INNOVATIVE TECHNOLOGY
Summary Report

DOE/EM-0560

Electrochemical Treatment of Alkaline Nuclear Wastes

Efficient Separations and Processing Crosscutting Program

Prepared for
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INNOVATIVE
TECHNOLOGY
Summary Report

Electrochemical Treatment of Alkaline Nuclear Wastes

OST/TMS ID 39

Efficient Separations and Processing
Crosscutting Program

Demonstrated at
Savannah River Site
Aiken, South Carolina

INNOVATIVE TECHNOLOGY
Summary Report

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine whether a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST Web site at http://ost.em.doe.gov under "Publications."

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SECTION 1
SUMMARY

Technology Summary

Nitrate and nitrite are two of the major hazardous non-radioactive species present in Hanford and Savannah River (SR) high-level waste (HLW). Electrochemical treatment processes have been developed to remove these species by converting aqueous sodium nitrate/nitrite into sodium hydroxide and chemically reducing the nitrogen species to gaseous ammonia, nitrous oxide and nitrogen. Organic complexants and other organic compounds found in waste can be simultaneously oxidized to gaseous carbon dioxide and water, thereby reducing flammability and leaching risks as well as process interferences in subsequent radionuclide separation processes.

Competing technologies include thermal, hydrothermal and chemical destruction. Unlike thermal and hydrothermal processes that typically operate at very high temperatures and pressures, electrochemical processes typically operate at low temperatures (<100 °C) and atmospheric pressure. Electrochemical processes effect chemical transformations by the addition or removal of electrons and, thus, do not add additional chemicals, as is the case with chemical destruction processes.

Hanford and SR have different plans for disposal of the low-activity waste (LAW) that results when radioactive Cs^{137} has been removed from the HLW. At SR, the decontaminated salt solution will be disposed in a cement waste form referred to as Saltstone, whereas at Hanford the waste will be vitrified as a borosilicate glass. Destruction of the nitrate and nitrite before disposing the decontaminated salt solution in Saltstone would eliminate possible groundwater contamination that could occur from the leaching of nitrate and nitrite from the cement waste form. Destruction of nitrate and nitrite before vitrification at Hanford would significantly reduce the size of the off-gas system by eliminating the formation of NO_x gases in the melter.

Throughout the 1990's, the electrochemical conversion process has been extensively studied at SR, the University of South Carolina, and elsewhere. Testing at the bench-scale has been completed using both surrogate and actual waste streams. A pilot-scale test facility was constructed and operated briefly at SR.

Demonstration Summary

Bench-scale tests have shown that electrochemical reactors can be used to decompose nitrates, nitrites and organic compounds found in alkaline tank wastes. A pilot-scale test loop was designed and constructed at Savannah River Technology Center (SRTC) that included an electrochemical reactor, power supply, safety shutdown system, flammable gas detectors, storage tanks, pumps, an off-gas system, instruments and a data acquisition system. Pilot-scale tests were conducted with simulated aqueous waste solutions containing nitrate, nitrite, and hydroxide salts of sodium.

The first test was conducted with no membrane between the anode and cathode. The simulated waste solution was continuously circulated through the space between the reactor plates. After an induction period of about 36 hours the concentration of nitrate decreased by about 70% in 40 additional hours of run time. The test was then terminated. About 60% of the charge that passed through the reactor was used to decompose nitrate and nitrite. The remainder of the charge produced hydrogen gas at the cathode.

The second test used a membrane between the electrodes. The simulated waste solution was circulated through the space between the cathode and the membrane, and caustic solution was circulated through the space between the anode and the membrane. The nitrate solution in the cathode compartment started to decrease immediately with power application, decreasing by 30% in ten hours. Thereafter, destruction of nitrate slowed and finally ceased because caustic concentration in the anode compartment became depleted. About 85% of the charge went into nitrate and nitrite destruction.

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Other

All published Innovative Technology Summary Reports are available on the OST Web site at http://ost.em.doe.gov under "Publications." The Technology Management System (TMS), also available through the OST Web site, provides information about OST programs, technologies, and problems. The OST TMS number for Electrochemical Treatment of Alkaline Nuclear Wastes is **39**.

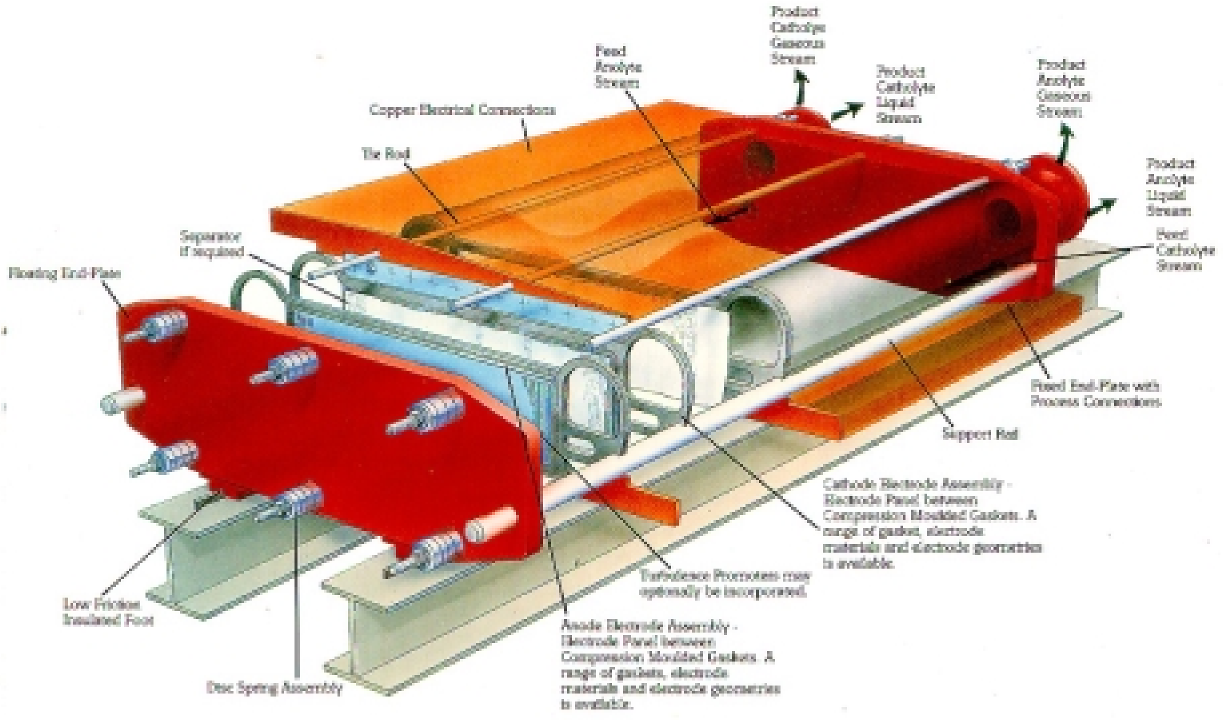

Figure 1. ICI FM21-SP Plate and Frame Flow Cell used in pilot-scale demonstration.

SECTION 2
TECHNOLOGY DESCRIPTION

Overall Process Definition

In an electrochemical reaction, charge is transferred at the interface between an electrode and the reactive species in a conductive liquid. An electrochemical reactor consists of an anode, a cathode, a conducting electrolyte, and power supply. At the cathode, electrons are passed from the electrode to the reacting species, resulting in a reduction in the oxidation state of the species. At the anode, electrons pass from the reactive species to the electrode, resulting in an increase in the oxidation state. These oxidation state changes alter the chemical properties and form of the reactants. The reduced or oxidized species can form a deposit on the electrode or desorb from the electrode surface and dissolve in the liquid phase or evolve as a gas.

Electrochemical treatment is one possible technology for the destruction of nitrate and nitrite as well as the removal of radionuclides and hazardous metals from alkaline waste solutions. In the electrochemical reactor, nitrate and nitrite are reduced (at the cathode) to form nitrogen-containing gases: nitrogen, ammonia and nitrous oxide. Water is also reduced in a competing reaction at the cathode, producing hydrogen gas and hydroxide ion. These gases have low solubility in the alkaline salt solution and are released into the vapor phase, thus separating from the solution. Metal ions in the electrolyte may also be reduced at the cathode, forming solids deposited on the cathode surface or precipitated from solution. At the anode, the dominant reaction is the oxidation of hydroxide ions to form oxygen gas, with the oxidation of any organic species dispersed in the electrolyte being a beneficial side reaction. Oxidation of nitrite ion to nitrate also occurs at the anode if nitrite is present in solution.

The chief effect of these chemical reactions on the waste solution is to replace each nitrite or nitrate ion with hydroxide ion. No additional chemicals would be added to the waste. Greater than 99% of the nitrate and nitrite can be removed in either an undivided or a divided cell reactor. The rate of destruction and the overall power consumption depend on the cell configuration, the current density, and the electrode materials. Special procedures to prevent electrode poisoning are required if chromate is present in the waste.

System Operation

The electrochemical process for removal of nitrate/nitrite from alkaline solution can be operated in either or two modes: undivided cell, or membrane-divided cell. Each mode has advantages and disadvantages that are summarized below.

Both modes share the following characteristics:
- capable of destroying >99% of nitrate and nitrite
- compatible with Saltstone and caustic recycle processes
- when no chromate is present, best results are obtained with a nickel cathode and a nickel anode
- presence of chromate inhibits nitrate/nitrite reduction at high current density
- chromate inhibition can be mitigated by
  - periodic current reversal (undivided cell) (Jha, Weidner and White 1995)
  - using a lead cathode (divided cell) (Bockris and Kim 1995)
  - operating at low current density
- ammonia gas generated at cathode requires further treatment before release to the environment

Undivided cell advantages:
- simpler facility design
- lower power consumption (lower resistance between electrodes)
- membrane lifetime is not an issue

Undivided cell disadvantages:
- wasted current due to cycling of nitrate← → nitrite reaction at anode and cathode

- mixing of anode and cathode product gases (hydrogen, ammonia, oxygen, etc.)
- longer induction period required before net nitrate destruction begins

Divided cell advantages:

- destruction of nitrate at cathode begins immediately with power application
- anodic and cathodic gases are collected separately
- higher electrical efficiency by preventing reoxidation of reduced nitrogen species

Divided cell disadvantages:

- higher power consumption resulting from higher cell resistance across the membrane
- first batch requires added caustic as anolyte; later batches use catholyte product as anolyte
- greater reactor complexity introduces more potential problems (e.g., membrane fouling, breakage and disposal; feed and product streams for both anolyte and catholyte)

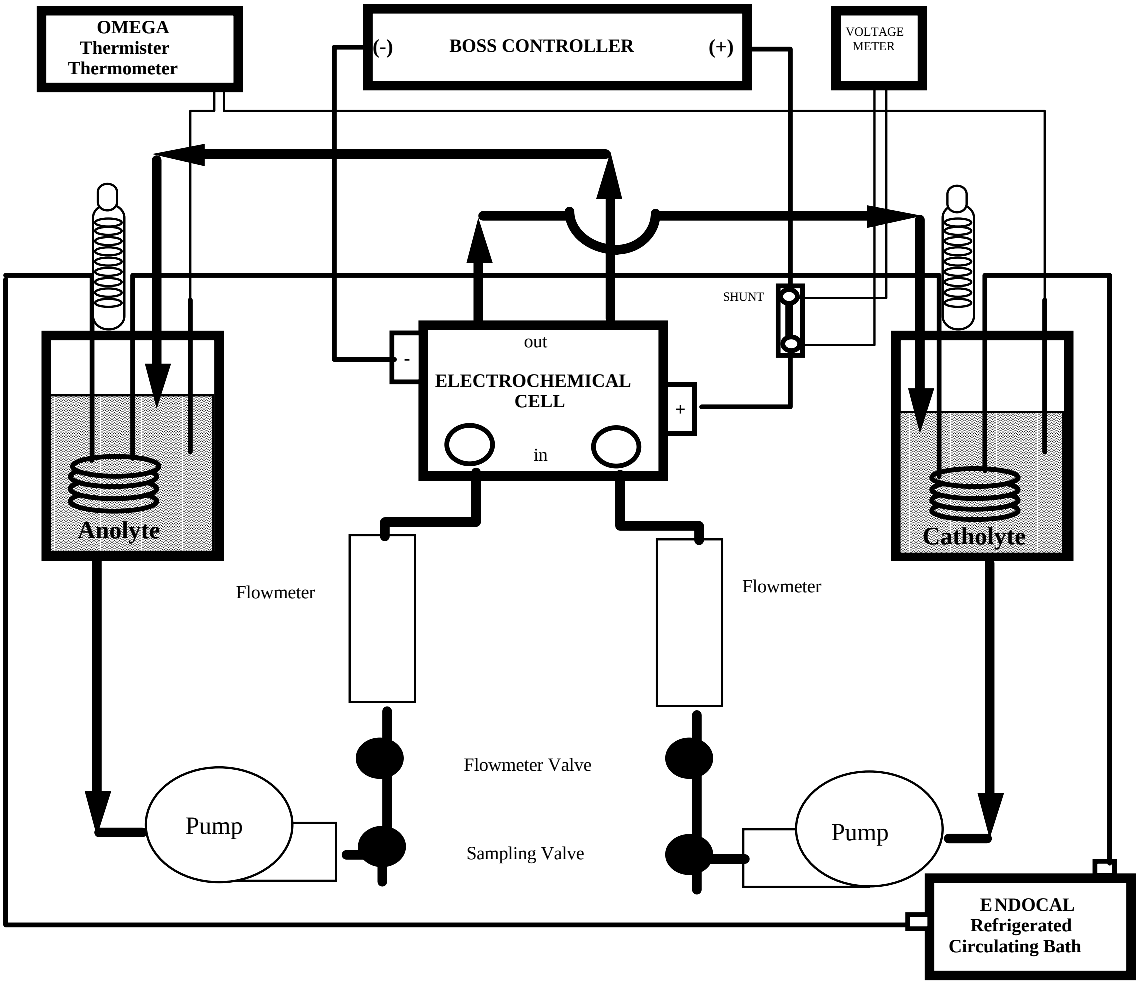

Figure 2. Schematic Diagram of Bench-scale Test Equipment

SECTION 3
PERFORMANCE

Demonstration Plan

Electrochemical destruction of nitrate in radioactive SR waste was demonstrated in bench-scale tests using a flow cell reactor in both divided and undivided modes (Hobbs, 1995). The 10-gal sample of SR waste contained very little hexavalent chromium, and no electrode poisoning due to chromium reduction was observed during testing. Current densities ranged from 2500 to 5000 amperes per square meter of electrode surface. The tests were conducted using a small flow reactor, the FM 01-LC, manufactured by ICI (Great Britain.) The working electrode surface area was 0.0064 m^2. A diagram of the test setup is shown in Figure 2.

These bench-scale test results showed that:

- >99% of the nitrate can be destroyed using either divided or undivided cells
- destruction rate and power consumption depend on the cell configuration and the electrode materials (Figures 3 and 4)
- fastest destruction rate for combined nitrate and nitrite was observed with an undivided cell equipped with nickel cathode and nickel anode
- the divided mode separator (Nafion^{TM}-350) increased power consumption by 30-50%
- nitrate destruction rates ranged from 1.53 micro-moles/coulomb (divided cell) to 1.98 micro-moles/coulomb (undivided cell)
- for tests in the divided mode, nitrate concentration in the catholyte started at 3.6 M and decreased to 0.1 M. Nitrite concentration started at 0.01 M and quickly increased to and remained at 0.1 M

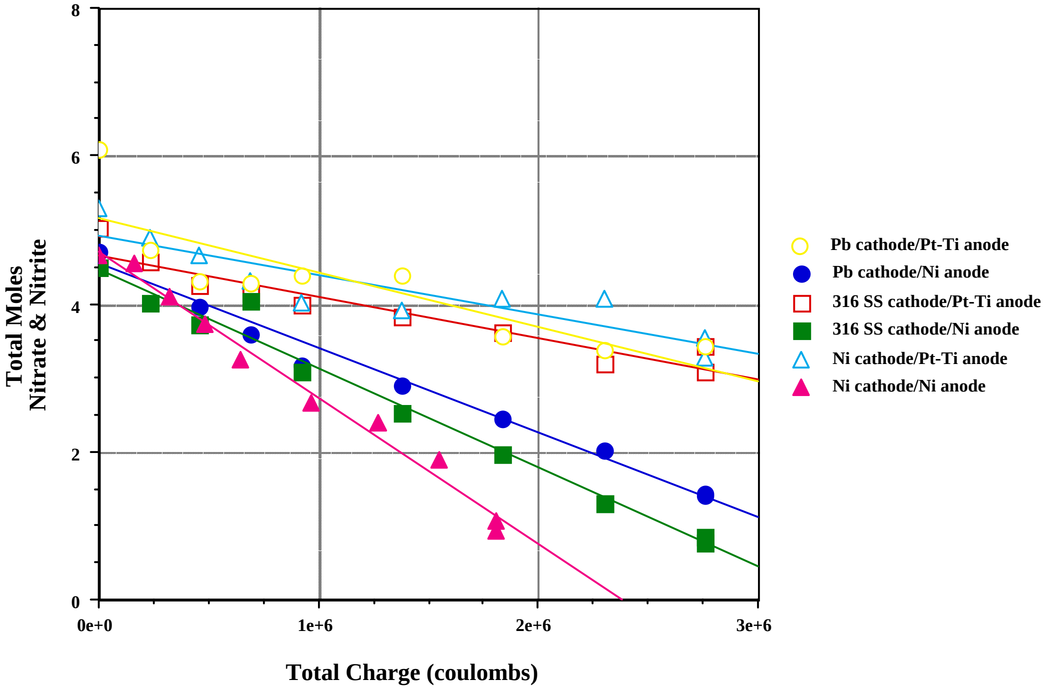

Figure 3. Nitrate and Nitrite Changes in Undivided Cell with Different Electrode Materials

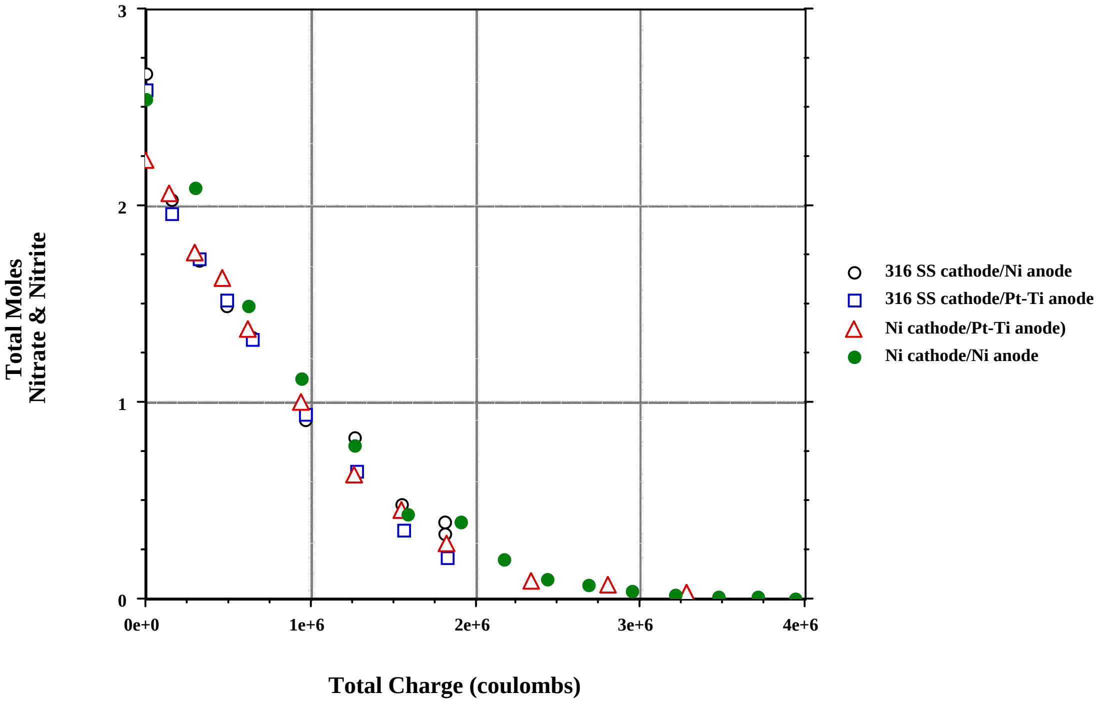

Figure 4. Nitrate and Nitrite Changes in Divided Cell with Different Electrode Materials

A pilot-scale test loop was designed and constructed at SRTC to evaluate process parameters and scale-up requirements. The heart of the apparatus is an ICI Model FM-21 SP electrochemical reactor, a commercial version of the bench-scale Model FM-01-LC that uses filter press construction, flat electrodes (nickel cathode and platinized titanium anode), and a 1500 ampere power supply (Figure 1.) The loop has instruments for measuring liquid flow, air flow, flammable gas concentrations, voltages, currents, temperatures and differential pressures (Steimke et al. 1997). Flammable off-gases (hydrogen and ammonia) that formed at the cathode were diluted with air to <25% of their lower flammability limit and vented to the outside air. (Ammonia would have to be treated rather than released if the process was full-scale.) Gas sample analysis was incomplete due to failures in the gas chromatograph.

Simulants used in the bench-scale tests featured major and minor components typically found in HLW supernatant liquids. The major components include cations such as sodium and potassium and anions such as nitrate, nitrite, hydroxide, aluminate, carbonate and sulfate. Minor components include mercuric salts, phosphate, oxalate, fluoride, chloride, silicate and chromate. Replicate tests indicated a high degree of reproducibility for both the extent and rate of nitrate/nitrite destruction. Analysis of errors indicated the largest variability in the performance of the electrochemical destruction process results from errors associated with measurement of nitrate and nitrite concentrations in highly alkaline salt solutions. Reactor performance characteristics (e.g., cell voltage and cell current) were shown to be good diagnostic tools for process control in tests conducted over extended time periods.

Results

Results from the Undivided Cell

The treated SR simplified waste simulant contained 1.65 M sodium nitrate, 0.52 M sodium nitrite, and 1.11 M sodium hydroxide. The process operated at a constant current of 735 amperes (A) (i.e., current density of 3500 A/m^2) for a period of 76 hours. Hydrogen production rates increased as the run progressed, and averaged 7 moles/hr over the final 30 hours of the run. About 40% of the current was consumed in the production of hydrogen. After 76 hours, the concentration of nitrate was reduced to 0.6 M and nitrite to nearly zero. Nitrate initially increased to a maximum of 1.9 M as nitrite decreased to 0.1 M during the first 10 hours of operation.

Results from the Divided Cell

The catholyte feed was initially 1.87 M sodium nitrate, 0.58 M sodium nitrite, and 1.26 M sodium hydroxide. Anolyte feed was initially 5.03 M sodium hydroxide. The process ran at constant current of 735 A for 38 hours, but current dropped to zero by 42 hours due to depletion of sodium hydroxide from the anolyte. Hydrogen evolution at the cathode averaged about 2 moles per hour, and consumed about 20% of the total charge. At test conclusion, anolyte concentration of sodium hydroxide was close to zero whereas catholyte concentration was 5.7 M; catholyte nitrate was 0.8 M and catholyte nitrite was 0.5 M (and remained constant after only 4 hours of run time.)

Comparison with Prior Work

The Electrosynthesis Company tested an ICI FM-21 SP Electrolyzer on simulated Hanford and SR waste in both divided and undivided modes (Chai, Hartsough and Genders 1995). The SR simulant employed in this testing contained a complex mixture of sodium salts including 0.77 g/L of sodium chromate. Results from this pilot-scale testing confirmed the inhibiting effect of chromate previously observed in bench-scale tests. After a 20-hour induction period during which time no nitrate was destroyed in a divided cell, nitrate dropped steadily to about 33% of the initial concentration over the next 30 hours of operation. In an undivided cell, only 5% of the nitrate was destroyed after 40 hours of cell operation. Similar results were observed with the Hanford simulant.

SECTION 4
TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

The baseline technology is defined as the direct conversion of SR low-activity waste (LAW) into Saltstone without prior conversion of nitrate and nitrite into hydroxide. The resulting Saltstone would therefore contain leachable nitrate and nitrite ions that pose a threat to groundwater at the final disposal site. If special containment vaults are required to isolate the Saltstone waste and thereby prevent groundwater contamination, disposal costs could be substantially higher than for disposal in concrete vaults.

Alternatives to the electrochemical process for treating nitrate and nitrite wastes also exist, and these were recently reviewed (RCS Corp. 1997). Two technologies were judged to be attractive competitors: vitrification, and nitrate to ammonia and ceramic (NAC). Because neither technology is compatible with the Saltstone waste form, they will not be discussed further in this report. Greater uncertainties are also associated with these technologies than with electrochemical reduction.

In comparison to the baseline (non-treatment), electrochemical reduction of nitrate/nitrite in decontaminated salt solution at SR offers the following:

Advantages

- >90% removal of nitrate and nitrite significantly lowers the threat of leaching from the final waste form
- production of hydroxide ion is compatible with the caustic recycle technology proposed for tank waste (U. S. DOE 1999) and the hydroxide concentrate may be useful in waste treatment applications
- organic compounds in the waste stream are simultaneously destroyed at the anode

Disadvantages

- ammonia and nitrous oxide gas produced by electrolysis will require treatment prior to discharge
- hydrogen gas produced at the cathode must be diluted to prevent explosions
- metals (including some radionuclides) in wastes may deposit on the electrodes and reduce electrolysis efficiency
- substantial treatment cost

Technology Applicability

Electrochemical destruction of aqueous nitrate in wastes may be useful for managing non-radioactive hazardous wastes such as those from the chemical, plating, pulp and paper, and electronics industries. Electrical energy costs can be the decisive factor in technology selection.

DOE sites that store large amounts of alkaline waste (Savannah River and Hanford) are the major potential users of this technology. Treatment of highly acidic wastes is not as attractive, as protons would compete with nitrate and nitrite for reduction at the cathode.

Patents/Commercialization/Sponsor

The Department of Energy Office of Science and Technology funded the development of the electrolytic denitration technology through the Efficient Separations and Processing Crosscutting Program. Participating institutions included: Savannah River Technology Center; Electrosynthesis Company, Inc.; University of South Carolina; University of Tennessee; ICI, Ltd.; Pacific Northwest National Laboratory; Texas A&M University; and the E. I. DuPont de Nemours and Co., Inc.

SECTION 5
COST

Methodology

Bechtel Savannah River, Inc., developed a preconceptual design for an electrochemical denitration system capable of treating 2 million-gallons per year (mgy) of alkaline nitrate-bearing waste (Bechtel Savannah River, Inc. 1996). The design was doubled in capacity and amended to include abatement of the ammonia discharges and partial recovery of hydroxide concentrate by RCS (RCS Corp. 1997). Cost analysis in the following sections is drawn principally from the RCS report. Costs for ammonia abatement are unknown and were not included in the estimate by RCS. RCS also assumed that 0.8 mgy of the 4 mgy of denitration product would be recovered as hydroxide concentrate for use in waste pretreatment applications. However, no costs or benefits were estimated for this facility by RCS. Hydroxide recovery had not been included in the original Bechtel flowsheet.

Cost Analysis

Total capital costs, operating costs and life cycle costs (1997 dollars) were estimated by for the electrochemical, chemical and thermal destruction processes. Table 5.1 provides a summary of the estimated costs for each technology. Cost estimates were based on processing 4 mgy with a plant life of 25 years. These costs do not include disposal costs for the residual waste stream from each technology. Estimation of the disposal costs is difficult because of the different disposal wasteforms (e.g., Saltstone for electrochemical destruction, ceramic for NAC chemical destruction, and borosilicate glass for vitrification and plasma arc treatment).

Capital costs for the electrochemical treatment facility are similar to that for the chemical treatment facility and well below that of the thermal treatment processes. Annual operating costs for the electrochemical facility are about 30% higher than than chemical, hydrothermal and steam reforming processes, but well below that estimated for plasma arc and vitrification processes. Ammonia abatement costs will add to the above figures, but the effect is expected to be small compared to the other estimated costs. Conventional abatement technology is available, but the required capacity is unknown because ammonia evolution has not been quantified in the denitration experiments, and will vary with the choice of electrode materials and current density used in plant operation.

Caustic recovery can be achieved with an electrochemical process similar in many respects to the denitration process described here (DOE 1999). Cost analysis of caustic recovery (DeMuth and Kurath 1998) has shown that yearly SR site requirements for fresh caustic (93,900 gal of 50 wt% solution) can be satisfied at a cost savings of $186 m over the 25-year life of the plant. (These are non-discounted costs, and should not be compared dollar for dollar to the present value life cycle costs of denitration.) The basis for cost savings rests principally with the reduced amount of waste that would have to be sent to Saltstone disposal. Even greater savings could be achieved if there was need for additional caustic on site, or if an off-site customer for the derived caustic could be found. Denitration makes a greater fraction of SR waste available for caustic recovery, and this becomes the major economic driver for adopting denitration technology by reducing the amount of waste that must be sent to Saltstone disposal. However, new customers for the additional caustic must be found in order to make this scenario viable.

Table 5.1 Comparison of Capital and Annual Operating Costs by Competing Technologies

	Cost ($ millions)		
Technology	Capital	Annual Operating	Life Cycle[a]
Electrochemical	22.6	4.0	83.8
Chemical – NAC	21.8	2.9	66.3
Thermal – Plasma Arc	46.6	10.2	204
Thermal – Steam Reforming	33.2	3.5	84

Thermal – Vitrification	46.6	11.7	226
Hydrothermal	29.3	3.0	75.4

[a] Present day value for capital and operating costs – 1997 dollars

Cost Conclusions

- Based on estimated life cycle cost, the unit cost for electrochemical destruction is $0.84 per gallon of treated waste.
- Without caustic recycle, there are no direct cost savings associated with electrochemical denitration. The Saltstone final waste form would be less susceptible to leaching by groundwater (and thereby more robust with respect to compliance with stricter future regulations regarding leachability of wastes), but site managers are unlikely to adopt denitration technology without economic incentives or mandates from regulators.
- Caustic recycle does offer substantial economic benefits by reducing the volume of waste that goes to Saltstone disposal. Savings are directly proportional to the amount recycled, and identification of additional customers for the beneficial use of caustic could pay large dividends.

SECTION 6
REGULATORY AND POLICY ISSUES

Regulatory Considerations

Decontaminated salt solution at SR would be classified as hazardous waste (U. S. Environmental Protection Agency Hazardous Waste Code D002) on the basis of its having a pH>12.5. (See Code of Federal Regulations 261.22 for the definition of D002.) The waste is therefore subject to the Resource and Conservation Recovery Act (RCRA). The electrochemical denitration process would require the following:

- RCRA Part B permit
- National Environmental Policy Act (NEPA) review
- Air pollution permit from the South Carolina Dept. of Health and Environmental Control
- Radioactive materials license

Secondary Waste Streams Regulatory Considerations

If caustic recycle is performed in conjunction with denitration, the caustic recycle product would not be classified as a hazardous waste because it is used as a product in tank waste treatment. However, on-site uses are not large enough to use all of the caustic that could be recovered. There are many off-site commercial uses for decontaminated caustic, but regulatory and institutional barriers restrict the release of materials derived from radioactive wastes. There is no *de minimus* level specified that would allow designation of formerly radioactive materials as non-radioactive.

All liquid waste 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. Denitration would create a Saltstone product that poses much less risk to groundwater than would the baseline product.

Gaseous emissions from the electrolyzers would include ammonia, nitrous oxide, hydrogen, and oxygen. Commercial air pollution control equipment should be adequate to reduce emission levels to acceptance standards.

CERCLA Considerations

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) evaluation criteria are addressed for this technology as follows:

- Overall Protection of Human Health and the Environment: The technology removes nitrate and nitrite from liquid waste that will ultimately be solidified as Saltstone. The resulting solid will be much less susceptible to leaching by groundwater than is Saltstone formed from untreated liquid waste.
- Compliance with applicable or relevant and appropriate requirements (ARARs) can be met.
- Long-term Effectiveness will be enhanced by the technology, with the residual final waste form (Saltstone) posing less risk to area groundwater.
- Reduction of Volume will occur to the extent that caustic recycle is used in conjunction with denitration, thereby reducing the volume of disposed Saltstone.
- Short-term Effectiveness: Construction of a denitration facility could delay Saltstone creation and disposal, but modular components and availability of all needed parts make this risk small.
- Implementability would require a decision on the mode of operation, choice of electrode materials and membranes (if needed), and the use of caustic recycle as part of the operation. If flow-through foam electrodes are used, some development work will be required.
- Costs have been addressed in Section 5.
- State and Community Acceptance should be favorable towards this technology. Off-site use of the caustic product may require approval and negotiation.

Safety, Risks, Benefits, and Community Reaction

Worker Safety

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 electrical hazards (low voltage, high current) to personnel. Electrical hazards could be effectively mitigated, however, by proper design and adherence to standard operating procedures.

Caustic liquids can cause severe burns to the skin and are extremely dangerous to the eyes. Goggles, gloves, and rubber boots in conjunction with Level B or C personnel protection are required. The caustic recycle process could be remotely operated and monitored, thus minimizing the potential for worker contact.

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 and explosively combustible if concentrations are allowed to exceed critical limits.

Community Safety

The risk to the community is low. Secondary containment for piping and storage tanks will reduce the potential for accidental release of liquid caustic. An off-gas system for treating gaseous emissions of ammonia and hydrogen can be constructed using commercially available air pollution control equipment.

SECTION 7

LESSONS LEARNED

Implementation Considerations

- Advantages and limitations of undivided and divided cell configurations have been investigated. A systems engineering review is recommended to determine optimum configuration for large-scale commercialization.
- Implementation of this technology should consider radioactive applications where contact maintenance is allowed. Complete remote operation of the relatively complex electrochemical reactors appears to be cost-prohibitive for treating large volumes of radioactive waste (i.e., more than 1 million gallons per year).
- High surface-area electrodes will be required if low current density is used. Bench-scale studies at the University of South Carolina have yielded good results with a nickel foam flow-through electrode (Jha, Weidner and White 1995). Undesired hydrogen generation at the cathode is also reduced by using foam electrodes.
- Hexavalent chromium is present in small concentration in SR waste, and this inhibits efficient nitrate/nitrite reduction at high current densities. Additional development is required to determine the most effective operating strategy (e.g., cathode material, periodic current reversal and lower current density) to counteract the effects of chromium inhibition

Technology Limitations and Needs for Future Development

- Problems of gas trapping in the pores of metal foam electrodes need to be addressed before these flow-through electrodes can be used with confidence.
- Identification of a cathode material that exhibits high selectivity for nitrogen production at high current density would reduce or eliminate the need for off-gas treatment
- Ammonia gas is sufficiently soluble in basic aqueous solution to require special methods for removing it from the catholyte product before sending that product to the anode for oxidation.
- Reactor performance and lifetime in treating complex waste compositions need to be determined.

Technology Selection Considerations

Pilot-scale testing of the technology with radioactive wastes may be required to demonstrate the technology and provide data with sufficient confidence to complete full-scale engineering design. An important need to enhance the acceptance of this technology is the development of a cathode material that promotes the formation of nitrogen (rather than ammonia or nitrous oxide) at high current density in the presence of hexavalent chromium.

The need for denitration technology depends strongly on release criteria for hazardous nitrates and nitrites. If these criteria change in the future, the need for and attractiveness of an electrolytic denitration process operating at low temperature and pressure could increase significantly

APPENDIX A
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APPENDIX B
ACRONYMS AND ABBREVIATIONS

A	Ampere
ARARs	Applicable or relevant and appropriate requirements
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
D&D	Deactivation and decommissioning
gal	Gallon
G/L	Gram per liter
HLW	High-level waste
hr	Hour
LAW	Low-activity waste
m	Meter
mgy	Million gallons per year
M	Molarity (moles of solute per liter of solution)
MWh	MegaWatt-hour
Nafion-350	Membrane manufactured by E. I. DuPont, Inc.
NEPA	National Environmental Policy Act
O&M	Operation and Maintenance
RCRA	Resource and Conservation Recovery Act
$…m	Million dollars
SR	Savannah River Site (Aiken, SC)
SRTC	Savannah River Technology Center
Wt%	Weight per cent