATE TYPE: PRE-CONCEPTUAL
SITE WBS: 1

DETAIL LINE ITEM REPORT

PRICING: POST 94 RATES

REPORT NAME: Detail Cost by WBS 9697 by seq

FILE: NITRRECV.PWS

WBS SOURCE / TWC	DESCRIPTION	QUANTITY	UOM	CREW SUB	BASE	HOURS ADJUST	LABOR	CONST. EQUIP.	MAT'L	ENGR'D EQUIP.	CONTRACT SERVICES	TOTAL COST
---------------------	-------------	----------	-----	-------------	------	-----------------	-------	------------------	-------	------------------	----------------------	---------------

1.2.2.1.2.1 C/S/A WORK - PROCESS AREA

TWC CODE:	EXTERIOR DOOR 3/0 X 7/0 W/HARDWARE	3 EA	EA	SRSX13	10,000	10,600	32.10		363.00			703
					1.06	32	1,021		1,089			2,110
TWC CODE:	INTERIOR DOOR 3/0 X 7/0 W/HARDWARE	9 EA	EA	SRSX13	8,000	8,480	32.10		363.00			635
					1.06	76	2,450		3,267			5,717
TWC CODE:	FREIGHT ROLL-UP DOOR	1 EA	EA	SRSX07	0.250	0.265	28.70		3,630.00			4,719
					1.06	34	1,089		3,630			4,719
TWC CODE:	F&I FORMWORK	30,000 SFCA	SFCA	SRSX07	15,009	7,950	228,165		54,450			282,615
					1.06	0.250	28.70		1.82			9
TWC CODE:	F&I REBAR	135 TN	TN	SRSX08	15,009	15,910	34.20		0.36			544
					1.06	2,148	73,456		49			73,505
TWC CODE:	F&I C.I.P. CONCRETE	1,500 CY	CY	SRSX06	1,500	1,590	28.30		96.80			142
					1.06	2,385	67,496		145,200			212,696
TWC CODE:	MISC. EMBEDS (ALLOWANCE) Memo: INCLUDES HATCH COVER HARDWARE.	40,000 LB	LB	SRSX09	0.070	0.074	33.50		2.42			5
					1.06	2,968	99,428		96,800			196,228
TWC CODE:	CIVIL / STRUCTURAL / ARCH. (TOTAL PROCESS AREA) Memo: INCLUDES ROOFING, SIDING, AND MISC. NON-CONCRETE PARTITIONS.	10,780 SF	SF		0.000	0.000	N/A					50
					1.00				539,000			539,000

ENGINEERING & CONSTRUCTION SERVICES DIVISION

WESTINGHOUSE SAVANNAH RIVER COMPANY

SITE PROJECT ESTIMATING

PAGE # 5

ESTIMATED BY: WNW/WLK/DM

LOCATION 2: 730-1B / 1080

DESIGN CLASSIFICATION: PS/C

TIME: 12:56:08

DATE 23-Aug-1996

FILE: NITRRCV.PWS

REPORT NAME: Detail Cost by WBS 9697 by seq

DETAIL LINE ITEM REPORT

PRICING: POST 94 RATES

PROJECT NO.:
LINE ITEM:
LOG NUMBER: 96-05-06, R/1
PROJECT NAME: ELECTROCHEMICAL DENITRATION & CAUSTIC REC., PHASE I
LOCATION 1: S-AREA

PROJ. MANAGER: D. HOBBS
ESTIMATE TYPE: PRE-CONCEPTUAL
SITE WBS: SITE WBS

WBS SOURCE / TWC	DESCRIPTION	QUANTITY	UOM	CREW SUB	HOURS BASE	ADJUST	LABOR	CONST. EQUIP.	MAT'L	ENGR'D EQUIP.	CONTRACT SERVICES	TOTAL COST
C/S/A WORK - PROCESS AREA												
	BRIDGE CRANE SUPPORT SYSTEM - FABRICATED				0.000	0.000	N/A				2,000	2000
TWC CODE:	Memo: INCLUDES HANDRAIL, STAIR TOWER, AND MISC. SUPPORTS.	150 TN			1.00						300,000	300,000
	BRIDGE CRANE SUPPORT SYSTEM - INSTALLATION				1.06	1,590	10.600	34.30				364
TWC CODE:		150 TN			1.06	1,590	54,537					54,537
	MISC. FLOOR & WALL COATINGS, SEALANTS, ETC.				1.06	4,240	133,136	48,400	1.21			5
TWC CODE:		40,000 SF			1.06	4,240	31.40					181,536
C/S/A WORK - PROCESS AREA SUBTOTAL												
					21,423	\$660,777			\$352,885		\$839,000	\$1,852,662

1.2.2.1.2.2 ELECTRICAL WORK - PROCESS AREA

	ELECTRIC BUS, BRIDGE CRANE				1.06	170	35.90			12,500		18,589
TWC CODE:		1 EA			1.06	170	6,089			12,500		18,589
	PROCESS INSTRUMENTS				1.06	106	35.90			12,500		16,305
TWC CODE:		1 LS			1.06	106	3,805			12,500		16,305
	INSTRUMENT LOOPS				1.06	38.160	35.90			2250		3620
TWC CODE:		20 EA			1.06	763	27,399			45,000		72,399
	CLOSED CIRCUIT TV SYSTEM FOR CRANE				1.06	424.000	35.90			41,250		56,472
TWC CODE:		1 LS			1.06	424	15,222			41,250		56,472

ENGINEERING & CONSTRUCTION SERVICES DIVISION

WESTINGHOUSE SAVANNAH RIVER COMPANY

SITE PROJECT ESTIMATING

PAGE # 8
ESTIMATED BY: WNW/WLK/DM
LOCATION 2: 730-1B / 1080
DESIGN CLASSIFICATION: PS/C
TIME: 12:56:08

PROJECT NO.:
LOG NUMBER: 96-05-06, R/1
PROJECT NAME: ELECTROCHEMICAL DENITRATION & CAUSTIC REC., PHASE I
LOCATION 1: S-AREA

PROJ. MANAGER: D. HOBBS
ESTIMATE TYPE: PRE-CONCEPTUAL
SITE WBS: SITE WBS

DETAIL LINE ITEM REPORT

PRICING: POST 94 RATES

REPORT NAME: Detail Cost by WBS 9697 by seq

SOURCE / TWC	DESCRIPTION	QUANTITY	UOM	CREW SUB	HOURS BASE	ADJUST	LABOR	CONST. EQUIP.	MAT'L	ENGR'D EQUIP.	CONTRACT SERVICES	TOTAL COST
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1.2.2.1.2.3.1 EQUIPMENT - PROCESS AREA

TWC CODE:	F&I SEAL POT	1 EA		SRSX01	40.000	42.400	35.20			6250		7742
					1.06	42	1,492			6,250		7,742
		10 EA	Unit Cost	SRSX01	300.000	318.000	35.20	605.00		137500		149299
	F&I ELECTROCHEMICAL REACTORS Memo: ELECTROLYSERS FM21-SP MANUFACTURED BY ICI, INC., - VENDOR BUDGET QUOTE @ \$100,000 EA. & INCLUDES 10% FOR FREIGHT & DUTY (EQ. # 100-EC-1 THRU 10).				1.06	3,180	111,936	6,050		1,375,000		1,492,986
	VENDOR TECHNICAL REPRESENTATIVE	1 LS			0.000	0.000	N/A			10,000		10000
					1.00					10,000		10,000
	VENTILATION SYSTEM	10,780 SF	Unit Cost	SRSX01	0.075	0.079	35.20	2.42				5
					1.06	857	30,167	26,088				56,254
	FIRE EXTINGUISHER / SMOKE DETECTORS ALLOWANCE	1 LS		SRSX25	160.000	169.600	34.80	4,840.00				10742
					1.06	170	5,902	4,840				10,742
	PROCESS ROOM HEPA FILTER Memo: (EQ. # 100-FLT-1 & 2)	2 EA	Unit Cost	SRSX01	40.000	42.400	35.20			12500		13992
					1.06	85	2,985			25,000		27,985
	BLOWER FOR HEPA FILTER Memo: (EQ. # 100-BLR-1)	1 EA		SRSX01	24.000	25.440	35.20			7500		8395
					1.06	25	895			7,500		8,395
	ROOM EXHAUST BLOWER Memo: (EQ. # 100-BLR-3)	1 EA		SRSX01	24.024	25.465	35.20			7500		8396
					1.06	25	896			7,500		8,396
	SPARE BLOWER FOR HEPA FILTER Memo: (EQ. # 100-BLR-2)	1 EA		SRSX01	24.000	25.440	35.20			5000		5895
					1.06	25	895			5,000		5,895

ENGINEERING & CONSTRUCTION SERVICES DIVISION

SITE PROJECT ESTIMATING

WESTINGHOUSE SAVANNAH RIVER COMPANY

PROJECT NO.: 96-05-06, R/1
LINE ITEM: 96-05-06, R/1
LOG NUMBER: ELECTOCHEMICAL DENITRATION & CAUSTIC REC., PHASE I
PROJECT NAME: S-AREA
LOCATION 1: D. HOBBS
PROJ. MANAGER: PRE-CONCEPTUAL
ESTIMATE TYPE: SITE WBS
SITE WBS: 1

PRICING: POST 94 RATES

ESTIMATED BY: WNW/WLK/DM
LOCATION 2: 730-1B / 1080
DESIGN CLASSIFICATION: PS/C
TIME: 12:56:08
DATE: 23-Aug-1996
FILE: NITRRECV.PWS
REPORT NAME: Detail Cost by WBS 9697 by seq

DETAIL LINE ITEM REPORT

WBS	SOURCE / TWC	DESCRIPTION	QUANTITY	UOM	CREW	SUB	BASE	ADJUST	LABOR	CONST. EQUIP.	MAT'L	ENGR'D EQUIP.	CONTRACT SERVICES	TOTAL COST
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1.2.2.1.2.3.1 EQUIPMENT - PROCESS AREA

HEATER FOR HEPA FILTERS					SRSX01		24.024	25.465	35.20			1250		2146
Memo: (EQ. # 100-ENHTR-1)														

EQUIPMENT - PROCESS AREA SUBTOTAL

1.2.2.1.2.3.2 PIPING - PROCESS AREA

MISC. PROCESS PIPING WITHIN BLDG.					SRSX25		14.011	18.214	34.80		242.00			876
Memo: INCLUDES FITTINGS, FLANGES, BOLT-UP, AND ALL WELDING TO FAB & INSTALL PIPING. ALSO INCLUDES ALLOWANCE FOR SEISMIC SUPPORTS. (BASED ON 4", 10", & 12" DIA. SS PIPE).														

MISC. PROCESS VALVES					SRSX25		6.002	7.802	34.80		7,260.00			7532
42 EA							1.30	328	11,403		304,920			316,323

MISC. CONTROL VALVES					SRSX25		11.994	15.592	34.80		24,200.00			24743
2 EA							1.30	31	1,085		48,400			49,485

PLUMBING					SRSX25		0.050	0.053	34.80		1.45			3
10,780 SF							1.06	571	19,883		15,653			35,535

PIPING - PROCESS AREA SUBTOTAL

								8,216	\$285,905		\$465,773			\$751,678
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ENGINEERING & CONSTRUCTION SERVICES DIVISION

WESTINGHOUSE SAVANNAH RIVER COMPANY

PROJECT NO.:
LINE ITEM:
LOG NUMBER:
PROJECT NAME:
LOCATION 1:
PROJ. MANAGER
ESTIMATE TYPE:
SITE WBS:

96-05-06, R/1
ELECTROCHEMICAL DENITRATION & CAUSTIC REC., PHASE I
S-AREA
D. HOBBS
PRE-CONCEPTUAL
SITE WBS

PAGE # 10
ESTIMATED BY: WNW/WLK/DM
LOCATION 2: 730-1B / 1080
DESIGN CLASSIFICATION: PS/C
TIME: 12:56:08
DATE 23-Aug-1996
FILE: NITRECV.PWS
REPORT NAME: Detail Cost by WBS 9697 by seq

SITE PROJECT ESTIMATING

DETAIL LINE ITEM REPORT

PRICING: POST 94 RATES

WBS	SOURCE / TWC	DESCRIPTION	QUANTITY	UOM	CREW	SUB	HOURS	ADJUST	LABOR	CONST. EQUIP.	MAT'L	ENGR'D EQUIP.	CONTRACT SERVICES	TOTAL COST
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1.2.2.2.1 CIVIL WORK - SITEWORK/UTILITIES

TWC CODE:	MISC. GPR & SUE INVESTIGATIONS	Unit Cost	0.000	0.000	N/A	3	3							
	Memo: ASSUME 1/2 AREA WILL BE CHECKED.	15,000 SY	1.00										45,000	45,000
TWC CODE:	AIR-KNIFE EXCAVATION & UNDERGROUND TIE-IN LOCATIONS	Unit Cost	0.000	0.000	N/A	300	300							
		10 EA	1.00										3,000	3,000
TWC CODE:	MISC. BARRICADES, TEMPORARY SIGNS AND TRAFFIC CONTROLS	SRSX03	80,000	84,800	29.20	1,815	4,291							
		1 LS	1.06	85	2,476									4,291
TWC CODE:	EXCAVATION DEWATERING ALLOWANCE	SRSX03	80,000	84,800	29.20	605.00	3081							
		1 LS	1.06	85	2,476	605	3,081							3,081
TWC CODE:	MISC. PERMANENT BUILDING SIGNS, FLOOR STRIPING, AREA IDENTIFICATION	SRSX13	100,000	106,000	32.10	1,210.00	4613							
		1 LS	1.06	106	3,403	1,210	4,613							4,613
TWC CODE:	MISC. EXCAVATION (HAND & MACHINE) - CLEAN AREA	SRSX05	0.750	0.795	32.80		26							
		1,900 CY	1.06	1,511	49,544								49,544	
TWC CODE:	MISC. EXCAVATION (HAND & MACHINE) - HAZARD AREA	SRSX05	0.750	1.050	32.80		34							
	Memo: & TIE-IN POINTS TO TRANSFER LINE.	100 CY	1.40	105	3,444								3,444	
TWC CODE:	SHORING	SRSX05	0.250	0.265	31.50	1.51	10							
		18,000 SF	1.06	4,770	150,255	27,225	177,480							

ENGINEERING & CONSTRUCTION SERVICES DIVISION

WESTINGHOUSE SAVANNAH RIVER COMPANY

SITE PROJECT ESTIMATING

PAGE # 11

ESTIMATED BY: WNW/WLK/DM
LOCATION 2: 730-1B / 1080
DESIGN CLASSIFICATION: PS/C
TIME: 12:56:08

DETAIL LINE ITEM REPORT

96-05-06, R/1
PROJECT NAME: ELECTROCHEMICAL DENITRATION & CAUSTIC REC., PHASE I

LOCATION 1: S-AREA

PROJ. MANAGER D. HOBBS

ESTIMATE TYPE: PRE-CONCEPTUAL

SITE WBS: SITE WBS

PRICING: POST 94 RATES

REPORT NAME: Detail Cost by WBS 9697 by seq

WBS	DESCRIPTION	QUANTITY	UOM	CREW	SUB	BASE	HOURS	ADJUST	LABOR	CONST. EQUIP.	MAT'L	ENGR'D EQUIP.	CONTRACT SERVICES	TOTAL COST
SOURCE / TWC														

1.2.2.2.1 CIVIL WORK - SITEWORK/UTILITIES

TWC CODE:	BACKFILL & COMPACTION	Unit Cost	SRSX03	0.150	0.159	29.20								5
	Memo: INCLUDES ALL EXCAVATIONS AND STRUCTURAL FILL	12,000 CY		1.06	1,908	55,714								55,714
TWC CODE:	LOAD & HAUL STRUCTURAL FILL	Unit Cost	SRSX03	0.220	0.233	29.20								7
		14,000 CY		1.06	3,265	95,332								95,332
TWC CODE:	S.O.G STONE BASE	Unit Cost	SRSX03	0.150	0.159	29.20					12.10			17
		1,000 TN		1.06	159	4,643					12,100			16,743
TWC CODE:	STORM SEWER CATCH BASINS	Unit Cost	SRSX03	20.000	21.200	29.20					1,512.50			2132
	3 EA			1.06	64	1,857					4,538			6,395
TWC CODE:	24" DIA. CMP DRAINAGE	Unit Cost	SRSX03	0.200	0.212	29.20					30.25			36
	170 LF			1.06	36	1,052					5,143			6,195
TWC CODE:	MISC. SITE GRADING	Unit Cost	SRSX03	0.020	0.021	29.20								1
	13,500 SY			1.06	286	8,357								8,357
TWC CODE:	MISC. SITE RESTORATION	Unit Cost	SRSX03	0.050	0.053	29.20					2.42			4
	11,700 SY			1.06	620	18,107					28,314			46,421
TWC CODE:	MISC. CONSTRUCTION		SRSX03	300.000	318.000	29.20					12,100.00			21386
	1 LS			1.06	318	9,286					12,100			21,386
TWC CODE:	SANITARY SEWER PIPE	Unit Cost	SRSX25	0.100	0.106	34.80					1.82			6
	500 LF			1.06	53	1,844					908			2,752

ENGINEERING & CONSTRUCTION SERVICES DIVISION

WESTINGHOUSE SAVANNAH RIVER COMPANY

SITE PROJECT ESTIMATING

PAGE # 12

ESTIMATED BY: WNW/WLK/DM
LOCATION 2: 730-1B / 1080
DESIGN CLASSIFICATION: PS/C
TIME: 12:56:08

DETAIL LINE ITEM REPORT

PRICING: POST 94 RATES

REPORT NAME: Detail Cost by WBS 9697 by seq

PROJECT NO.: 96-05-06, R/1
LOG NUMBER: ELECTROCHEMICAL DENITRATION & CAUSTIC REC., PHASE I
LOCATION 1: S-AREA

PROJ. MANAGER: D. HOBBS
ESTIMATE TYPE: PRE-CONCEPTUAL
SITE WBS: SITE WBS

WBS	DESCRIPTION	QUANTITY	UOM	CREW	SUB	BASE	HOURS	ADJUST	LABOR	CONST. EQUIP.	MAT'L	ENGR'D EQUIP.	CONTRACT SERVICES	TOTAL COST
SOURCE / TWC														

1.2.2.2.1 CIVIL WORK - SITEWORK/UTILITIES

TWC CODE:	PAVING BASE			SRSX03	0.100	1.06	16	0.106	29.20	12.10				15
		150 TN							464	1,815				2,279
TWC CODE:	MISC. SITE PAVING					0.000	0.000		N/A			170		170
		100 TN										17,000		17,000
TWC CODE:	MISC. C/S/A TESTING & INSPECTIONS					0.000	0.000		N/A			10,000		10,000
		1 LS										10,000		10,000

CIVIL WORK - SITEWORK/UTILITIES SUBTOTAL

							13,386		\$408,255		\$95,772		\$75,000	\$579,026
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1.2.2.2.2 ELECTRICAL WORK - SITEWORK/UTILITIES

TWC CODE:	DUCTBANK			SRSX20	1.600	1.06	763	1.696	35.60	42.35				103
		450 LF							27,170	19,058				46,227
TWC CODE:	ELECTRICAL MANHOLES			SRSX20	16.000	1.06	34	16.960	35.60	605.00				1209
		2 EA							1,208	1,210				2,418
TWC CODE:	OUTSIDE WIRING			SRSX20	85.000	1.06	90	90.100	35.60	39,930.00				43,138
		1 LT							3,208					43,138
TWC CODE:	YARD LIGHTING			SRSX20	220.000	1.06	233	233.200	35.60	2,420.00				10,722
		1 LT							8,302	2,420				10,722

ELECTRICAL WORK - SITEWORK/UTILITIES SUBTOTAL

							1,120		\$39,987		\$62,618			\$102,504
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ENGINEERING & CONSTRUCTION SERVICES DIVISION

WESTINGHOUSE SAVANNAH RIVER COMPANY

PROJECT NO.:

LINE ITEM:

LOG NUMBER: 96-05-06, R/1

PROJECT NAME:

ELECTROCHEMICAL DENITRATION & CAUSTIC REC., PHASE I

LOCATION 1:

S-AREA

PROJ. MANAGER

D. HOBBS

ESTIMATE TYPE:

PRE-CONCEPTUAL

SITE WBS:

1

PRICING: POST 94 RATES

DETAIL LINE ITEM REPORT

PAGE # 13

ESTIMATED BY: WNW/WLK/DM

LOCATION 2: 730-1B / 1080

DESIGN CLASSIFICATION: PS/C

TIME: 12:56:08

DATE 23-Aug-1996

FILE: NITRRECV.PWS

REPORT NAME: Detail Cost by WBS 9697 by seq

WBS	SOURCE / TWC	DESCRIPTION	QUANTITY	UOM	CREW	SUB	BASE	HOURS	ADJUST	LABOR	CONST. EQUIP.	MAT'L	ENGR'D EQUIP.	CONTRACT SERVICES	TOTAL COST
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1.2.2.2.3.1 EQUIPMENT - SITEWORK/UTILITIES

TWC CODE:	EXHAUST STACK FOR HEPA FILTER SYSTEM - FABRICATED	Unit Cost	8,000 LB	0.000	0.000	N/A	3	20,000	3	20,000					
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TWC CODE:	EXHAUST STACK FOR HEPA FILTER SYSTEM - INSTALLATION	Unit Cost	8,000 LB	0.013	0.013	34.30	3,636								3,636
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TWC CODE:	LIFT STATION	SRSX01	120,000	1.06	127	4,477	18,150.00	22,627							22,627
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TWC CODE:	LIFT STATION	1 EA	1.06	127	4,477	18,150	22,627								22,627
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EQUIPMENT - SITEWORK/UTILITIES SUBTOTAL

				233	\$8,113	\$18,150	\$20,000	\$46,263							\$46,263
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1.2.2.2.3.2.1 CORE/JKT. WASTE TRANSFER LINE - SITEWORK

TWC CODE:	SHOP FAB 3" DIA. CORE / 4" DIA. JACKETED TRANSFER PIPING	Unit Cost	320 LF	5.000	5.000	34.80	42.35	216							216
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TWC CODE:	TIE-IN NEW CORE/JKT. TRANSFER PIPING	Unit Cost	320 LF	1.00	1,600	55,680	13,552	69,232							69,232
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TWC CODE:	TIE-IN NEW CORE/JKT. TRANSFER PIPING	Unit Cost	2 EA	40.000	112,000	34.80	3898	3898							3898
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TWC CODE:	TIE-IN NEW CORE/JKT. TRANSFER PIPING	2 EA	2.80	224	7,795	7,795		7,795							7,795
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TWC CODE:	FIELD INSTALL NEW CORE/JKT. TRANSFER PIPING	Unit Cost	320 LF	6.000	12,000	34.80	418	418							418
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TWC CODE:	FIELD INSTALL NEW CORE/JKT. TRANSFER PIPING	320 LF	2.00	3,840	133,632	133,632		133,632							133,632
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ENGINEERING & CONSTRUCTION SERVICES DIVISION

WESTINGHOUSE SAVANNAH RIVER COMPANY

SITE PROJECT ESTIMATING

PROJECT NO.:
LINE ITEM:
LOG NUMBER:
PROJECT NAME:
LOCATION 1:
PROJ. MANAGER
ESTIMATE TYPE:
SITE WBS:

96-05-06, R/1
ELECTROCHEMICAL DENITRATION & CAUSTIC REC., PHASE I
S-AREA
D. HOBBS
PRE-CONCEPTUAL
SITE WBS

PAGE # -14
ESTIMATED BY: WNW/WLK/DM
LOCATION 2: 730-1B / 1080
DESIGN CLASSIFICATION: PS/C
TIME: 12:56:08
DATE 23-Aug-1996
FILE: NITRRCV.PWS
REPORT NAME: Detail Cost by WBS 9697 by seq

DETAIL LINE ITEM REPORT

PRICING: POST 94 RATES

WBS	SOURCE / TWC	DESCRIPTION	QUANTITY	UOM	CREW	BASE	HOURS	LABOR	CONST. EQUIP.	MAT'L	ENGR'D EQUIP.	CONTRACT SERVICES	TOTAL COST
					SUB		ADJUST						

1.2.2.2.3.2.1 CORE/JKT. WASTE TRANSFER LINE - SITEWORK

TWC CODE:		TESTING OF NEW TRANSFER LINE	Unit Cost	SRSX25	0.400	0.424	34.80	15
	320 LF		1.06	136	4,722			4,722
TWC CODE:		OUTSIDE MAN & FIRE WATCH	SRSX25	3800.00	3800.00	34.80		132240
	1 LS		1.00	3,800	132,240			132,240
TWC CODE:		VALVE BOX W/ISOLATION VALVES	Unit Cost	SRSX25	240.000	360.000	34.80	14948
	2 EA		1.50	720	25,056	4,840		29,896

CORE/JKT. WASTE TRANSFER LINE - SITEWORK SUBTOTAL

10,320 \$359,125 \$18,392 \$377,517

1.2.2.2.3.2.2 DOMESTIC WATER - SITEWORK

TWC CODE:	2" DIA. DOMESTIC WATER PIPING								
	Unit Cost	SRSX25	0.090	0.117	34.80	6.05	10		
	225 LF		1.30	26	916	1,361	2,277		
TWC CODE:	FLUSHING AND TESTING OF SYSTEM								
	Unit Cost	SRSX25	0.200	0.212	34.80	2.42	10		
	225 LF		1.06	48	1,660	545	2,204		

DOMESTIC WATER - SITEWORK SUBTOTAL

74 \$2,576 \$1,906 \$4,482

1.2.2.2.3.2.3 FIRE PROTECTION PIPING - SITEWORK

TWC CODE:	INSTALL NEW 6" DIA. PVC UNDERGROUND FIRE PROTECTION PIPE								
	Unit Cost	SRSX25	0.140	0.182	34.80	9.68	16		
	175 LF		1.30	32	1,108	1,694	2,802		

ENGINEERING & CONSTRUCTION SERVICES DIVISION

WESTINGHOUSE SAVANNAH RIVER COMPANY

SITE PROJECT ESTIMATING

PAGE # 15
ESTIMATED BY: WNW/WLK/DM
LOCATION 2: 730-1B / 1080
DESIGN CLASSIFICATION: PS/C
TIME: 12:56:08
DATE 23-Aug-1996
FILE: NITRRECV.PWS
REPORT NAME: Detail Cost by WBS 9697 by seq

DETAIL LINE ITEM REPORT

PRICING: POST 94 RATES

PROJECT NO.:
LINE ITEM:
LOG NUMBER: 96-05-06, R/1
PROJECT NAME: ELECTOCHEMICAL DENITRATION & CAUSTIC REC., PHASE I
LOCATION 1: S-AREA
PROJ. MANAGER: D. HOBBS
ESTIMATE TYPE: PRE-CONCEPTUAL
SITE WBS: 1

WBS	SOURCE / TWC	DESCRIPTION	QUANTITY	UOM	CREW	HOURS	LABOR	CONST. EQUIP.	MAT'L	ENGR'D EQUIP.	CONTRACT SERVICES	TOTAL COST
					SUB	BASE	ADJUST					

1.2.2.2.3.2.3 FIRE PROTECTION PIPING - SITEWORK

TWC CODE:		TIE-IN NEW UNDERGROUND FIRE PROTECTION PIPING	2 EA		SRSX25	6,000	9,600	34.80				334
						1.60	19	668				668
TWC CODE:		TESTING OF UNDERGROUND FIRE PROTECTION PIPING	175 LF		SRSX25	0.250	0.265	34.80	1.21			10
						1.06	46	1,614	212			1,826
TWC CODE:		FIRE HYDRANT	1 EA		SRSX25	2,000	2,600	34.80	1,331.00			1,421
						1.30	3	90	1,331			1,421
TWC CODE:		POST INDICATOR VALVE	1 EA		SRSX25	8,000	10,400	34.80	1,210.00			1,572
		Memo: INCLUDES POST AND CONCRETE GUARDS.				1.30	10	362	1,210			1,572

FIRE PROTECTION PIPING - SITEWORK SUBTOTAL

						110	\$3,843		\$4,447			\$8,290
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1.2.2.2.4 MISC. ITEMS - SITEWORK/UTILITIES

TWC CODE:		CONTAINMENT HUT	1 EA		SRSX27	70,000	74,200	24.40	4,840.00			6,650
						1.06	74	1,810	4,840			6,650
TWC CODE:		BURIAL BOX			SRSX27	8,000	8,480	24.40	423.50			630
						1.06	17	414	847			1,261

MISC. ITEMS - SITEWORK/UTILITIES SUBTOTAL

						91	\$2,224		\$5,687			\$7,911
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ENGINEERING & CONSTRUCTION SERVICES DIVISION

WESTINGHOUSE SAVANNAH RIVER COMPANY

PROJECT NO.:
LINE ITEM:
LOG NUMBER:
PROJECT NAME:
LOCATION 1:
PROJ. MANAGER:
ESTIMATE TYPE:
SITE WBS:

96-05-06, R/1
ELECTOCHEMICAL DENITRATION & CAUSTIC REC., PHASE I
S-AREA
D. HOBBS
PRE-CONCEPTUAL
SITE WBS

PRICING: POST 94 RATES

ESTIMATED BY: WNW/WLK/DM
LOCATION 2: 730-1B / 1080
DESIGN CLASSIFICATION: PS/C
TIME: 12:56:08
DATE 23-Aug-1996
FILE: NITRECV.PWS
REPORT NAME: Detail Cost by WBS 9697 by seq

PAGE # 17

DETAIL LINE ITEM REPORT

WBS	SOURCE / TWC	DESCRIPTION	QUANTITY	UOM	CREW	SUB	BASE	HOURS	ADJUST	LABOR	CONST. EQUIP.	MAT'L	ENGR'D EQUIP.	CONTRACT SERVICES	TOTAL COST

1.2.3.9 CRAFT SUPPORT

TEMPORARY CONSTRUCTION @ 7% OF DIRECT CONST. HRS.															
TWC CODE:	9100														
			5,433	HRS			1.00	5,433	1,000	30.10					30
										163,547					163,547
PROJECT SERVICES @ 6.5% OF DIRECT CONST. M.HRS															
TWC CODE:	9200														
			5,045	HRS			1.00	5,045	1,000	30.10					30
										151,865					151,865
MISC. CONSTRUCTION @ 2.5% OF DIRECT CONST. M.HRS															
TWC CODE:	9300														
			1,941	HRS			1.00	1,941							30
										58,410					58,410

CRAFT SUPPORT SUBTOTAL

1.2.4 CONSTRUCTION NONMANUAL

CONSTRUCTION NON-MANUAL @ 15% OF DIRECT CONSTRUCTION M.HRS															
TWC CODE:															
			13,196	HRS			1.00	13,196	1,000	56.96					57
										751,617					751,617
SITE TECHNICAL REPRESENTATIVE (STR) @ 7% OF SUBCONTRACT COSTS															
TWC CODE:															
			1,617	HRS			1.00	1,617							57
										92,106					92,106

CONSTRUCTION NONMANUAL SUBTOTAL

1.4.1 PROJECT MANAGEMENT

PROJECT MANAGEMENT @ 6% OF TEC LESS PROJ. SUPPORT															
TWC CODE:															
			8,216	M.HRS			1.00	8,216	1,000	77.60					78
										637,562					637,562

ENGINEERING & CONSTRUCTION SERVICES DIVISION

WESTINGHOUSE SAVANNAH RIVER COMPANY

SITE PROJECT ESTIMATING

PAGE # 18
ESTIMATED BY: WNW/WLK/DM
LOCATION 2: 730-1B / 1080
DESIGN CLASSIFICATION: PS/C
TIME: 12:56:08
DATE 23-Aug-1996
FILE: NITRREC/PWS
REPORT NAME: Detail Cost by WBS 9697 by seq

DETAIL LINE ITEM REPORT

PRICING: POST 94 RATES

PROJECT NO.:
LINE ITEM:
LOG NUMBER: 96-05-06, R/1
PROJECT NAME: ELECTOCHEMICAL DENITRATION & CAUSTIC REC., PHASE I
LOCATION 1: S-AREA
PROJ. MANAGER: D. HOBBS
ESTIMATE TYPE: PRE-CONCEPTUAL
SITE WBS: SITE WBS

WBS	SOURCE / TWC	DESCRIPTION	QUANTITY	UOM	CREW	BASE	ADJUST	LABOR	CONST. EQUIP.	MAT'L	ENGR'D EQUIP.	CONTRACT SERVICES	TOTAL COST
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1.4.1 PROJECT MANAGEMENT

PROJECT MANAGEMENT SUBTOTAL

1.4.2 PROJECT CONTROLS PM

PROJECT CONTROLS PM & ESTIMATING @ 3% OF TEC LESS PROJ. SUPPORT	Unit Cost	PCE	1,000	1,000	1,000	1,000	1,000	65.69					66
	4,562 MHRS		1.00	4,562	299,661								299,661

PROJECT CONTROLS PM SUBTOTAL

1.4.3 PROJECT CONTROLS DESIGN ENGINEERING

PROJECT CONTROLS DE @ 1% OF TEC LESS PROJ. SUPPORT	Unit Cost	PCE	1,000	1,000	1,000	1,000	1,000	65.69					66
	1,521 MHRS		1.00	1,521	99,887								99,887

PROJECT CONTROLS DESIGN ENGINEERING SUBTOTAL

1.4.4 PROJECT CONTROLS CONSTRUCTION

PROJECT CONTROLS CONSTR. @ 7% OF CONSTRUCTION MHRS	Unit Cost	PCE	1,000	1,000	1,000	1,000	1,000	65.69					66
	5,433 MHRS		1.00	5,433	356,923								356,923

PROJECT CONTROLS CONSTRUCTION SUBTOTAL

\$637,562

\$299,661

\$99,887

\$356,923

\$637,562

ENGINEERING & CONSTRUCTION SERVICES DIVISION

WESTINGHOUSE SAVANNAH RIVER COMPANY

SITE PROJECT ESTIMATING

PAGE # 19
ESTIMATED BY: WNW/WLK/DM
LOCATION 2: 730-1B / 1080
DESIGN CLASSIFICATION: PS/C
TIME: 12:56:08

DETAIL LINE ITEM REPORT

DATE 23-Aug-1996
FILE: NITRREC.V.PWS
REPORT NAME: Detail Cost by WBS 9697 by seq

PRICING: POST 94 RATES

WBS	DESCRIPTION	QUANTITY	UOM	CREW	BASE	HOURS	LABOR	CONST. EQUIP.	MAT'L	ENGR'D EQUIP.	CONTRACT SERVICES	TOTAL COST
PROJECT SUBTOTAL					156,403		\$7,195,146	\$678,897	\$1,910,462	\$2,175,000	\$1,394,748	\$13,354,253
PROJECT ESCALATION							\$565,199	\$65,853	\$185,315	\$210,975	\$135,291	\$1,162,632

SUBTOTAL COST INCLUDING ESCALATION

156,403	\$7,760,344	\$744,750	\$2,095,777	\$2,385,975	\$1,530,039	\$14,516,885
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FY 97 G & A RATE @ 22.00 % AND APPLIED TO 100.00 % OF ALL TOTALS \$461,071 \$524,915 \$336,608 \$3,193,715

SUBTOTAL INCLUDING ESCALATION

156,403	\$9,467,620	\$908,595	\$2,556,847	\$2,910,890	\$1,866,647	\$17,710,599
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MANAGEMENT RESERVE @30.00 %

\$5,313,000

CONTINGENCY @ 0.00 %

\$0

PROJECT TOTAL COST

\$23,024,000