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Recommendation for Supplemental Technologies for Potential Mission Acceleration

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

CH2MHILL
Hanford Group, Inc.
Richland, Washington

Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC27-99RL14047

Approved for public release; further dissemination unlimited

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Revision 0

Recommendation for Supplemental Technologies for Potential Mission Acceleration

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Release Approval Date

RECOMMENDATION FOR SUPPLEMENTAL TECHNOLOGIES FOR POTENTIAL MISSION ACCLERATION

RPP-11261
REVISION 0

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Billie M. Mauss
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Approval of this document indicates that this document adequately documents the flow sheet analysis of the technologies and how they would be implemented to accelerate the Tank Farm mission and that the document defines the recommended technologies or combinations of technologies for fiscal year 2003 testing consistent with the Performance Management Plan for the Accelerated Cleanup of the Hanford Site and the Cleanup Challenges and Constraints (C3T) ORP Baseline Opportunities Working Group (also called the C3T Mission Acceleration Initiative Team). This signature does not constitute a decision to implement the recommended technologies.

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EXECUTIVE SUMMARY

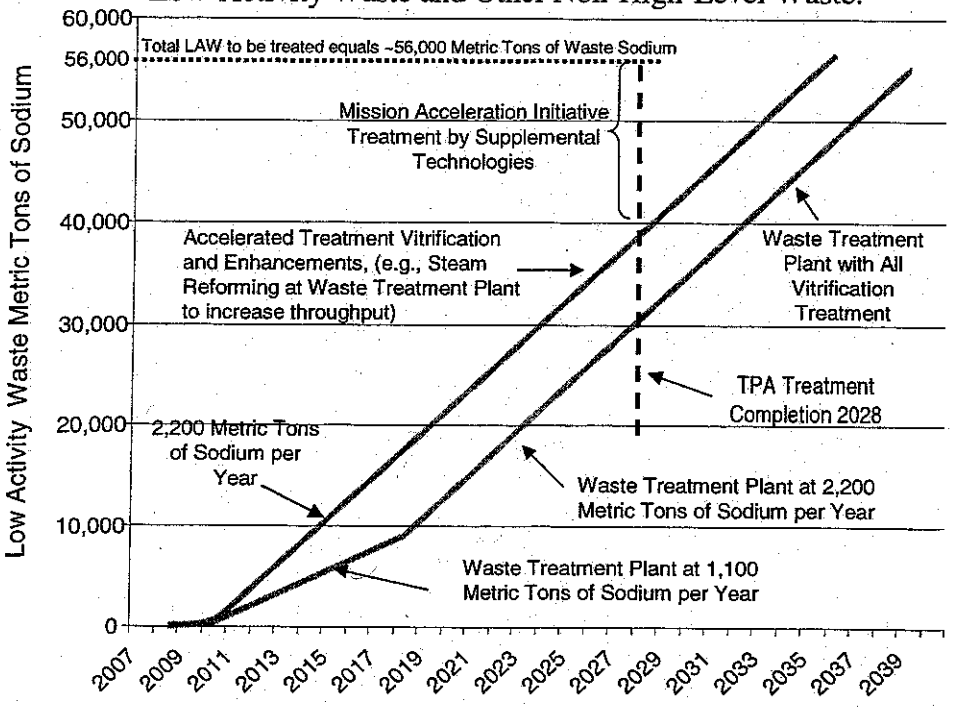
In May of 2002, the U. S. Department of Energy issued the *Performance Management Plan for the Accelerated Cleanup of the Hanford Site*. The plan proposes an accelerated cleanup for the entire Hanford Site. As part of this accelerated cleanup, the plan proposes an "end state" for the Hanford Site Tank Farms in the year 2035 in which the tank waste will have been treated, immobilized, and disposed of, and the tanks will have been closed. On this accelerated schedule, the goal is to ". . . accelerate tank waste treatment completion by 20 years, accelerate risk reduction, and save $20 billion." One of the key elements of this initiative is to ". . . accelerate waste stabilization by developing and deploying alternative treatment and immobilization solutions that are aligned with the waste characteristics to add assurance that overall waste treatment/immobilization will be completed 20 or more years sooner." The implementation of this initiative includes several elements to be performed starting in fiscal year 2003. This document addresses one of these elements: development of recommendations for the supplemental technologies that have the greatest potential to supplement the Waste Treatment Plant throughput and achieve completion of processing by 2028.

The Performance Management Plan identifies a strategy premised on building the currently scoped Waste Treatment Plant and to demonstrate and deploy parallel non-Waste Treatment Plant systems to treat and immobilize tank wastes. This document focuses on recommendations for alternative technologies that have the potential to

- Accelerate Waste Treatment Plant throughput rates
- Provide a potentially suitable low-activity waste alternative to glass that could be used to supplement the treatment of low-activity waste pretreated in the Waste Treatment Plant
- Provide a supplement to Waste Treatment Plant treatment for wastes that can be suitably treated and immobilized using non-Waste Treatment Plant treatment approaches
- Provide more space in the double-shell tank system.

As shown in Figure ES-1, acceleration requires both enhancements to the current Waste Treatment Plant and supplemental treatment technologies to meet the Tri-Party Agreement commitment of completing processing by 2028.

Figure ES-1. Comparison of Baseline and Accelerated Cases for Treating Low-Activity Waste and Other Non-High-Level Waste.



The combination of accelerated LAW treatment in the WTP and supplemental technologies provides a pathway to complete waste treatment by 2028.

Figure ES-1 shows that low-activity waste treatment in the Waste Treatment Plant needs either to be enhanced or supplemented to enable the full amount of low-activity feed in the single-shell and double-shell tanks to be processed by 2028. The bracketed quantity shows the increment needed to achieve the target employing treatment by the supplemental technologies recommended for evaluation in this report. The supplemental technologies are considered for low-activity waste feed that represents the maximum effectiveness of treatment compared with Waste Treatment Plant processing.

The candidate feed for treatment with these supplemental technologies is the saltcake portion of the single-shell tank inventory consisting of 68 single-shell tanks that contain at least 50,000 gallons of saltcake waste. This would be the bulk of the feed to the Waste Treatment

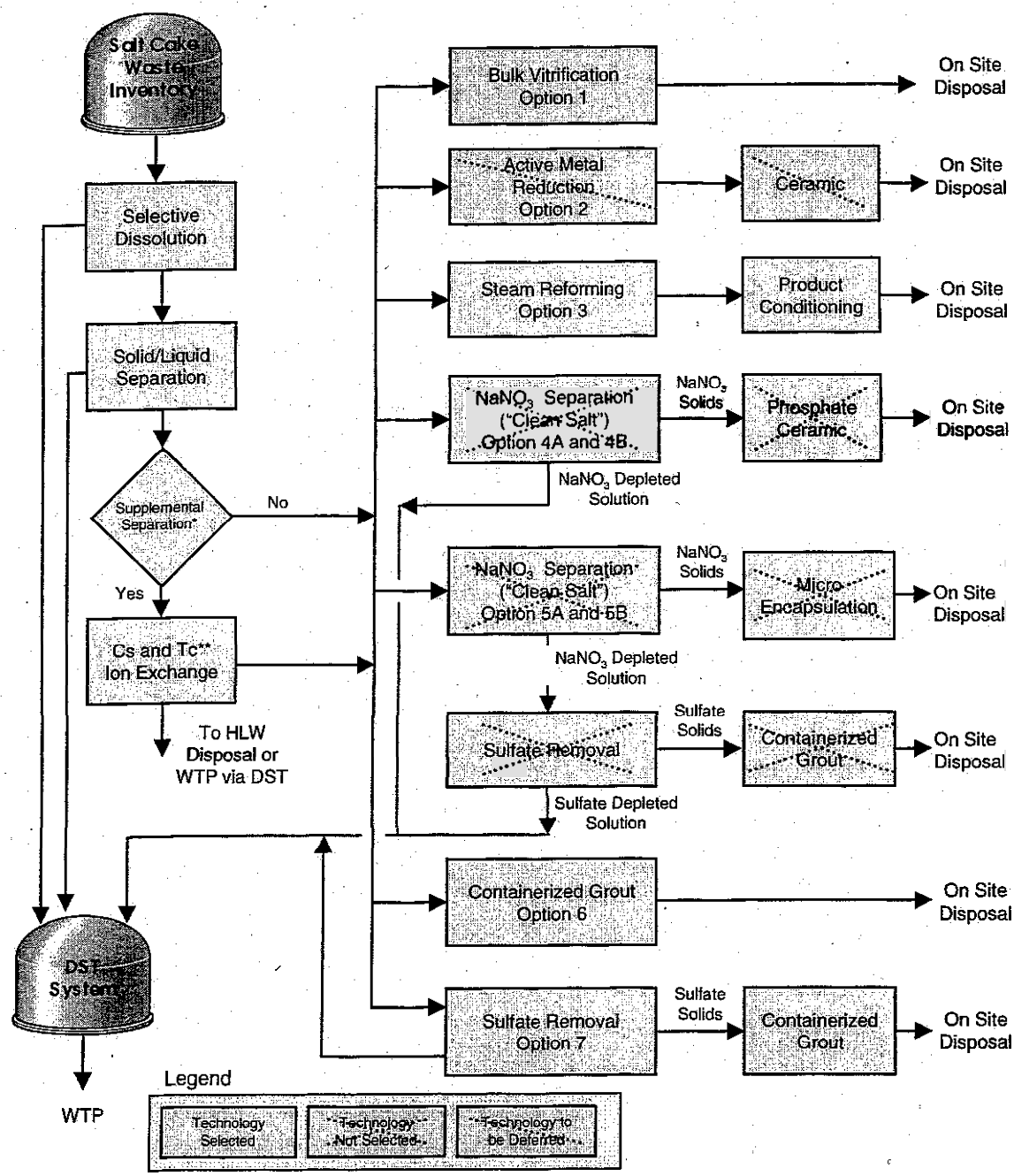
Plant low-activity waste vitrification plant in later years. Double-shell tank saltcake waste already is scheduled for processing in the Waste Treatment Plant, so it was not considered for mission acceleration. Cumulatively, the 68 single-shell tanks contain over 20 million gallons of saltcake, approximately 85 percent of the total saltcake inventory in all single-shell and double-shell tanks.

During March 2002, over two dozen candidate technologies were assessed and presented to a panel of experts assembled in a workshop on April 2 and 3 by the Office of Science and Technology's Tank Focus Area in collaboration with CH2M HILL Hanford Group, Inc. Seven representative flow sheets (technology options) resulted from that workshop as described in Chapter 3. To provide a more quantitative comparison of the retained options, Daniel, Mann, Johnson & Mendenhall — Holmes and Narver, Inc., performed technical data development of the options. The Hanford Site Cleanup Constraints and Challenges Team Mission Acceleration Initiative Subgroup held a workshop May 21 through May 23 to evaluate the options. Independent experts assisted the U.S Department of Energy and the regulators in performing the evaluation. Figure ES-2 shows the supplemental treatment options evaluated and the results of that evaluation.

Four technologies were down-selected by the Cleanup Constraints and Challenges Subgroup and approved by CH2M HILL Hanford Group, Inc., for further development beginning in fiscal year 2003 as reported in Appendices A and C. The four technologies are listed below and described in Chapter 5.0:

- **Sulfate Removal** (option 7 in Figure ES-2) consisting of sulfate precipitation using strontium nitrate addition, filtration, and solidification with grout-forming additives for immobilized waste suitable for land disposal; sulfate removal would allow acceleration of cleanup by reducing the amount of glass produced in the Waste Treatment Plant by increasing the waste loading in the low-activity waste

Figure ES-2. Low-Activity Waste Supplemental Treatments.



* Clean Salt Option 4A and Option 5A don't include Cs and Tc removal
** Tc Ion Exchange added as a result of May 21-23 Workshop

CHG0205-6.ppt

- **Containerized Grout** (option 6 in Figure ES-2) consisting of solidification with grout-forming additives to form immobilized waste suitable for land disposal; containerized grout would allow acceleration of the tank waste cleanup by reducing the amount of sodium that the Waste Treatment Plant would need to process

- **Bulk Vitrification** (option 1 in Figure ES-2) consisting of vitrification inside of the eventual disposal container suitable for land disposal; bulk vitrification would allow accelerated tank waste cleanup by reducing the mass of sodium requiring vitrification in the Waste Treatment Plant

- **Steam Reforming** (option 3 in Figure ES-2) consisting of denitration in a high-temperature fluidized bed with additives then or later to make an immobilized waste suitable for land disposal; steam reforming would allow acceleration of the cleanup of tank waste by reducing the amount of waste requiring vitrification in the Waste Treatment Plant.

A summary of the evaluation of the different technologies is depicted in Figure ES-3 and the results are discussed in Chapter 7.0. The technologies not carried forward are discussed in Chapter 6.0. The four supplemental technologies selected tended to rank higher than those not selected in nearly the entire major groupings of the criteria: compliance and safety, project utility, operability, technical risk, and programmatic risk.

The Cleanup Constraints and Challenges Team Mission Acceleration Initiative Subgroup recommended that all the down-selected technologies require radionuclide separations before low-activity waste feed treatment to ensure that radiation exposures were as low as reasonably achievable and to meet waste disposal requirements. The subgroup also commented that sulfate removal and steam reforming were likely to be enhancements to the Waste Treatment Plant, while the containerized grout and bulk vitrification options would provide supplemental capacity outside the Waste Treatment Plant. The benefits of each low-activity waste supplemental technology in treating waste from the 68 single-shell tanks containing saltcake are summarized in Table E-1. Future work would address any benefits from applying these treatment technologies to double-shell tank inventories.

Figure ES-3. Comparison of Rating Scores.

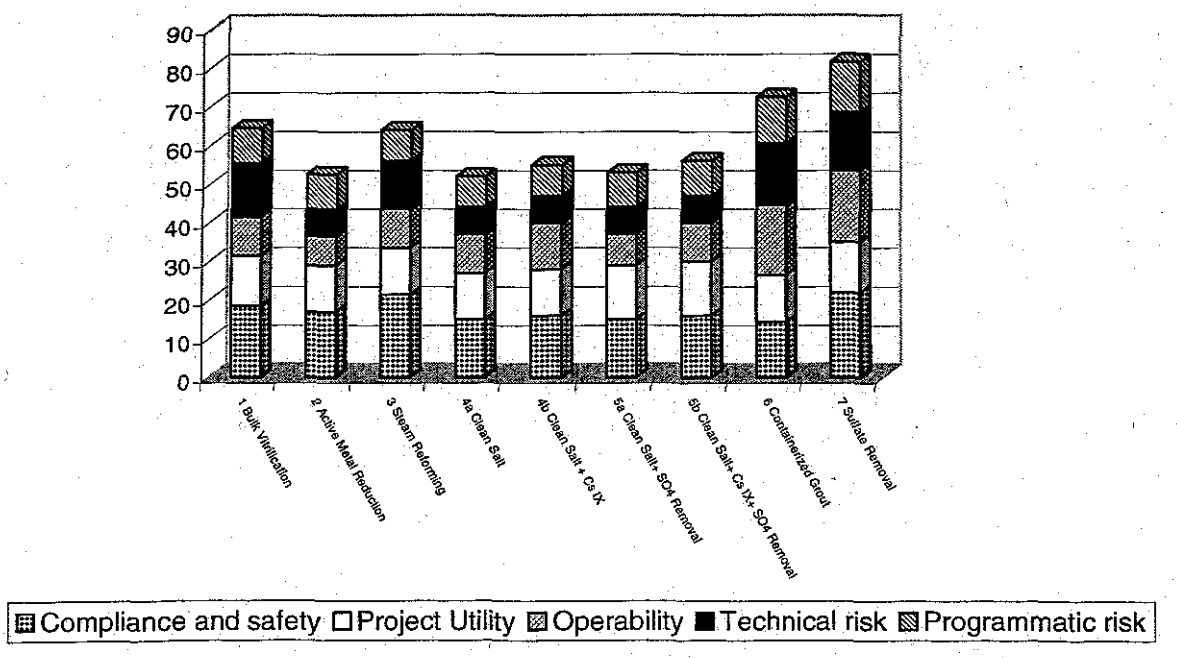


Table E-1. Technology Performance Comparison.

Attribute	Baseline	Sulfate removal	Containerized grout	Bulk vitrification	Steam reforming[a]
Years to process ILAW in WTP at 30 MTG/D (1,100 MT/year)	49.5	36.4	23	23	23
Years to process ILAW in WTP at 30 MTG/D from 2007 to 2018 and at 60 MTG/D from 2018 to *completion*	32	24.2	17.5	17.5	17.5
Total ILAW volume	205,000m^3	183,400m^3	358,900 m^3	148,200 m^3	248,900 m^3

[a] Estimate of steam reforming product is based on the presentation, "THOR Steam Reformer Technology for Hanford Tank Waste Support," made by Brad Mason, Studsvik, AB, to the Cleanup Constraints and Challenges Team Mission Acceleration Initiative Subgroup on May 22, 2002.

ILAW = immobilized low-activity waste.
MT = metric tons.
MTG/D = metric tons of glass per day.
WTP = Waste Treatment Plant.

Although the primary focus in support of the Performance Management Plan has been to select the low-activity waste supplemental treatment technologies for evaluation during fiscal year 2003, other findings also were developed during this effort.

- The waste form disposal requirements for the selected technologies need to be established.
  - The radionuclide separation requirements for these wastes need to be revisited.
  - The waste forms need to meet all necessary regulatory requirements and performance assessment constraints.
- The benefits of denitrating the tank waste was identified at both of the workshops conducted as part of the Cleanup Constraints and Challenges Team evaluation of supplemental alternatives. The successful denitration of the tank waste would allow for a greater range of supplemental technologies (e.g., waste forms) to be explored (e.g., grout, fractional crystallization).
- Previous work summarized in Chapter 8.0 addresses treating transuranic waste using an alternative treatment technology to vitrification as high-level waste in the Waste Treatment Plant. This supports completion of processing by 2028. The transuranic waste is contained predominantly in three double-shell tanks and nine single–shell tanks. Treatment and immobilization of transuranic waste outside of the Waste Treatment Plant results in immobilized material that could be a candidate for disposal at the Waste Isolation Pilot Plant. Not only would the processing of this waste supplement Waste Treatment Plant throughput, but the early processing of the waste in the double-shell tanks could assist in the resolution of a critical risk in the next decade: availability of double-shell tank space to support timely retrieval of single-shell tank waste.

Recommendations

Chapter 9.0 of this report provides recommendations with respect to the Office of River Protection acceleration and the path forward for accelerated cleanup of tank waste. The four recommendations for the acceleration of cleanup of tank waste deal with (1) technology investigation recommended by the Cleanup Constraints and Challenges Team Mission Acceleration Initiative Subgroup, (2) pretreatment and immobilization requirements analysis, (3) other denitration technology investigations, and (4) transuranic and low-level waste tank processing possibilities.

1. Laboratory-scale demonstration and other investigations that would be required (e.g., follow-on engineering evaluations) for the four technologies selected by the Cleanup Constraints and Challenges Team Mission Acceleration Initiative Subgroup should be pursued in fiscal year 2003: sulfate removal, containerized grout, steam reforming, and bulk vitrification. Adequate work is needed to obtain data necessary to determine merit and likelihood of successful deployment. If warranted, one or more of these technologies would then result in pilot testing during fiscal year 2005 and hot field deployment between fiscal years 2006 to 2008. Chapter 5.0 of this report provides the detailed discussion of these four supplemental technologies.

2. An evaluation of the proposed supplemental technologies should be conducted to confirm, or establish, the treatment and disposal requirements for the treated saltcake waste, including the following:

   - The degree of radionuclide separations necessary for the treated saltcake waste in accordance with waste disposal considerations. Chapter 4.0 provides a discussion of pretreatment common to all of the flow sheets considered and recommends additional work starting in fiscal year 2003 to support the laboratory- and pilot-scale testing of the supplemental technologies as well as the hot field deployment demonstration between fiscal years 2006 and 2008. Recommendations include support for gathering additional selective dissolution data on the tank 241-U-107 test, and gathering performance data on solid–liquid separation and cesium and technetium ion exchange starting with maintaining cognizance of the corresponding research and testing by the WTP Project.

   - The degree of hazardous chemical constituent separations necessary for the treated saltcake to meet land disposal restrictions; this evaluation will clarify the leachability requirements for the immobilization supplemental technologies.

   - The impact on the Hanford Site immobilized low-activity waste performance assessment; this evaluation will supplement the assessment of the long-term environmental and human health effects to account for Mission Acceleration

Initiative changes to the baseline-planned disposal of vitrified low-activity fraction of waste presently contained in Hanford Site tanks.

3. The Office of Science and Technology should perform an evaluation of denitration technology.

4. Formal evaluation should be conducted of the waste contained in the Hanford Site tanks to designate which tanks contain transuranic waste suitable for treatment and disposal in the Waste Isolation Pilot Plant. The development program for the Mission Acceleration Initiative technology alternative processes needs to evaluate treatment approaches and waste forms suitable for this approach. The evaluation also would generate engineering data for equipment and facility selection and compliance strategies for disposal of the wastes.

It also is recommended that continued investigation of promising technologies be pursued by the Office of River Protection together with the Office of Science and Technology through their jointly agreed-upon projects on immobilization alternatives to expedite cleanup, single-shell high-level waste tank disposition, and remediation of leaked high-level waste below Hanford Site tanks. These activities ensure that innovative technologies are available on a continuing basis to support the Mission Acceleration Initiative at the Hanford Site.

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CONTENTS

1.0 INTRODUCTION 1-1

2.0 FRAMING THE PROBLEM 2-1

3.0 PROCESS FOR TECHNOLOGY SELECTION 3-1

4.0 PRETREATMENT COMMON TO ALL OF THE FLOW SHEET OPTIONS CONSIDERED 4-1
- 4.1 SELECTIVE DISSOLUTION OF SALTCAKE WASTE 4-1
  - 4.1.1 Process Description 4-1
  - 4.1.2 Technical Analysis 4-2
  - 4.1.3 Implementation for Demonstration 4-4
  - 4.1.4 Implementation for Deployment 4-5
- 4.2 SOLID–LIQUID SEPARATION 4-5
  - 4.2.1 Process Description 4-5
  - 4.2.2 Technical Analysis 4-6
  - 4.2.3 Implementation for Demonstration 4-7
  - 4.2.4 Implementation for Deployment 4-8
- 4.3 CESIUM ION EXCHANGE 4-8
  - 4.3.1 Process Description 4-8
  - 4.3.2 Technical Analyses 4-9
  - 4.3.3 Implementation for Demonstration 4-11
  - 4.3.4 Implementation for Deployment 4-11
- 4.4 TECHNETIUM ION EXCHANGE 4-11
  - 4.4.1 Process Description 4-11
  - 4.4.2 Technical Analyses 4-12
  - 4.4.3 Implementation for Demonstration 4-14
  - 4.4.4 Implementation for Deployment 4-14

5.0 FLOW SHEET OPTIONS CONSIDERED AND RECOMMENDED BY THE CLEANUP CONSTRAINTS AND CHALLENGES TEAM 5-1
- 5.1 SULFATE REMOVAL 5-1
  - 5.1.1 Process Description 5-1
  - 5.1.2 Technical Analysis 5-4
  - 5.1.3 Implementation for Demonstration 5-6
  - 5.1.4 Implementation for Deployment 5-7
  - 5.1.5 Summary 5-7
- 5.2 CONTAINERIZED GROUT 5-7
  - 5.2.1 Process Description 5-7
  - 5.2.2 Technical Analysis 5-8
  - 5.2.3 Implementation for Demonstration 5-10
  - 5.2.4 Implementation for Deployment 5-10
  - 5.2.5 Summary 5-11
- 5.3 BULK VITRIFICATION 5-12

5.3.1 Process Description 5-12
5.3.2 Technical Analysis 5-12
5.3.3 Implementation for Demonstration 5-14
5.3.4 Implementation for Deployment 5-15
5.3.5 Summary 5-15
5.4 STEAM REFORMING 5-16
5.4.1 Process Description 5-17
5.4.2 Technical Analysis 5-18
5.4.3 Implementation for Demonstration 5-20
5.4.4 Implementation for Deployment 5-20
5.4.5 Summary 5-20

6.0 FLOW SHEET OPTIONS ALSO CONSIDERED 6-1
6.1 ACTIVE METAL REDUCTION 6-1
6.2 CLEAN SALT WITHOUT CESIUM ION EXCHANGE 6-1
6.3 CLEAN SALT WITH CESIUM ION EXCHANGE 6-2
6.4 CLEAN SALT AND SULFATE REMOVAL WITHOUT CESIUM ION EXCHANGE 6-3
6.5 CLEAN SALT AND SULFATE REMOVAL WITH CESIUM ION EXCHANGE 6-3

7.0 CLEANUP CONSTRAINTS AND CHALLENGES TEAM ANALYSIS OF OPTIONS CONSIDERED 7-1
7.1 INPUTS TO THE EXPERT PANEL 7-1
7.2 EXPERT EVALUATION 7-5
7.3 CONCLUSIONS AND RECOMMENDATIONS 7-5

8.0 OTHER TANK WASTE TREATMENT OPTIONS 8-1
8.1 TRANSURANIC TANK WASTE SOLIDIFICATION FOR DISPOSAL AT THE WASTE ISOLATION PILOT PLANT 8-1
8.1.1 Process Description 8-2
8.1.2 Transuranic Waste Treatment Alternatives 8-3
8.2 SOLIDIFICATION OF TANK 241-T-110 LOW-LEVEL WASTE SOLIDS 8-6

9.0 RECOMMENDATIONS AND PATH FORWARD 9-1
9.1 RECOMMENDATIONS 9-1
9.1.1 Technologies for Investigation Fiscal Year 2003 9-1
9.1.2 Waste Disposal Requirements 9-3
9.1.3 Supplemental Analysis of Denitration of Tank Waste 9-3
9.1.4 Transuranic Waste Treatment 9-4
9.1.5 Continued Development of Office of Science and Technology Initiatives 9-4
9.2 PATH FORWARD 9-4

10.0 REFERENCES 10-1

APPENDICES

A EVALUATION OF LOW-ACTIVITY WASTE FEED SUPPLEMENTAL TREATMENT OPTIONS BY THE CLEANUP CONSTRAINTS AND CHALLENGES TEAM MISSION ACCELERATION INITIATIVE TEAM FOR THE OFFICE OF RIVER PROTECTION ..... A-I

B THREE-DAY WORKSHOP TO EVALUATE ALTERNATIVE TREATMENT OPTIONS FOR HANFORD SITE TANK WASTE MEETING MINUTES ..... B-I

C CLEANUP CONSTRAINTS AND CHALLENGES MISSION ACCELERATION INITIATIVE SUBGROUP REPORT ..... C-I

D CANDIDATE SALTCAKE WASTE FOR SELECTIVE DISSOLUTION ..... D-I

E FLOW SHEET OPTIONS ALSO CONSIDERED ..... E-I

F IDENTIFICATION OF TRANSURANIC AND LOW-LEVEL TANK WASTES ..... F-I

FIGURES

Figure 1-1. The Role of Technology Initiatives in the Hanford Site Accelerated Cleanup.....1-1

Figure 2-1. Comparison of Baseline and Accelerated Cases for Treating Low-Activity Waste and Other Non-High-Level Waste.....2-2

Figure 3-1. Low-Activity Waste Supplemental Treatment Alternatives.....3-3

Figure 4-1. Sintered Metal Crossflow Filter Elements.....4-6

Figure 4-2. Oak Ridge National Laboratory Wastewater Triad: Solid–Liquid Separation Unit.....4-8

Figure 5-1. Sulfate Removal Process Diagram.....5-4

Figure 5-2. Containerized Grout Block Flow Diagram.....5-7

Figure 5-3. In-Container Vitrification Block Flow Diagram.....5-12

Figure 7-1. Comparison of Rating Scores.....7-6

Figure 8-1. Preliminary Conceptual Flow Diagram for Transuranic Tank Waste Treatment.....8-3

TABLES

Table 3-1. Treatment Technologies Candidates....3-2

Table 4-1. Predicted Selective Dissolution Factors for Chemicals....4-3

Table 4-2. Predicted Selective Dissolution Factors for Radionuclides....4-4

Table 5-1. Immobilized Low-Activity Waste Glass Production at Baseline and as Reduced by Sulfate Removal....5-3

Table 5-2. Comparison of Containerized Grout with Original Baseline....5-11

Table 5-3. Comparison of Bulk Vitrification with the Original Baseline....5-16

Table 5-4. Comparison of Steam Reforming with the Original Baseline....5-21

Table 7-1. Impact of Each Option on Waste Treatment Plant Low-Activity Waste Processing Duration and Immobilized Low-Activity Waste Total Volume....7-2

Table 7-2. Evaluation Criteria....7-3

TERMS

BNI	Bechtel National, Inc.
C3T	Cleanup Constraints and Challenges Team
CH-TRU	contact-handled transuranic
CHG	CH2M HILL Hanford Group, Inc.
DOE	U.S. Department of Energy
DST	double-shell tank
FY	fiscal year
HLW	high-level waste
ICV	in-container vitrification
ILAW	immobilized low-activity waste
INEEL	Idaho National Engineering and Environmental Laboratory
LAW	low-activity waste
LDR	land disposal restriction
MAI	Mission Acceleration Initiative
MT	metric tons
MTG/D	metric tons of glass per day
NRC	U.S. Nuclear Regulatory Commission
ORP	Office of River Protection
RCRA	*Resource Conservation and Recovery Act*
RL	Richland Operation Office
RH-TRU	remote-handled transuranic
RPP	River Protection Project
SST	single-shell tank
TRU	transuranic
WIPP	Waste Isolation Pilot Plant
WTP	Waste Treatment Plant

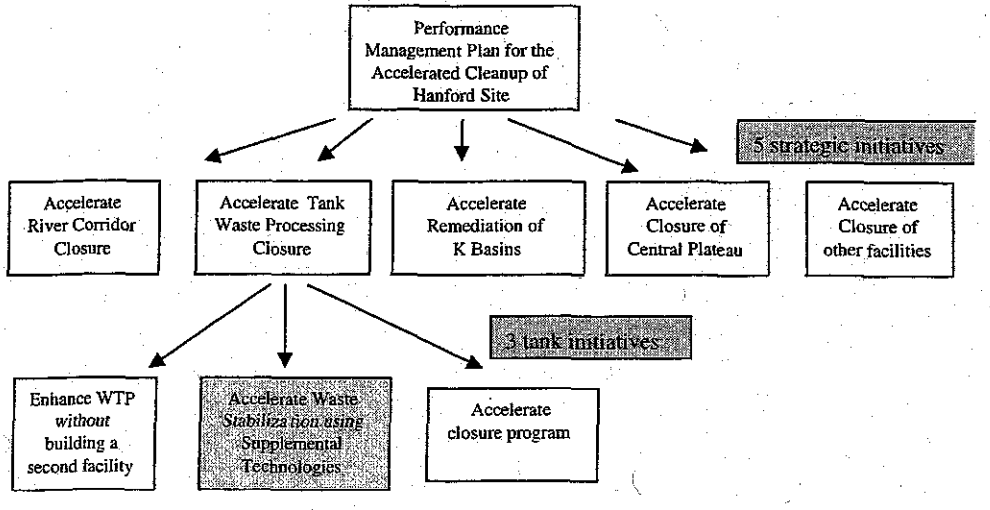
1.0 INTRODUCTION

The U.S. Department of Energy (DOE), Office of River Protection (ORP), is responsible for the remediation and stabilization of the Hanford Site tank farms, including 53 million gallons of highly radioactive mixed waste contained in 149 single-shell tanks (SST) and 28-double-shell tanks (DST). This program is called the River Protection Project (RPP). The current plan calls for all wastes retrieved from the tanks to be transferred to a new Waste Treatment Plant (WTP) where they will be chemically partitioned to separate the highly radioactive materials requiring permanent isolation (high-level waste [HLW]) from very large volumes of chemical wastes. The HLW constituents will be vitrified, stored onsite, and ultimately disposed of in the offsite national repository. The less radioactive chemical waste, referred to as low-activity waste (LAW), will be vitrified and then disposed of onsite in trenches that comply with the *Resource Conservation and Recovery Act of 1976* (RCRA). Current estimates for this mission predict completion around 2070 if no additional processing facilities are deployed. A second LAW vitrification plant and expansion of the HLW vitrification capacity will be required to achieve commitments made in the *Hanford Federal Facility Agreement and Consent Order* (Ecology 1989), also know as the Tri-Party Agreement.

In May of 2002, the DOE issued *Performance Management Plan for the Accelerated Cleanup of the Hanford Site* (Performance Management Plan), a plan to transform and accelerate cleanup of the Hanford Site. The plan provides a five-point acceleration strategy to complete cleanup of the entire Site by 2035. The second of these five strategies calls for accelerated closure of the Tank Farms by the year 2035 by means of three more initiatives. To meet the closure schedule, two of the three initiatives will be developed in parallel with the aim of completing all tank waste treatment by 2028. Figure 1-1 shows the interrelationship between initiatives in the plan and the specific role of new supplemental technologies in the overall acceleration program.

The purpose of this document is to recommend supplemental technologies that have the greatest potential to accelerate the RPP mission.

Figure 1-1. The Role of Technology Initiatives in the Hanford Site Accelerated Cleanup.



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2.0 FRAMING THE PROBLEM

The Performance Management Plan describes three key elements of accelerated treatment to complete tank waste processing by 2028:

1. Build only one WTP facility but enhance its throughput

2. Provide a potentially suitable LAW alternative to glass that could be used to supplement the LAW pretreated in the WTP

3. Provide a supplement to WTP treatment for wastes that can be suitably treated and immobilized using non-WTP treatment approaches.

From these three elements it is clear that in order to complete tank waste processing by 2028, the RPP must establish an integrated approach to selecting supplemental technologies.

Figure 2-1 (based on Figure 8 of the Performance Management Plan) shows how the synergy between WTP enhancements and supplemental treatments can achieve the 2028 milestone. The basic plant design supports a 1X capacity of 30 metric tons of glass per day (MTG/D) LAW, which corresponds to 1,100 metric tons (MT) of sodium processed per year. WTP pretreatment features support a 2X throughput, and improvements in LAW immobilization capacity are expected to support the same 2X rate by some combination of increased melter capacity and use of in-plant improvements such as steam reforming. As shown in Figure 2-1, the 2X WTP would complete treatment after 2035. Supplemental treatments on selected LAW feeds allow completion by 2028. As the figure implies, before selecting appropriate supplemental technologies it is important to understand which waste should be targeted.

The selection of appropriate target waste took into consideration several factors in anticipation of technology comparisons. CH2M HILL Hanford Group Inc. (CHG) performed a comprehensive analysis of tank waste in order to provide a rational basis for the technology selection process. Target waste was selected according to the following logic:

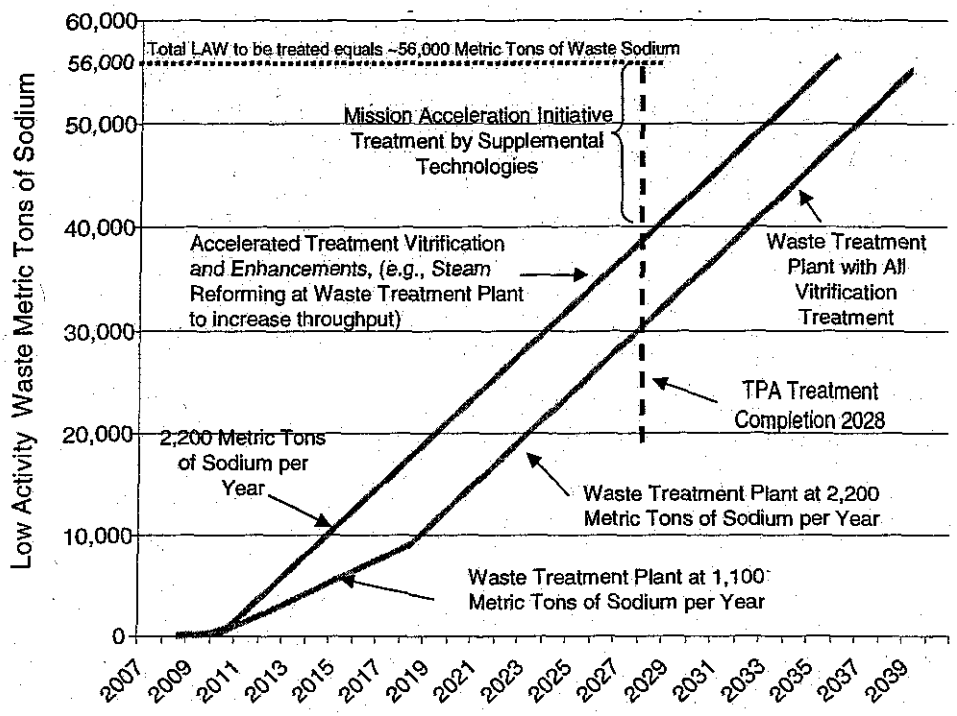
1. No DST waste and waste included in WTP phase 1 (although the analysis did consider some DST waste that, if treated by a different technology, could show significant cost and schedule savings over the baseline)

2. Waste that contained species non-optimal for processing in the WTP (such as sulfates)

3. Waste that existed in sufficient quantity such that the deployment of a minimum set of right-sized technologies (preferably one) could provide a complete treatment solution by 2028 alongside WTP

4. Waste that did not compromise the retrieval demonstration and Tank Closure Program

Figure 2-1. Comparison of Baseline and Accelerated Cases for Treating Low-Activity Waste and Other Non-High-Level Waste.



The combination of accelerated LAW treatment in the WTP and supplemental technologies provides a pathway to complete waste treatment by 2028.

5. Waste that was located as centrally as possible so that a minimum number of deployments could achieve the desired effect

6. Waste that was representative of LAW because treating this fraction simplified retrieval and made the largest contribution to overall treatment commitments.

This target analysis provided the basis for the selection of supplemental technologies.

- The primary strategy was focused on treating 68 SSTs. These tanks contain predominantly saltcake, and at least 50,000 gallons of saltcake waste each. Cumulatively, these tanks contain over 20 million gallons of saltcake, approximately 85 percent of the total saltcake inventory for all tanks. These tanks contain about 60 percent of the sodium and over 70 percent of all the nitrates and sulfates in the total tank waste inventory.[1] If processed through the WTP, the amount of immobilized LAW (ILAW) glass produced from the saltcake waste contained in these 68 SSTs would be about 65 percent of the total ILAW glass produced. This represents enough waste to

[1] Tank waste inventories are from the Tank Waste Information Network System best basis inventory as of April 10, 2002 (http://twins.pnl.gov: 8001/twins.html).

ensure the parallel achievement of the 2028 completion alongside WTP even for the non-accelerated WTP case. No other waste groupings were able to meet the above criteria, and although other waste treatment options may contribute further to acceleration and will be discussed in this report, the LAW contained in these 68 tanks became the basis for the supplemental technology selection process. A more detailed discussion of the candidate saltcake waste associated with the 68 SSTs is provided in Appendix D.

- Twelve tanks were identified as not containing HLW using a source-based definition. These wastes would be classified as transuranic (TRU) wastes and as such could be treated and sent to the Waste Isolation Pilot Plant (WIPP).

Initial studies have shown that considerable savings over the baseline are possible. Additionally, three of these tanks are DSTs and their early treatment would free up DST space during a time frame that may be valuable in mitigating risks with WTP startup. This alternative treatment would contribute about 3 years reduction in HLW vitrification duration to the 2028 commitment but is considered because of its other value to the RPP and is consistent with the Performance Management Plan strategy.

- One tank (241-T-110) was identified as containing low-level waste, predominantly as bismuth phosphate and metal (e.g., iron, chromium) hydroxide precipitates. This waste also could be processed using non-WTP-based treatment for onsite disposal thus reducing waste processing duration at the WTP.

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3.0 PROCESS FOR TECHNOLOGY SELECTION

Technologies for treating the Hanford Site tank wastes, including the saltcake waste, have been researched and evaluated for a number of years. A systematic review of all possible technologies was conducted in the early 1990's, and resulted in the issuance of DOE/EIS-0189, *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement*, and subsequent Record of Decision (62 FR 8693). The Tank Waste Remediation System is now the RPP. The studies were reviewed in January and February of 2002, and vendors, national laboratories, and universities were consulted for additional technologies, as time allowed, in order to establish a list of possible technologies for treating the LAW. All candidate technologies and the assembly of those technologies into flow sheet options were screened to ensure that they met the criteria defined as closing the LAW treatment gap by accelerating cleanup and reducing risk while maintaining cleanup quality.

During the month of March of 2002, candidate technologies were grouped into families that met the basic screening principles but differed in implementation (e.g., all calcination technologies were grouped together, all polymer-based microencapsulation technologies were grouped together). Treatment technologies identified are listed in Table 3-1. SST 241-S-112 was selected as a good representative for the targeted LAW source stored in the SSTs. Technology experts were asked to prepare short briefings on their technology and how it could be applied to tank 241-S-112-type waste with the objective of a tank-scale (approximately 5 gal/min throughput) demonstration with real waste in 2005 or 2006. Additionally, separation technologies were combined with immobilization technologies to constitute complete treatment options.

At the Mission Acceleration Initiative (MAI) Technology Demonstration Workshop held on April 2 and 3, 2002, staff from CHG, Bechtel National, Inc. (BNI), ORP, the Tank Focus Area, and Pacific Northwest National Laboratory and other technical and programmatic experts from the DOE complex assembled to review this relatively high level information on technologies proposed for LAW treatment, to discuss how these technologies could be combined into viable treatment flow sheet options other than the current baseline WTP process, and to screen out technologies and combinations that did not appear viable for short-term demonstrations. Screened out technologies with longer term potential were referred to the Office of Science and Technology for further development. Experts from national laboratories, DOE contractors, and selected technology experts were invited to make presentations describing their approach for treating a representative tank of LAW saltcake waste in a demonstration to be conducted within 4 years that would be applicable for addressing the WTP LAW processing capacity gap.

Table 3-1. Treatment Technologies Candidates.

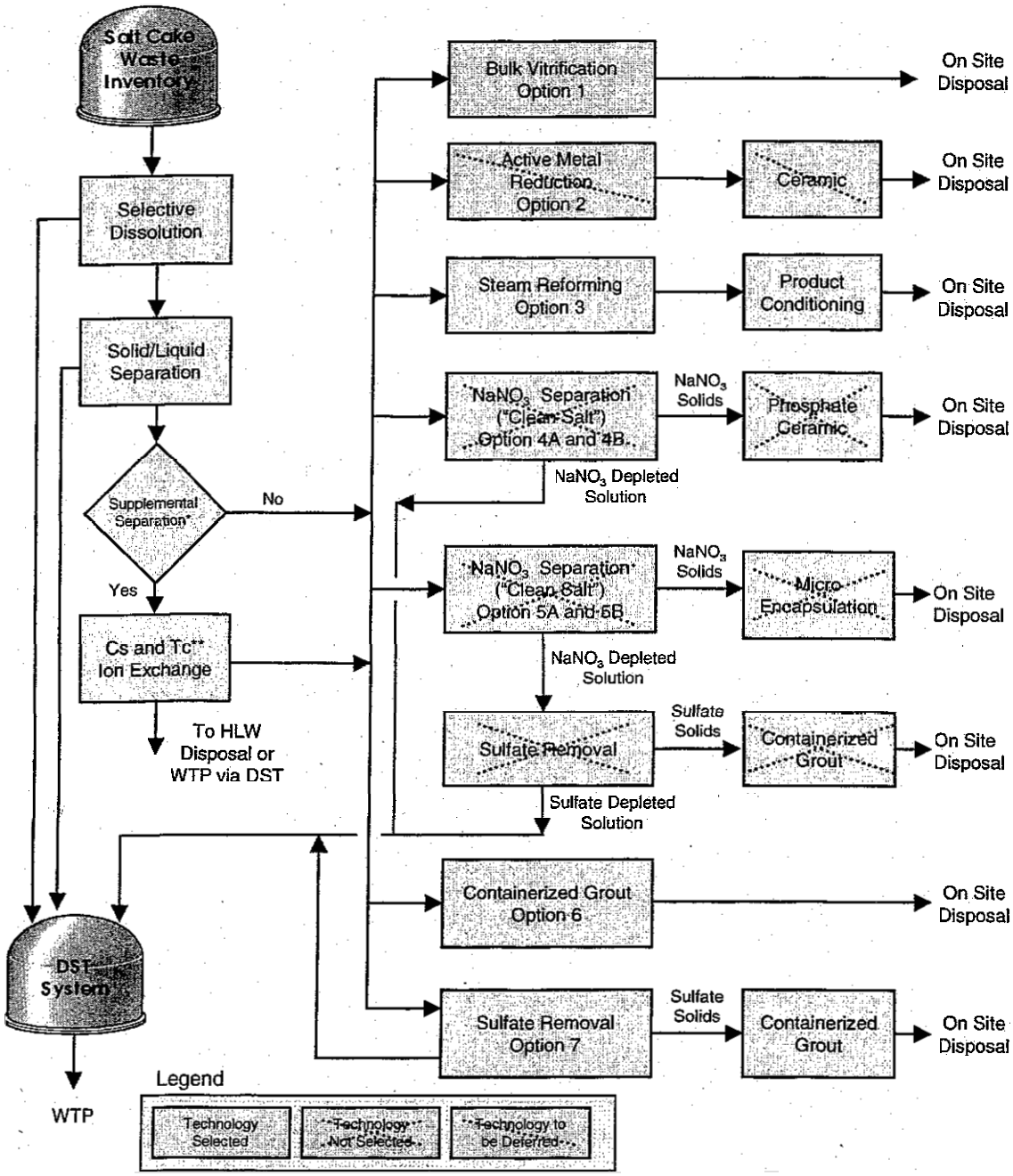
Pretreatment Options	Immobilization Options
Selective dissolution	Ex situ, bulk, mobile vitrification
^{137}Cs ion exchange	Grouting/sorption
Cesium and technetium removal by solvent extraction	Microencapsulation
Thermal denitration by steam reforming, fluidized bed, or rotary kiln	Other ambient temperature immobilization
Active metal reduction of nitrate	Thermal processes for immobilization (steam reforming; active metal reduction)
Electrochemical denitration with or without NaOH recovery (by electrochemical or solvent extraction	None
Fractional crystallization for sodium salt removal	None
Sulfate removal by precipitation or factional crystallization	None

The results of the workshop are documented as an appendix in reference RPP-11131, *Mission Acceleration Initiative Demonstration Information Package.* They were reviewed by ORP, CHG, Pacific Northwest National Laboratory, and the Cleanup Constraints and Challenges Team (C3T) MAI Subgroup to agree upon those flow sheets for which more detailed evaluation would be conducted with the purpose of submitting the selected flow sheets for evaluation by the C3T MAI Subgroup by the end of May of 2002. The options selected were either those with the highest scores in the April workshop or options built around technologies that had received the highest scores when scores from all options, including the particular technology, were added. Two technologies were included in the selected options despite relatively low scores: Active metal reduction and microencapsulation with polymers because there was a concern that they may have been scored low because most workshop participants were unfamiliar with them.

During April and early May of 2002, CHG developed flow sheets for the six selected treatment options (plus two variants). Sulfate separation by strontium precipitation in acidic conditions was added as a seventh option during that period. Sulfate separation had not been considered in the previous months, mainly because a relevant production reference had not been identified. Subsequent to the April workshop, CHG identified that sulfate separation by strontium precipitation in acidic condition had been conducted at the Hanford Site B Plant from 1974 through 1985.

Figure 3-1 summarizes the process used in the nine flow sheets options for which mass balance and other data were developed.

Figure 3-1. Low-Activity Waste Supplemental Treatment Alternatives.



* Clean Salt Option 4A and Option 5A don't include Cs and Tc removal.
** Tc Ion Exchange added as a result of May 21-23 Workshop

CHG0205-6.ppt

A three-day workshop was held on May 21, 22, and 23, 2002, to evaluate selected supplemental treatment options for Hanford Site LAW. The C3T MAI Subgroup together with invited experts listened to presentations on flow sheet options for the MAI to close the gap between LAW treatment capacity and the total quantity requiring treatment by 2028 according to the Tri Party

Agreement. The workshop participants then evaluated the combinations of technologies as presented and as they deemed to be better adapted to meeting the criteria.

Chapters 4.0 through 7.0 of this report provide descriptions of the pretreatment steps common to all of the flow sheets (Chapter 4.0), the flow sheet options that were considered and recommended by the C3T workshop (Chapter 5.0) and those considered by the C3T workshop but not recommended (Chapter 6.0). Chapter 7.0 summarizes the comparative analysis of the options with each other and with the baseline to the extent performed by the engineering staff between the April 2-3 workshop and the May 21-23 workshop and by the evaluators at the May 21-23 workshop. Appendix A provides the evaluation report describing the three-day workshop. It includes background information, a summary of the LAW treatment flow sheet options, a discussion of the evaluation process, and the results of the workshop. The minutes of that workshop are contained in Appendix B. Included as attachments of the minutes are (1) a list of attendees; (2) condensed evaluation factors for possible RPP technologies; (3) evaluation results for possible RPP technologies; (4) presentation viewgraphs; and (5) evaluators' post-meeting comments. Chapter 8.0 discusses supplemental treatment options for TRU tank waste and low-level tank waste. Chapter 9.0 summarizes the recommendations for development of supplemental treatment options during fiscal year (FY) 2003.

4.0 PRETREATMENT COMMON TO ALL OF THE FLOW SHEET OPTIONS CONSIDERED

Participants at the C3T workshop conducted April 2-3, 2002, recommended that the saltcake waste be pretreated using selective dissolution, solid–liquid separation, and ion exchange to separate analytes (e.g., sulfate and sodium), ^{137}Cs, and other radionuclides from the saltcake waste before conducting further treatment process steps. Participants at the C3T workshop conducted May 21-23, 2002, recommended that in addition to cesium separation, ^{99}Tc should be separated from the saltcake waste.

The participants at the C3T workshops assumed ^{137}Cs and ^{99}Tc needed to be separated from the saltcake waste. A combination of selective dissolution and ion exchange was assumed necessary to achieve a high degree of ^{137}Cs and ^{99}Tc separation from the dissolved saltcake solution. The following sections discuss selective dissolution, solid–liquid separation, cesium ion exchange, and technetium ion exchange.

4.1 SELECTIVE DISSOLUTION OF SALTCAKE WASTE

Selective dissolution in this concept is a process that would be used in-tank during waste retrieval to selectively separate chemical and radionuclide species by means of their solubility. More soluble chemical and radionuclide species such as cesium, technetium, and aluminum, would be removed preferentially by controlled water addition to saltcake waste. After removal of the more soluble species, the remaining saltcake waste would be dissolved by addition of water.

4.1.1 Process Description

The MAI supplemental treatment alternatives assume that a demonstration of selective dissolution will be conducted as part of retrieving saltcake waste from a SST. The first step in selective dissolution of saltcake waste involves removing the pumpable liquid from the saltcake waste using the existing interim stabilization salt well pumps and transfer pipelines. Next, a controlled volume of water is added to the SST to displace interstitial liquid that contains ^{137}Cs and selectively dissolve constituents of the saltcake waste, producing a waste stream rich in cesium and low in sulfate and sodium. The cesium-rich waste stream is transferred to a DST and staged for processing as LAW feed in the WTP. Finally, the remaining saltcake waste is dissolved by controlled addition of water. The dissolved saltcake waste is then transferred to the MAI supplement treatment for processing.

The benefits of selective dissolution are as follows:

- Improved waste loading in the ILAW glass produced at the WTP because of reduced sulfate concentration in some of the LAW feed (i.e., cesium-rich stream from selective dissolution of saltcake waste) (treating and disposing of the sulfate through the supplemental (MAI) pathway will reduce the amount of glass the WTP needs to produce)

- Reduced waste pretreatment requirements for the supplemental treatment and immobilization options through removal of some of the ^{137}Cs from the LAW
- Less shielding required for the equipment if cesium ion exchange is not employed.

Although the flow sheet analyses for the MAI supplemental treatment alternatives assumed that selective dissolution was successful, the performance of the MAI supplemental treatment alternatives is not dependent on the performance of selective dissolution. The MAI supplemental treatment alternatives can still achieve the goals of reducing RPP mission risks, schedule, and cost regardless of the method used to retrieve waste from the SSTs.

4.1.2 Technical Analysis

4.1.2.1 Partitioning of Waste Components

Selective dissolution of saltcake waste is based on the higher solubility of aluminum, cesium, iodine, technetium, hydroxide, chromate, and nitrite in saltcake waste as predicted by solution solubility modeling and laboratory experiments with tank waste samples. Carbonate, nitrate, phosphate, and sulfate exhibit lower solubility in the saltcake waste. This phenomenon has been verified by recent saltcake dissolution testing conducted at the Hanford Site, which has shown at the laboratory scale that chemical and radioactive species selectively dissolve from the saltcake waste (see HNF-8849, *Saltcake Dissolution FY 2001 Status Report*, for details). According to WSRC-TR-2001-00277, *Tank 37H Salt Removal Batch Process and Salt Dissolution Mixing Study*, this phenomenon also has been observed with saltcake waste in underground storage tanks at the Savannah River Site. Both the Hanford and Savannah River Sites are evaluating this phenomenon as a means to separate a cesium-rich stream from a sodium salt-rich stream.

Tables 4-1 and 4-2 provide estimates of the percentages of selected chemicals and radionuclides that would be removed during selective dissolution of saltcake waste and sent to the WTP for processing. The information in Tables 4-1 and 4-2 is based on laboratory-scale dissolution tests conducted with core 292 from tank 241-S-112 in which a 25 wt% water dilution of the saltcake waste was conducted. Higher levels of cesium and technetium separation from the salts can be achieved by additional water washing of the saltcake. This could be beneficial for demonstrating the MAI supplemental treatment alternatives and eliminate the need for cesium and technetium separation using ion exchange.

Table 4-1. Predicted Selective Dissolution Factors for Chemicals.

Specie	Percentage to Waste Treatment Plant
Al	60
Ca	0
CrO_4	55
K	20
Na	30
NO_3	35
NO_2	60
OH	60
Cl	60
F	0
PO_4	25
SO_4	10
TIC	15
TOC	10

Note: The fraction of analyte dissolved and transferred to the WTP is based on laboratory-scale tests conducted by D. L. Herting with core number 292 from single-shell tank 241-S-112, as reported April 2, 2002.

Table 4-2. Predicted Selective Dissolution Factors for Radionuclides.

Radionuclide	Percentage to Waste Treatment Plant
^{90}Sr	0[a]
^{99}Tc	60
^{129}I	60
^{137}Cs	60
^{241}Am	0[a]
Pu	0[a]

[a] These radionuclides are expected to be associated with solids and would be separated from the dissolved saltcake by filtration. These solids and radionuclides would then be transferred to the Waste Treatment Plant for treatment.

CHG will be conducting a demonstration of selective dissolution in tank 241-U-107 late in fiscal year (FY) 2002. This demonstration will evaluate the effectiveness of the sprinkler system for distribution of water across the saltcake waste surface. Information from this demonstration will be used for the waste retrieval project for tank 241-S-112. Westinghouse Savannah River Company also plans to conduct a demonstration in late FY 2002 to flush (i.e., selectively displace) cesium that is contained in the interstitial liquid within the saltcake waste contained in tank 41H.

Recommendation: It is recommended that sufficient information be collected as part of the tank 241-U-107 proof-of-concept test for the low-volume density gradient approach to retrieval to enable verification of waste component partitioning. This may require extending the duration of the demonstration and retrieving additional saltcake waste from tank 241-U-107 as part of the selective dissolution test. The partitioning of waste components during selective dissolution of saltcake waste needs to be verified to improve estimates of the waste fraction processed in the WTP and of the WTP processing duration and to support design of the MAI supplemental treatment alternative.

4.1.3 Implementation for Demonstration

Existing waste retrieval projects present a unique opportunity to collect data that may be used to avoid or reduce the need to deploy additional demonstrations to support evaluation of the selective dissolution process. The waste retrieval project for tank 241-S-112 is deploying an in-tank water sprinkler system to distribute water across the saltcake waste surface to leach and dissolve saltcake waste for retrieval. The sprinkler system also is used to control introduction of water to limit the free liquid inventory in the SST while dissolving saltcake waste. A salt-well pump that connects to an aboveground transfer pipeline is then used to transfer supernatant from the SST to a DST.

If the sprinkler system proves successful, a similar sprinkler system could be deployed in another SST for dissolution of saltcake waste that would comprise the feed to the MAI supplemental treatment alternative demonstration. Alternatively, the dissolved saltcake solution from tank 241-S-112, after receipt into the DST system, or any other supernatant contained within the DST system could be used as feed for the MAI supplemental treatment alternative demonstration.

4.1.4 Implementation for Deployment

Following the successful MAI technology demonstration, sprinkler-type systems could be used to dissolve saltcake waste in the 68 SSTs to provide the waste feed to all MAI supplemental treatment alternatives. However, if selective dissolution proves not to be viable, alternative methods can be used to retrieve the waste contained in these 68 SSTs. Leak detection, mitigation, and monitoring systems would also be deployed as appropriate in conjunction with the selected waste retrieval method.

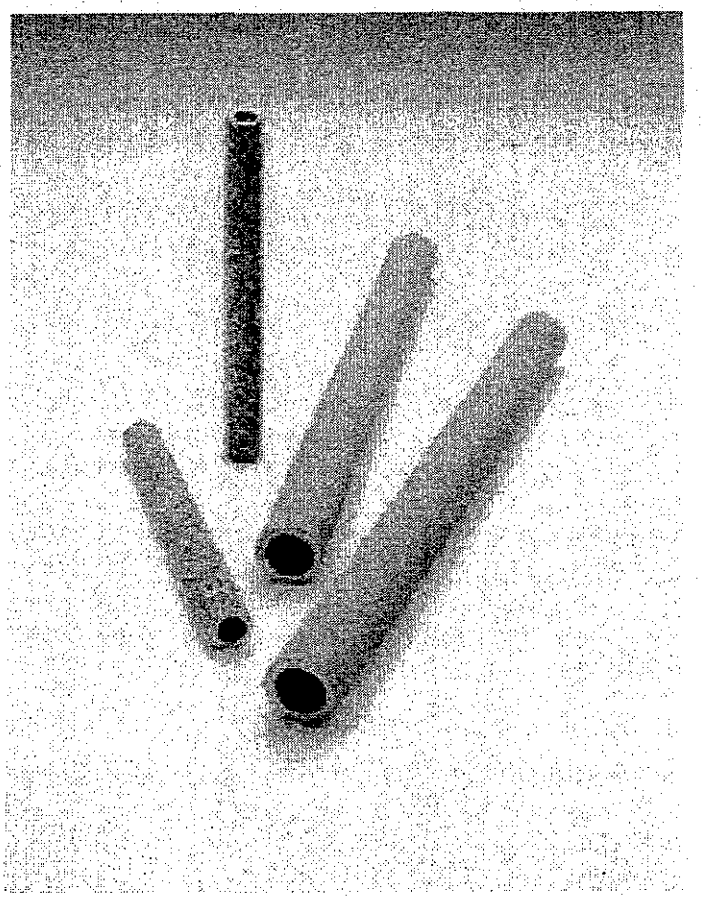
4.2 SOLID–LIQUID SEPARATION

4.2.1 Process Description

Saltcake waste that has been dissolved and retrieved from the SSTs will contain entrained solids. These entrained solids contain ^{90}Sr and actinides (e.g., ^{237}Np, ^{239}Pu, ^{240}Pu, ^{241}Am). Removal of these entrained solids is assumed to be necessary in order for the immobilized waste produced from any of the MAI supplemental treatment alternative processes to meet waste disposal requirements. Furthermore, separation of entrained solids is necessary to prevent plugging of the cesium and technetium ion exchange columns due to accumulation of solids during several of the MAI supplemental treatment alternative processes.

Solid–liquid separation is assumed to be conducted using a crossflow filter that contains 0.1-μm, sintered metal filter elements (see Figure 4-1). Crossflow filtration using 0.1-μm, sintered metal filter elements is the solid–liquid separation technology selected for use in the WTP.

Figure 4-1. Sintered Metal Crossflow Filter Elements.



4.2.2 Technical Analysis

There are no identified high risks with the solids–liquid separation process. However, engineering data must be obtained for the specific waste to support the design of the solid–liquid separation unit for the MAI supplemental treatment alternatives. The engineering data obtained from tests conducted with saltcake waste samples will benefit the WTP project by providing additional confidence that crossflow filtration can be used to separate entrained solids from saltcake waste. As an additional benefit, this testing will enhance the available tank data for WTP design and operations. This will reduce the technical risk that the crossflow filtration system selected for use in the WTP might not meet performance requirements.

4.2.2.1 Crossflow Filter Sizing

The surface area of the crossflow filter needed to separate entrained solids from the dissolved saltcake waste has not been determined. The required surface area of the crossflow filter unit is dependent on the desired waste processing throughput, waste characteristics, and filter media characteristics (e.g., pore size, filter flux versus transmembrane pressure and axial velocity). The characteristics of the candidate dissolved saltcake waste and those of the filter media need to be determined as part of the development program for the MAI supplemental treatment alternative processes.

4.2.2.2 Solids Separation Efficiency

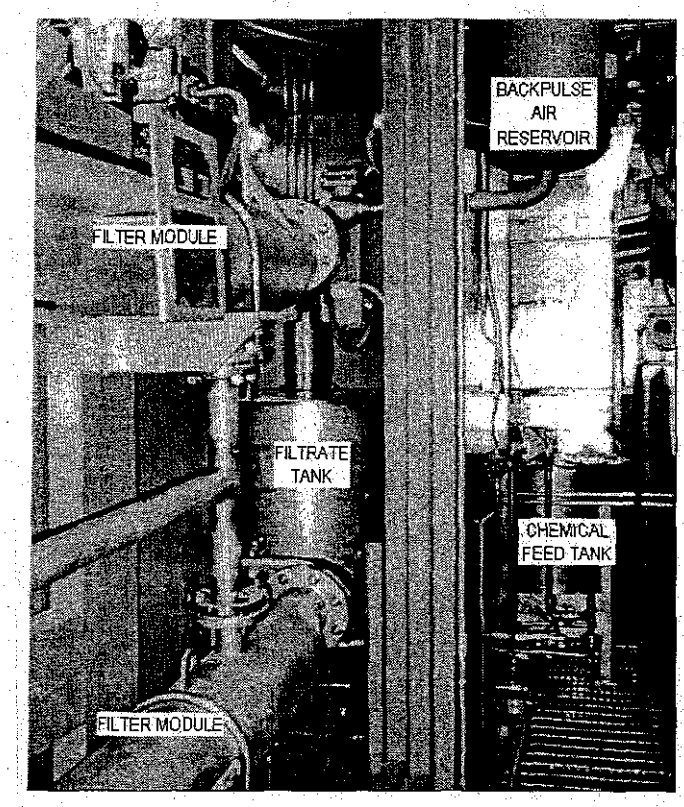
Crossflow filtration using 0.1-μm, sintered metal filter elements has been tested for separating solids from the waste planned for processing in the WTP (for details see BNF-003-98-0221, *Pilot-Scale Crossflow Ultrafiltration Test Using a Hanford Site Tank 241-AN-105 Waste Simulant – Envelope A + Entrained Solids*; PNWD-3024, *Characterization, Washing, Leaching, and Filtration of C-104 Sludge*; and PNWD-3025, *Characterization, Washing, Leaching, and Filtration of AZ-102 Sludge*). The 0.1-μm, sintered metal filter element has been demonstrated to be effective at removing greater than 99.99 percent of the solids contained in the waste slurries tested. The solid–liquid separation process applied to the dissolved saltcake waste is assumed to achieve 99.99 percent solids separation efficiency.

Recommendation: Crossflow filtration testing has not been previously conducted with dissolved saltcake waste. The performance of the crossflow filter is dependent on the characteristics of the waste processed. Therefore, engineering data on the performance of crossflow filtration should be obtained using samples of the dissolved saltcake waste planned for feed to the MAI supplemental treatment process. This engineering data combined with the crossflow filtration data derived by the WTP can be used to support design of the solid–liquid separation system.

4.2.3 Implementation for Demonstration

For the demonstration phase of the MAI supplemental treatment alternatives, solid–liquid separation is assumed to be conducted using skid-mounted equipment. The skid-mounted solid–liquid separation unit could be colocated or located separately from the other process equipment used in each MAI supplemental treatment alternative. The skid-mounted solid–liquid separation equipment could be similar to the skid-mounted crossflow filtration unit that was deployed June 1999 through April 15, 2000, as part of the Wastewater Triad Project at the Oak Ridge National Laboratory. The crossflow filtration unit deployed for the Wastewater Triad Project is depicted in Figure 4-2. For more details on the Wastewater Triad Project see ORNL/TM-2000-0186, *Wastewater Triad Project: Solid–Liquid Separator FY2000 Deployment*; and ORNL/TM-2001-0129, *Wastewater Triad Project: Final Summary Report.*

Figure 4-2. Oak Ridge National Laboratory Wastewater Triad: Solid–Liquid Separation Unit.



4.2.4 Implementation for Deployment

Following the MAI technology demonstration, all MAI supplemental treatment alternatives except for sulfate removal are assumed to continue to use the skid-mounted solid–liquid separation unit to separate entrained solids from the dissolved saltcake waste contained in the 68 SSTs.

The sulfate removal process alternative would likely be colocated with the WTP to utilize the crossflow filtration and cesium and technetium ion exchange unit operations within the pretreatment facility. Therefore, the sulfate removal process would use the crossflow filtration system provided within the WTP to remove entrained solids from the dissolved saltcake waste.

4.3 CESIUM ION EXCHANGE

4.3.1 Process Description

The ^{137}Cs is removed from the dissolved saltcake waste following entrained solids separation to reduce the radiation dose rate of the waste and for waste disposal considerations. Reducing the radiation dose rate of the dissolved saltcake waste reduces the shielding requirements and cost

for subsequent processing equipment and extends the operating life of the ion exchange material used in the subsequent technetium ion exchange process.

For the MAI technology demonstration, ^{137}Cs removal is assumed to be conducted using SuperLig 644 resin[1] contained in ion exchange columns. SuperLig 644 resin is the ion exchange material selected for use in the WTP. The RPP is evaluating alternative cesium ion exchange materials. If the RPP selects an alternative cesium ion exchange material for use in the WTP, the MAI technology demonstration would also use the alternative cesium ion exchange material. The following process description for the cesium ion exchange system that would be deployed as part of the MAI technology demonstration is consistent with that for the WTP cesium ion exchange system.

SuperLig 644 resin is installed in ion exchange columns and is preconditioned to remove fines using water followed by 0.25M sodium hydroxide solution to condition the columns for separating cesium from the dissolved saltcake waste. SuperLig 644 resin will selectively separates cesium from the dissolved saltcake waste. The ion exchange columns are contained in a shielded module because of the gamma radiation from radioactive decay of ^{137}Cs and ^{137m}Ba.

Ion exchange requires a uniform (non-transient) feed composition in order to work well. If the feed composition changes with time during the column load step, relative increases in the concentration of some components (such as sodium) could cause the captured cesium to be released. Therefore, the dissolved saltcake waste is accumulated in a vessel where the concentrations can reach equilibrium (equalization/feed tank). Dissolved saltcake waste that has been treated to separate entrained solids is pumped through the ion exchange columns where cesium is preferentially adsorbed onto the resin. The cesium-depleted waste solution is collected in an intermediate vessel and then transferred to the next unit operation for the specific MAI supplemental technology.

The cesium is removed from the SuperLig 644 resin by contacting the resin with 0.5M nitric acid solution. Then, 0.25M NaOH solution followed by water are contacted with the SuperLig 644 resin to condition the column for compatibility (i.e., prevent solids precipitation) with the next batch of dissolved saltcake waste solution. The eluted cesium in nitric acid solution is accumulated in a vessel, evaporated to concentrate the cesium solution, collected in an interim storage vessel, and eventually transferred to the WTP for HLW vitrification. The nitric acid solution evolved from evaporation of the cesium eluate is collected and reused during subsequent elution cycles of the ion exchange resin.

4.3.2 Technical Analyses

4.3.2.1 Cesium Adsorption by SuperLig 644

Cesium-137 is assumed to be removed using SuperLig 644 resin contained in ion exchange columns. ORP has conducted testing of SuperLig 644 resin for adsorption of cesium from Hanford Site tank wastes as part of the research, technology, and modeling program for the

[1] SuperLig 644 resin is manufactured by IBC Advanced Technologies Inc., American Fork, Utah.

WTP. The WTP Contractor is continuing to obtain information on the performance of SuperLig 644 resin for separating cesium from Hanford Site tank wastes.

Radiation and chemical stability testing of SuperLig 644 resin has been conducted and is documented in WSRC-TR-2000-00422, *Effects of Radiation on the Physical Properties of SuperLig 644 Resin*, BNF-003-98-051, *SuperLig Ion Exchange Resin Swelling and Buoyancy Study*; and *Chemical Stability of Ion Exchange Resins* (Bruening 2000).

Laboratory-scale column tests with SuperLig 644 resin using simulated and radioactive waste samples as well as pilot-scale column tests using simulated waste solutions have demonstrated the effectiveness of this ion exchange material for separating cesium from Hanford Site tank wastes. The laboratory-scale column tests are documented in WSRC-TR-MS-2000-00499, *Comprehensive Scale Testing of the Ion Exchange Removal of Cesium and Technetium from Hanford Tank Wastes*; WSRC-TR-2000-00420, *Intermediate Scale Ion Exchange Removal of Cesium and Technetium from Hanford Tank 241-AN-102*; PNWD-3001, *Small Column Testing of SuperLig 644 for Removing ^{137}Cs from Hanford Tank Waste Envelope A (Tank 241-AW-101)*; WSRC-TR-2000-00419, *Small-Scale Ion Exchange Removal of Cesium and Technetium from Envelope B Hanford Tank 241-AZ-102*; BNF-003-98-0146, *Small-Scale Ion Exchange Removal of Cesium and Technetium from Hanford Tank 241 AN 103*. The pilot-scale column tests are documented in WSRC-TR-2000-00505, *Summary of Initial Testing of SuperLig 644 at the TFL Ion Exchange Facility.*

The Savannah River Technology Center also has conducted preliminary modeling of SuperLig 644 resin to enable prediction of column performance with various waste solutions and has documented that modeling in BNF-003-98-0220, *Preliminary Ion Exchange Modeling for Removal of Cesium from Hanford Waste Using SuperLig 644 Resin.*

Recommendation: The development program for the MAI supplemental treatment alternative processes will need to determine the effectiveness of SuperLig 644 resin for separating cesium from the candidate waste to be treated. This information is required to accurately model the performance of the SuperLig 644 ion exchange columns, which is necessary for designing the ion exchange system that will be used for the MAI supplemental treatment alternative.

4.3.2.2 Percentage of Cesium Removed from Dissolved Saltcake Waste

The percentage of ^{137}Cs removed from the dissolved saltcake waste is assumed to be in excess of 99 percent. Laboratory-scale and pilot-scale testing of SuperLig 644 resin with Hanford Site tank wastes has shown that this percentage of cesium removal is technically practical.

Recommendation: The development program for the MAI supplemental treatment alternative processes will need to conduct laboratory-scale batch contact and column tests using dissolved saltcake waste samples along with modeling to determine the size and geometry of the ion exchange columns necessary for treating the dissolved saltcake waste.

4.3.2.3 SuperLig 644 Technical Risks

The WTP project has identified the performance of the ion exchange materials for cesium (SuperLig 644) and technetium (SuperLig 639) as a high risk (number TEC-00-00219 in RPT-W375-PR00017, *WTP Risk Assessment Report*). The WTP project has categorized the performance of SuperLig 644 resin as a potential high risk because of the limited testing conducted with this ion exchange material. Furthermore, SuperLig 644 resin has only been manufactured in small quantities (less than 1 kg), and the manufacture needs to demonstrate product quality can be maintained when manufacturing larger scale batches. The WTP project is conducting extensive research and testing of SuperLig 644 resin to mitigate this risk.

Recommendation: The development program for the MAI supplemental treatment alternative processes should maintain cognizance of the SuperLig 644 research and testing being conducted by the WTP project.

4.3.3 Implementation for Demonstration

Cesium ion exchange is assumed to be conducted as an integral part of each MAI supplemental treatment alternative demonstration. However, the sulfate removal supplemental treatment inherently separates cesium and technetium from the sulfate precipitate waste. Therefore, it is recommended that cesium and technetium removal not be conducted as part of the sulfate removal process. It is recommend that further evaluation be conducted of the benefit of cesium ion exchange as part of the sulfate removal process to reduce the radiation dose rate and reduce radiation shielding requirements for the sulfate removal equipment.

4.3.4 Implementation for Deployment

Following the MAI technology demonstration, cesium is assumed to continue to be removed from the dissolved saltcake waste using the regenerable ion exchange system.

4.4 TECHNETIUM ION EXCHANGE

4.4.1 Process Description

Separating technetium from the dissolved saltcake waste is assumed to be necessary for waste disposal considerations. The ^{99}Tc is removed from the dissolved saltcake waste following separation of entrained solids and removal of cesium. It is recommended that technetium be removed from the dissolved saltcake waste using SuperLig 639 resin,[2] which is the ion exchange material selected for use in the WTP.

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[2] SuperLig 639 resin is manufactured by IBC Advanced Technologies Inc., American Fork, Utah.

SuperLig 639 resin is installed in ion exchange columns and is preconditioned to remove fines using water followed by 0.25M sodium hydroxide solution to condition the columns for separating technetium from the dissolved saltcake waste. SuperLig 639 resin selectively separates pertechnetate, the dominant form of soluble technetium from the dissolved saltcake waste. The ion exchange columns are contained in a shielded module since trace amounts of other radionuclides (e.g., ^{241}Am and ^{154}Eu) may be present in the dissolved saltcake waste.

Ion exchange requires a uniform (non-transient) feed composition in order to work well. If the feed composition changes with time during the column load step, relative decreases in ionic strength or increases in the concentration of some components (such as nitrate) could cause the captured pertechnetate to be released. Therefore, the dissolved saltcake waste is accumulated in an equalization tank or a feed tank where the concentrations can reach equilibrium. Dissolved saltcake waste that had been treated to separate entrained solids and cesium is pumped through the ion exchange columns where pertechnetate is preferentially adsorbed by the SuperLig 639 resin. The technetium-depleted waste solution is collected in an intermediate vessel and then transferred to the next unit operation for the specific MAI supplemental technology alternative.

Water at 60 °C to 70 °C is contacted with the SuperLig 639 resin to elute pertechnetate. Then, 0.25M NaOH solution is contacted with the SuperLig 639 resin to condition the column for compatibility (i.e. prevent solids precipitation) with the next batch of dissolved saltcake waste solution. The ^{99}Tc eluted from the ion exchange column is transferred to an interim storage vessel for eventual processing in the WTP.

4.4.2 Technical Analyses

4.4.2.1 Technetium Adsorption by SuperLig 639

Technetium-99 is assumed to be removed using SuperLig 639 resin contained in ion exchange columns. ORP has conducted testing of SuperLig 639 resin for adsorption of technetium from Hanford Site tank wastes as part of the research, technology, and modeling program for the WTP. The WTP Contractor is continuing to obtain information on the performance of SuperLig 639 resin for separating technetium from Hanford Site tank wastes.

Radiation and chemical stability testing of SuperLig 639 resin has been conducted and is documented in SRTC-BNFL-013, *Evaluation of the Radiation Stability of SuperLig 639*; BNF-003-98-051; and Bruening (2000). Laboratory-scale column tests with SuperLig 639 resin using simulated and radioactive waste samples as well as pilot-scale column tests using simulated waste solutions have demonstrated the effectiveness of this ion exchange material for separating technetium from Hanford tank wastes.

The laboratory-scale column tests are documented in WSRC-TR-MS-2000-00499; WSRC-TR-2000-00420; PNWD-3004, *Small Column Testing of SuperLig 639 for Removing ^{99}Tc from Hanford Tank Waste Envelope A (Tank 241-AW-101)*; WSRC-MS-2001-00573, *SuperLig 639 Equilibrium Sorption Data for Technetium from Hanford Tank Waste Supernates*; WSRC-TR-2000-00419; BNF-003-98-0146. The pilot-scale column tests are documented in WSRC-TR-2000-00302, *Summary of Testing of SuperLig 639 at the TFL Ion Exchange Facility.*

The Savannah River Technology Center also has conducted preliminary modeling of SuperLig 639 resin to enable prediction of column performance with various waste solutions and has documented that modeling in WSRC-TR-2000-00305, *Preliminary Ion Exchange Modeling for Removal of Technetium from Hanford Waste Using SuperLig 639 Resin.*

Recommendation: The development program for the MAI supplemental treatment alternative processes will need to determine the effectiveness of SuperLig 639 resin for separating pertechnetate from the candidate waste to be treated. This information is required to accurately model the performance of the SuperLig 639 ion exchange columns, which is necessary for designing the ion exchange system that will be used for the MAI supplemental treatment alternative.

4.4.2.2 Percentage of Technetium-99 Removed from Dissolved Saltcake Waste

The percentage of ^{99}Tc (as pertechnetate) removed from the dissolved saltcake waste is assumed to be in excess of 90 percent. Laboratory-scale and pilot-scale testing of SuperLig 639 resin with Hanford tank wastes has shown this percentage of technetium removal is technically practical.

Recommendation: The development program for the MAI supplemental treatment alternative processes will need to conduct laboratory-scale batch contact and column tests using dissolved saltcake waste samples along with modeling to determine the size and geometry of the ion exchange columns necessary for treating the dissolved saltcake waste.

4.4.2.3 SuperLig 639 Technical Risks

The WTP project has identified the performance of the ion exchange materials for cesium (SuperLig 644) and technetium (SuperLig 639) as a high risk (number TEC-00-00219 in RPT-W375-PR00017). The WTP project has categorized the performance of SuperLig 639 resin as a potential high risk due to the limited testing conducted with this ion exchange material. Furthermore, SuperLig 639 resin has only been manufactured in small quantities (less than 1 kg), and the manufacture needs to demonstrate product quality can be maintained when manufacturing larger scale batches. The WTP project is conducting extensive research and testing of SuperLig 639 resin to mitigate this risk.

Recommendation: The development program for the MAI supplemental treatment alternative processes should maintain cognizance of the SuperLig 639 research and testing being conducted by the WTP project.

4.4.2.4 Valence State of Technetium-99 in Dissolved Saltcake Waste

The valence state of the soluble technetium in the Hanford Site tank wastes is predominantly $^{+}7$, with technetium present as the pertechnetate (TcO_4^-) anion. SuperLig 639 resin is capable of only removing technetium present as the pertechnetate anion. Batch contact and laboratory-scale ion exchange column tests have indicated that 1 to 5 percent of the technetium present in samples of non-complexed tank wastes is not present as the pertechnetate anion and cannot be extracted using SuperLig 639 resin (WSRC-MS-2001-00573). The non-extractable form of technetium is

presumed to be technetium ($^{+}4$) diolate complexes (see *Research Program to Investigate the Fundamental Chemistry of Technetium* [Shuh et al. 2000]).

Approximately 20% of the Hanford Site tank wastes contain soluble organic compounds such as gluconate and ethylenediaminetriacetic acid. The fraction of soluble technetium as the pertechnetate species has been determined to be significantly lower for these wastes that contain organic complexant, for example averaging approximately 20 percent for the complexed waste stored in DST 241-N-107.

The fraction of technetium present as pertechnetate in the dissolved saltcake wastes is not presently known. This adds uncertainty to the amount of technetium that can be extracted from the dissolved saltcake waste using SuperLig 639 resin.

Recommendation: The development program for the MAI supplemental treatment alternative processes will need to conduct laboratory-scale batch contact and column tests using dissolved saltcake waste samples to determine the fraction of technetium that can be extract using SuperLig 639 resin.

4.4.3 Implementation for Demonstration

Technetium ion exchange is assumed to be conducted as an integral part of each MAI supplemental treatment alternative demonstration. However, the sulfate removal process inherently separates cesium and technetium from the sulfate precipitate waste. Therefore, it is recommended that cesium and technetium removal not be conducted as part of the sulfate removal process supplement.

4.4.4 Implementation for Deployment

Following the MAI technology demonstration, technetium is assumed to continue to be removed from the dissolved saltcake waste using the regenerable ion exchange system.

5.0 FLOW SHEET OPTIONS CONSIDERED AND RECOMMENDED BY THE CLEANUP CONSTRAINTS AND CHALLENGES TEAM

Technologies and flow sheets described in this chapter were presented in the April 2-3 workshop and were included in the flow sheet analysis work to develop material balances and other information. All of these flow sheets options were included in the evaluation done by the May 21-23 C3T MAI Subgroup and associated expert group. For various reasons summarized in Chapter 8.0 of this report and described in detail in Appendices B, C, and D, the C3T MAI Subgroup recommended that these options be pursued for FY 2003 bench-scale or cold testing. The expert group and the C3T MAI Subgroup regarded these options as having the best potential to accelerate risk reduction and shorten RPP mission completion time. In examining the supplemental technologies, reduction in the length of time needed to complete tank waste treatment was used as a surrogate measure for life-cycle cost.

As summarized in Chapter 9, it is recommended that work be conducted on each of the four supplemental technologies described in this section on a limited scale in FY 2003 to obtain data needed to determine merit and likelihood of successful deployment, potential mission acceleration, and risk reduction. These data include those that can be gathered from the following sources:

- Hot and cold laboratory testing
- Related input to establish the requirements for radionuclide removal on a tank by tank basis
- Related input for regulatory analysis to establish the requirements for hazardous waste constituent removal or immobilization
- Facility configuration and approaches for demonstration and deployment.

The following four technologies have been recommended by the C3T MAI Subgroup (see Appendix C):

- Sulfate removal
- Containerized grout
- Bulk vitrification
- Steam reforming.

5.1 SULFATE REMOVAL

5.1.1 Process Description

High concentrations of sulfate in the LAW feed solutions present problems for the current WTP baseline LAW vitrification process using joule-heated melters. These problems can lead to a

reduction in waste incorporation in the ILAW glass. Additionally, preliminary testing of the LAW vitrification system indicated that a separate molten sulfur layer would form in the melter at the maximum sulfate-to-sodium mole ratio in the LAW solutions. This molten sulfur layer is highly corrosive to the melter components. The sulfate removal process is beneficial in the reduction or removal of sulfate from LAW that requires vitrification in the WTP. The sulfate removal process is not proposed for use on waste that is provided as feed to the other recommended MAI supplemental technology alternatives: ex situ bulk vitrification, containerized grout, or steam reforming.

Separating sulfate from the saltcake waste contained in the 68 candidate SSTs has the benefit of reducing the amount of ILAW glass produced and thus reducing the duration of the RPP mission. Table 5-1 provides a comparison of the amounts of ILAW glass produced from the saltcake waste contained in the candidate 68 SSTs with and without sulfate removal.

The sulfate removal process is diagrammed in Figure 5-1. Entrained solids must initially be separated from the dissolved saltcake waste. The solids entrained in the dissolved saltcake waste contain ^{90}Sr and TRU elements and would be transferred to the DST system for eventual processing the WTP. If these entrained solids are not removed before conducting the sulfate removal process, the radionuclide content of the resulting sulfate precipitate could exceed the Class C radionuclide limits for low-level waste in Title 10, *Code of Federal Regulations*, Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste" (10 CFR 61), Section 61.55, "Waste Classification." The dissolved saltcake waste does not need to be treated to separate cesium and technetium before the sulfate removal process in order to meet Class C radionuclide limits because these radionuclides are not incorporated into the sulfate precipitate. However, cesium removal may be beneficial in reducing the radiological shielding requirements for the sulfate removal equipment.

Following solids–liquid separation to remove the entrained solids, the liquid LAW solution is adjusted to pH 1.0 by addition of nitric acid. Strontium nitrate is then added to the acidic waste to precipitate strontium sulfate. The strontium sulfate precipitate is separated from the acidic solution using solid–liquid separation equipment. The strontium sulfate precipitate is washed with water and processed again through the solid–liquid separation step to remove residual acidic solution. The strontium sulfate precipitate is solidified in a low-temperature waste form such as grout or phosphate-bonded ceramic. The solidified sulfate precipitate would be disposed of in the Hanford Site disposal trenches for mixed low-level waste.

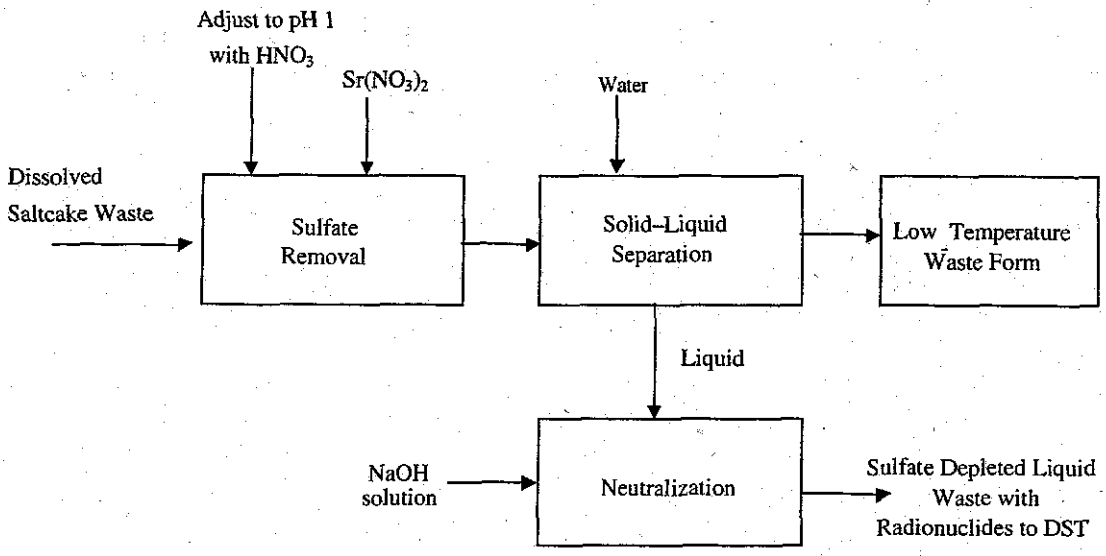
Table 5-1. Immobilized Low-Activity Waste Glass Production at Baseline and as Reduced by Sulfate Removal.

Attribute	Baseline	Sulfate removal
Tanks processed by WTP	177	109
Tanks processed by supplemental technology	0	68
ILAW glass produced by WTP [a]	205,000 m^3 543,300 MT	150,600 m^3 399,100 MT
Strontium sulfate precipitate low-temperature waste form	0	32,800 m^3
Years to process ILAW in WTP at 30 MTG/D	49.5 years	36.4 years [b]
Years to process ILAW in WTP at 30 MTG/D from 2007 to 2018 and 60 MTG/D from 2018 to completion	32 years	24.2 years
Total ILAW volume	205,000 m^3	183,400 m^3

[a] Does not include sodium added as part of HLW pretreatment or LAW pretreatment operations conducted in WTP. The added sodium could increase the ILAW glass produced by as much as 10 percent.
[b] Processing years could be reduced by an additional 3 years if sulfate-depleted LAW were not neutralized before processing in LAW melter system

HLW = high-level waste.
ILAW = immobilized low-activity waste.
LAW = low-activity waste.
MT = metric tons.
MTG/D = metric tons of glass per day.
WTP = Waste Treatment Plant.

Figure 5-1. Sulfate Removal Process Diagram.



The wash solution is combined with the acidic filtrate from the solid–liquid separation step, neutralized by addition of sodium hydroxide solution, and returned to the DST system for eventual processing in the WTP. If the sulfate removal process is conducted integral to the WTP, the acidic filtrate may not need to be neutralized before processing in the LAW vitrification system, which would further reduce the amount of ILAW glass produced.

5.1.2 Technical Analysis

5.1.2.1 Sulfate Removal Process Selection

The process selected for removing sulfate from the LAW solutions is precipitation by addition of strontium nitrate. Strontium sulfate precipitation was successfully performed at the Hanford Site B Plant in the 1970's when strontium was selectively precipitated as $SrSO_4$ by addition of Na_2SO_4. The process converted the strontium nitrate in the feed solution to a strontium sulfate precipitate that was separated, via a centrifuge, from the supernatant waste containing the bulk of the feed impurities. This process was called the first sulfate strike and is documented in ARH-2973, *Sulfate Precipitation Flowsheet for Purification of Crude Strontium Products from B Plant Solvent Extraction*. More than 95 percent of the strontium precipitation occurred within the first 15 minutes after sulfate was added. Strontium recoveries were from 90 to 95 percent.

The Westinghouse Savannah River Company performed initial scoping tests for the ORP in order to investigate evaporation and precipitation methodologies for sulfate removal from Hanford waste envelope A, B, and C. The majority of the work was performed using simulants of these waste envelopes and is documented in WSRC-TR-2000-00489, *Sulfate Removal Studies for River Protection Project Part B1*. A series of three hot beaker tests also was conducted with a waste sample from tank 241-AN-102 (envelope C). WSRC-TR-2000-00489 includes a discussion of the acidification (pH = 3) of AN-107 simulant (envelope C waste) and an actual

waste sample from tank 241-AN-102 (envelope C waste, generated from Strontium–TRU precipitation tests) to evolve carbon dioxide followed by barium addition to precipitate sulfate. Some aluminum precipitation occurred (probably due to the waste or simulant pH increasing above pH 3.5, $AlPO_4$), along with PO_4, CrO_4, fluorine, and chlorine, as well as ^{90}Sr and actinide precipitation. Saltcake waste that does not contain large concentrations of aqueous soluble complexants will not have soluble ^{90}Sr and actinides, and therefore these radionuclides should not be of concern for the strontium sulfate precipitation process. The Westinghouse Savannah River Company tests demonstrate the feasibility of acidifying Hanford supernatant and using an alkaline earth metal (calcium, strontium, barium) to precipitate sulfate.

Other processes to separate sulfate from alkaline waste solutions that also were tested at the laboratory scale include the following:

- Ion exchange resin, which did not result in satisfactory sulfate removal (for details see PNWD-3053, *Ion Exchange Studies for Removal of Sulfate from Hanford Tank Waste Envelope C (241-AN-107) Using SuperLig 655 Resin*)

- Low-temperature (-22 °C to -38 °C) crystallization where no SO_4 was removed unless there was a large excess of SO_4 relative to CO_3; 50 to 60 percent of Na_2SO_4 crystallized, but crystals sublimed when washed (see WSRC-TR-2000-00489)

- Addition of barium nitrate, $Ba(NO_3)_2$, tested on waste from tank 241-AN-107 (756.6 mL actual waste tested) to precipitate $BaSO_4$; the competing reaction of $BaCO_3$ requires a CO3 removal step before barium addition for successful SO4 removal; addition of calcium to precipitate calcium carbonate (for details see PNNL-3050, *Development and Demonstration of a Sulfate Precipitation Process for Hanford Waste Tank 241-AN-107*).

5.1.2.2 Chemical Reactions

Sulfate precipitation is a batch-type process that involves selectively precipitating sulfate using strontium nitrate, $Sr(NO_3)_2$. The dissolved saltcake waste (feed) contains carbonate, which if present in sufficient concentration, would preferentially precipitate as strontium carbonate, requiring excess reagent to precipitate the sulfate. In order to minimize the use of strontium nitrate, the feed must be acidified to decompose carbonate to carbon dioxide. This acidification reaction can lead to the formation of foam in the waste.

To remove the sulfate as the $SrSO_4$ precipitate, the feed is adjusted to pH 1.0 using nitric acid, followed by the addition of excess $Sr(NO_3)_2$. According to ARH-2973, near minimum solubility of $SrSO_4$ is attained at approximately pH 1.3 and 1.0 M sulfate. The acidified solution is allowed to digest approximately 1 hour to allow the $SrSO_4$ to precipitate by the following reactions:

$$Na_2SO_4 + 2HNO_3 \rightarrow H_2SO_4 + 2NaNO_3$$

$$Na_2CO_3 + 2HNO_3 \rightarrow H_2O + 2NaNO_3 + CO_2\ (gas)$$

$$H_2SO_4 + Sr(NO_3)_2 \rightarrow SrSO_4\ (ppt) + HNO_3$$

The development program for the MAI supplemental treatment processes will need to verify process conditions for acidifying the dissolved saltcake waste and for sulfate precipitation, control of foam formation, gas management, and de-entrainment.

5.1.2.3 Inclusion of Other Anions and Cations

Other cations (e.g., aluminum, calcium, chromium, barium, lead) and anions (e.g., PO_4, fluorine, chlorine) present in the feed are expected to partially precipitate at the given conditions. $AlPO_4$, $BaSO_4$, $CaSO_4$, $PbSO_4$, SrF_2, $SrCl_2$ $Sr_3(PO_4)_2$, and $SrCrO_4$ are all expected to partially precipitate with the strontium sulfate.

The development program for the MAI supplemental treatment processes will need to verify the extent and conditions that these other cations and anions coprecipitate.

5.1.2.4 Solids–Liquid Separation

The technology bases assumptions and risks are the same as for the solid–liquid separation process described in Chapter 4.2.

5.1.2.5 Low-Temperature Waste Form

The strontium sulfate precipitate is assumed to be solidified in a low-temperature waste form such as grout or phosphate-bonded ceramic in order to meet low-level waste disposal criteria and land disposal restrictions (LDRs) for solid waste disposal in Washington State. No testing has been conducted of the proposed low-temperature waste form. If washed to remove acidity and dried, the strontium sulfate precipitate may comply with the LDR for solid waste disposal in Washington State without immobilization.

The development program for the MAI supplemental treatment processes will need to conduct toxicity characteristic leach procedure testing of the strontium sulfate precipitate to determine the need for solidification. Additional testing is required to determine the appropriate low-temperature waste form (if any) required for solidification and disposal of the strontium sulfate precipitate. The final waste form will need to comply with *Washington Administrative Code,* Section 173-303, "Dangerous Waste Regulations" (WAC 173-303), for disposal at the Hanford Site.

5.1.3 Implementation for Demonstration

Sulfate removal needs to be demonstrated on representative tank waste at the laboratory scale to evaluate the process and its parameters. Feed for this process evaluation needs to have undergone solids–liquid separation. The resulting sulfate precipitate then needs to be processed into a waste form and demonstrated to meet the LDR. This can be done at engineering scale followed by cold pilot-scale activity. Since the actual sulfate removal step for deployment is most likely to occur integral to the WTP pretreatment facility, no large demonstration-scale effort is anticipated. An annex facility would likely need to be constructed to contain the sulfate removal process if this process were integrated with operation of the WTP.

5.1.4 Implementation for Deployment

Most of the saltcake waste that is sent to the WTP will benefit from sulfate removal after the baseline pretreatment steps and before being sent to the LAW vitrification facility. Only a handful of tanks have waste that would not benefit from such supplemental processing. Any waste going into the supplemental immobilization processes described in this document (e.g., bulk vitrification, containerized grout, or steam reforming) would not be sent through the sulfate removal process.

5.1.5 Summary

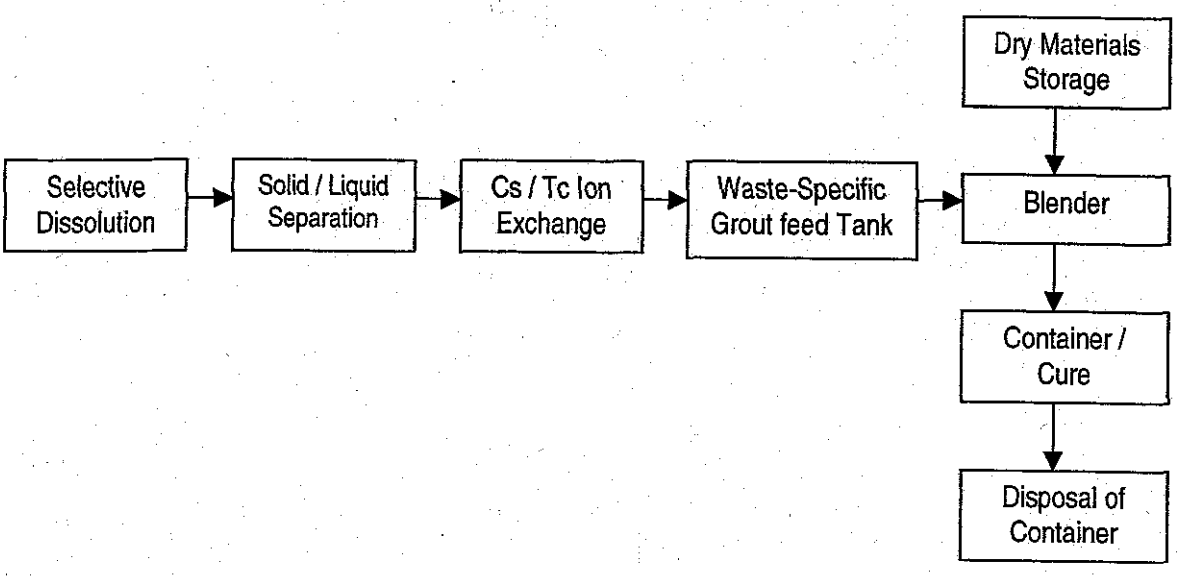
The sulfate removal option is compared with the original baseline in Table 5-1. This option supports the treatment of the dissolved saltcake waste from 68 SSTs in less time than the baseline by allowing an increased glass loading to be achieved in the LAW vitrification facility. The sulfate removal process supplements the WTP pretreatment activities for those wastes being provided to the WTP.

5.2 CONTAINERIZED GROUT

5.2.1 Process Description

The containerized grout supplemental treatment process is diagrammed in Figure 5-2. The pretreated dissolved saltcake solution is mixed with a Portland cement-type grout solid, pumped into disposal containers, and allowed to cure or solidify. The cured product may now be managed with handling equipment for intermediate storage and disposal. The solid grout is estimated to correspond to Class C low-level waste as defined in 10 CFR 61.55.

Figure 5-2. Containerized Grout Block Flow Diagram.



5.2.2 Technical Analysis

Historically the inorganic additives that have been successfully used for grout are Portland cement, fly ash, and slag. The following are the main reasons for the widespread use of these materials:

- Relatively low cost
- Good long-term stability, both physically and chemically
- Documented use on a variety of wastes for a period of over 20 years
- Widespread availability
- Non-toxicity of the chemical ingredients
- Ease of use in processing (processing is done normally at ambient temperature and pressure with no special equipment)
- High resistance to biodegradation
- Low water solubility and permeability for most isotopes and chemicals
- Good mechanical and structural characteristics.

These three additives are brought into the facility and are stored in individual containers, each equipped with a solids conveyer and dust control system. These three additives are proportionally premixed before the cementitious mixture is added to the waste feed in the grout mixer. Pneumatic transfer may be used to transfer the mix to the grout blender.

Grout additives and the waste feed effluent are blended in a grout mixer. The contents are slowly mixed with low-shear mixing equipment for about 10 to 15 minutes (actual mixing equipment, mixing speed, and mixing time are yet to be determined). It is assumed that the grout mixture will be transferred into 3.6-m^3 boxes (nominally 1.2 m by 1.2 m by 2.4 m, or 4 ft by 4 ft by 8 ft overall) and that these will be filled to 100 percent. It is estimated that about 14 containers per day will be needed to process the equivalent of a 5M sodium salt solution at 5 gal/min. An appropriate quality assurance plan and program will be implemented.

Freshly prepared grout is normally cured for a period of time to gain strength when used structurally. This extended time will probably not be needed for this nonstructural application. Normal curing is done at about 30 °C and 100 percent relative humidity. Several tests have been conducted to determine whether the curing process can be expedited at elevated temperatures, but no substantial improvement has been observed. Curing tests conducted by the Savannah River Technology Center at a temperature 90 °C have indicated possible structural failure according to WSRC-TR-98-00337, *Direct Grout Stabilization of High Cesium Salt Waste, Salt Waste Alternative Phase III Feasibility Study.* The curing and storage area must be large enough to hold about 400 containers to allow for curing.

5.2.2.1 Process Chemistry

Portland-type cements usually consist of mixtures of lime (calcium oxides) and various silico-aluminates. In normal structural use, the setting process allows recombination of the primary ingredients to form large atomic structures where calcium, aluminum, et al., and oxygen are combined to form water-insoluble compounds with high strength. When formulated for waste disposal, slags, clays, and other agents are added to enhance the chemistry. In particular, chrome is reduced from its hexavalent state to the trivalent form, which is much less soluble. Most of the metals of concern (e.g., chrome, mercury, uranium) can substitute in the chemical structure for the calcium and become part of the direct chemical structure of the waste form. It should be noted that the alkali metals (sodium, potassium, and cesium) and sodium nitrate are not bound in the chemical structure and therefore do not become part of the cement compound.

Testing of specific grout formulations is needed to determine the leachate of constituents of concern (e.g., radionuclide RCRA metals, nitrate) for conducting a performance assessment of the grouted waste. A significant fraction of this data is available from the former Hanford Grout Disposal Project.

5.2.2.2 Process Experience

Commercial nuclear power plants have successfully used grout for some of their waste streams. Large quantities of dilute flush water are used and eventually evaporated. The remaining solids are high in phosphate and metallic ions that bond well in the chemical cement. The commercial electroplating industry has used the process for disposal of plating bath residues. The metals copper, nickel, chromium, and other multivalent cations are chemically bonded in the cement.

The Savannah River Site has formulated grout (saltstone) for major disposal operations. The Hanford Site had a grout disposal program at one time, and other sites have used similar formulations.

5.2.2.3 Scale

Equipment and systems are available to make grout at any scale desired. As indicated above, the Savannah River Site has made millions of gallons of the material. Commercial structural concrete mixers deliver batches of 500 to 1,000 gal. Drum mixers (55 gal) are available and used by commercial nuclear power plants. Laboratory equipment is used for test programs where batch sizes are a fraction of a gallon.

5.2.2.4 Disposal of Containerized Grout

Grout containers would be disposed in the ILAW disposal trenches. Since the overall volume and number of containers is more than doubled, the trench would have to be expanded. The ILAW trench has some limits on expansion by natural boundaries within 200 East Area; further study is required to identify a solution.

5.2.2.5 Secondary Waste Generation

Secondary waste generation for containerized grout will be minimal, consisting primarily of process equipment, high-efficiency particulate air filters, and other consumable materials. There

will be no process off-gas emissions requiring treatment because of the low operating temperature. No secondary liquid effluent streams are anticipated, as there are no rinses in this process and any liquids from the grout curing process are anticipated to be recycled

5.2.2.6 Process Flow Diagram

The process flow diagram is shown in Figure 5-2. Details that went into the flow sheet assumptions are discussed below.

It has been established in WSRC-TR-98-00337 that the direct grout alternative is a viable option for treatment and stabilization of liquid waste containing a ^{137}Cs concentration of 1 Ci/gal to 3 Ci/gal. The composition of the liquid waste that was tested at the Savannah River Technology Center for grout is similar to the dissolved saltcake waste. Consequently, the processing, setting, and leaching properties of the grout from dissolved saltcake waste are assumed to be similar to the product tested at the Savannah River Technology Center. To meet the NRC stability requirements, the waste form must maintain its structural integrity to prevent (1) slumping, collapse, or other structural failure when the engineered disposal structure is not used and (2) release of radionuclides due to leaching that could be caused by premature disintegration of the waste form under the expected disposal conditions.

5.2.3 Implementation for Demonstration

The equipment required for the containerized grout process demonstration at 5 gal/min is similar in capacity to the Grout Treatment Facility at the Hanford Site. However, the Hanford Site Grout Treatment Facility was a continuous feed plant, whereas the new unit will need a container handling system in addition. With modifications, the Grout Treatment Facility in the 200 East Area is a candidate for mixing the grout. Container boxes could be similar to the ILAW containers planned for WTP.

Lag storage tanks are needed for Portland cement, fly ash slag storage, and stabilizing chemicals. Feed will accumulate in a receiver tank. Waste and the grout additives are mixed in the grout mixer and poured into portable containers (3.6-m^3 boxes).

5.2.4 Implementation for Deployment

The application of the containerized grout process to 68 SSTs requires a 10 gal/min capacity facility be completed by 2028 if all the waste in the 68 SSTs were to be processed through the containerized grout facility. The grout throughput can be readily adopted for the full mission by sizing the batch equipment for 10 gal/min during the demonstration phase. It is likely that most of the equipment sizing would not change and the impact for a 10 gal/min demonstration would be negligible relative to the cost of two 5 gal/min facilities (the second constructed after the demonstration phase).

5.2.5 Summary

The grout option is compared with the original baseline in Table 5-2. This option allows treatment of the alternate stream from 68 SSTs in less than 20 years and would achieve the 2028 completion date for processing. The disadvantage of containerized grout is that the volume of waste disposed of onsite is about 1.5 times more than the volume of glass, and the retention of alkali metals and nitrates is lower than glass, although release limits may still be met because of the reduced inventory and the use of engineered barriers. Additional performance assessment work is required.

	Original baseline	Containerized grout
Tanks processed by WTP	177	109
Tanks processed by grout facility	0	68
ILAW glass produced by WTP [a]	205,000 m^3 543,300 MT	94,900 m^3 251,500 MT
Alternate waste volume (containerized grout)	0	264,000 m^3
Years to process ILAW in WTP at 30 MTG/D	49.5 yrs	23 yrs
Years to process ILAW in WTP at 30 MTG/D from 2007 to 2018 and at 60 MTG/D from 2018 to completion	32 yrs	17.5 yrs
Total ILAW volume	205,000 m^3	358,900 m^3

[a] Does not include sodium added as part of HLW pretreatment or LAW pretreatment operations conducted in WTP. The added sodium could increase the ILAW glass produced by 5 to 10 percent.

HLW = high-level waste.
ILAW = immobilized low-activity waste.
LAW = low-activity waste.
MT = metric tons.
MTG/D = metric tons of glass per day.
WTP = Waste Treatment Plant.

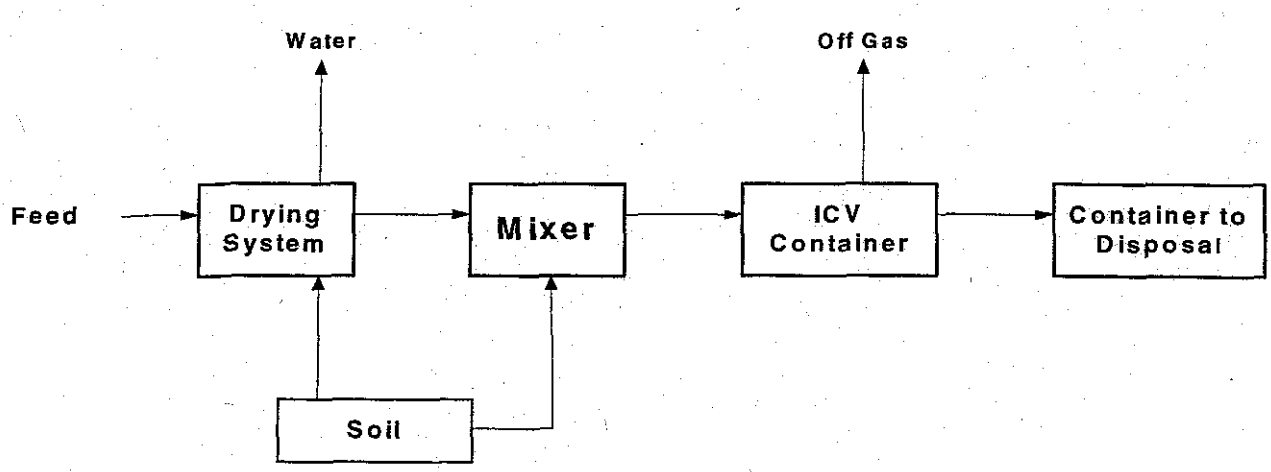
5.3 BULK VITRIFICATION

5.3.1 Process Description

The bulk vitrification process converts low-level mixed waste into a solid glass form by mixing the waste with soil and applying electrical current. The configuration and approach analyzed involved a vitrification step conducted within a large steel container via the GeoMelt in-container vitrification (ICV) process licensed by AMEC Earth and Environmental.

The bulk vitrification module consists of a drying step, a mixing step, and an ICV step as depicted in Figure 5-3. The drying unit blends process soil with the waste and removes water through evaporation. The remaining process soil is then mixed with the evaporated soil/waste stream and delivered to the vitrification container by a screw auger. A temporary off-gas hood is placed over the container and electrodes inserted. Power is applied to the electrodes to melt the waste/soil mixture. After cooling, the resulting vitrified product is sent to a disposal site.

Figure 5-3. In-Container Vitrification Block Flow Diagram.



5.3.2 Technical Analysis

The bulk vitrification process is used for contaminated site remediation and waste treatment. This process can be applied in several different configurations ranging from deep subsurface in situ treatment to aboveground batch plants. The ICV method is the technology being evaluated for treating Hanford Site low-level mixed waste. All of the GeoMelt technologies involve the electrical melting of contaminated soils and debris resulting in the destruction, removal or permanent immobilization of contaminants.

The melting process is initiated within a waste or soil mixture. Electrical power is directed to the treatment zone via graphite electrodes and regulated to maintain the desired melt rate. The melt temperature typically ranges from 1,400 °C to 2,000 °C depending on the materials being treated and the process configuration. The melt grows downward and outward until the target waste volume has been treated and the electrical power is shut off.

5.3.2.1 Process Chemistry

Organic contaminants are destroyed via pyrolysis and dechlorination reactions at elevated temperatures in reducing conditions around the melt. No organic contaminants remain in the melt due to the inability of organics to exist at the temperatures involved. The melt incorporates most heavy metal and radionuclide contaminants resulting in permanent immobilization in the resulting vitrified product. Nonvolatile metals and radionuclides such as uranium and plutonium have a high degree of retention in the melt (e.g., 99.999 percent) (Luey 1992; Spalding 1997). For semi-volatile radionuclides like cesium, a number of tests and demonstrations, including full-scale operations, have demonstrated the retention of cesium in the melts as being very high (99 percent to 99.99 percent). The degree of retention in the melt of semi-volatile heavy metal contaminants such as lead, cadmium, and arsenic is quite high (generally around 80 percent to 90 percent). Volatile metals, such as mercury, are released from the melt and captured by the off-gas treatment system. The process can accommodate relatively high contaminant concentrations of heavy metals and radionuclides. Sulfate, in the waste feed stream, is volatized into the off-gas during the ICV process.

5.3.2.2 Process Experience

Bulk vitrification has been successfully used to treat a wide range of contaminated wastes and debris including mixed low-level radioactive wastes, mixed TRU wastes, polychlorinated biphenyls, pesticides, dioxins, and a range of heavy metals. The ICV treatment configuration has been used in Australia and Japan and is being developed for DOE and commercial applications. The batch technique involves staging and treating wastes in refractory-lined steel containers. The containers can vary in size and shape from 208-L (55-gal) drums to large roll-off boxes. After each batch is treated, the melted waste is allowed to cool and solidify in the container. The container can be reused or disposed of after each melt. After each batch of waste is treated, the vitrified waste solidified, and the off gas hood removed, a lid is placed on the container and the vitrified waste is transported to the disposal site.

The GeoMelt ICV method was used in Japan to treat an abandoned industrial waste incinerator that was heavily contaminated with dioxins, furans, and polychlorinated biphenyls. The incinerator was dismantled and decontaminated to the extent possible, and bulk vitrification was used to treat the residual wastes, including steel, ash, brick, and decontamination wastes.

In Australia, the design is nearly finalized for a batch plant that will treat a 60,000-drum inventory of concentrated hexachlorobenzene wastes. The concentrated chlorinated organic waste will be mixed with soil to facilitate treatment.

In the United States, the subsurface planar method was recently applied in a demonstration project to treat a portion of a mixed low-level radioactive liquid waste adsorption bed at the Los Alamos National Laboratory (Geosafe 2001). The process previously has been demonstrated for planar melting of mixed radioactive waste at the Oak Ridge National Laboratory (Spalding 1997).

5.3.2.3 Scale

The bulk vitrification process has been successfully used in large-scale operations. A 30-ton per day unit in Japan processed the waste within a 6 m by 6 m (20 ft by 20 ft) crucible.

5.3.2.4 Secondary Waste Generation

The amount and type of secondary wastes generated by bulk vitrification operations depend on the configuration of the process system and the nature of the waste materials being treated. Solid wastes such as filters and used protective clothing can be vitrified along with the wastes being treated. Scrub solution is generated by those projects requiring wet scrubbing and can be vitrified as well.

Off-gases that evolve from the melt are typically collected in a steel containment hood and directed to an off-gas treatment system. The off-gas treatment steps vary depending on the particular requirements of the project but generally consist of an initial step of particulate filtration followed by quenching, wet scrubbing, two stages of high-efficiency particulate filtration, and carbon adsorption or thermal oxidation.

A condensate stream is generated by the waste drying equipment and discharged from the main condenser at about 60 °C (140°F). This secondary waste stream consists primarily of water and volatile organics evaporated from the waste feed stream and input soil stream. Alternatives for disposal of this stream are as follows: (1) recycle to SST system for saltcake dissolution; (2) cool to 21 °C (70 °F) and discharge to the Effluent Treatment Facility; (3) heat to 100 °C (212 °F) and release as steam; (4) feed to subsequent melts and release as steam from the off-gas treatment system.

5.3.3 Implementation for Demonstration

Waste would be selected for processing in the demonstration that, together with the amount of pretreatment required and regulatory analysis, would enable the vitrified product to be disposed of in compliance with the LDR at a permitted Hanford Site burial ground. The contributions to the ILAW Performance Assessment also would need to be considered according to DOE-ORP-2000-24, *Hanford Immobilized Low-Activity Waste Performance Assessment 2001 Version*. The number and size of the ICV containers processed would be determined in conjunction with the engineering studies and hot laboratory tests carried out in FY 2003.

5.3.3.1 Waste Staging Tank

For the demonstration, equipment is deployed to support staging and vitrification of the waste. The equipment consists of a staging tank, an evaporative dryer, a mixer, and the ICV container. The equipment may be placed in a containment facility.

5.3.3.2 In-Container Vitrification Description

The waste stream is mixed with soil and dried in an evaporator that operates at subatmospheric conditions. After drying, the remaining waste is mixed with the soil. The mixture of waste and solids is added to the ICV container. The ICV process converts a mixture of waste and soil into

glass by inserting electrodes into the ICV container and applying electrical current. The mixture of waste and soil is melted into glass.

The size and configuration of the container used for the ICV process depends on the application of the treatment technology. Two roll-off boxes are typically processed in parallel. The boxes can be staged to accommodate melts in the 25 to 30 metric ton range. Typical melt time is 2 to 3 days per pair of melts. Upon completion of a melt, the box will be topped off as necessary with clean sand or soil, a cover will be permanently affixed to the top, and the box will be shipped to the low level waste burial ground. The box will be allowed to cool for 3 days to a temperature of 85 °C (185 °F) before being transferred to the disposal site. The container will be designed to minimize the amount of top-off material required.

5.3.3.3 Product Description

The vitrified waste form normally consists of a mixture of glass and crystalline materials and often has an appearance similar to volcanic obsidian. The product is typically five to ten times stronger than concrete and ten or more times more durable and leach resistant than typical borosilicate glasses used to immobilize HLW. The durability and leach resistance of the glass is due to a high concentration of glass formers (SiO_2 and Al_2O_3). The process of vitrifying the waste results in an approximate net volume reduction of one-third to one-half due to loss of volatile components and void space reduction (due to melting).

Based on the assumptions used in this analysis, the estimated waste loading of the product is 20 wt% sodium oxide, with the radionuclide concentration meeting the limits for Class C low-level waste as defined in 10 CFR 61.55.

5.3.4 Implementation for Deployment

The application of bulk vitrification to 68 SSTs would require a 10 gal/min throughput capacity in order to complete the process by 2028 if all the waste in the 68 tanks were to be processed through the bulk vitrification facility. The bulk vitrification throughput capacity can be deployed for the full mission by sizing for 10 gal/min. The ICV system can support the vitrification of two simultaneous containers. Equipment sizing is expected to be very similar for a 5 gal/min system and for a 10 gal/min system. Multiple parallel systems may be deployed if necessary.

5.3.5 Summary

The bulk vitrification option is compared to the original baseline in Table 5-3. The use of bulk vitrification treatment for the waste from 68 SSTs allows the WTP to complete ILAW processing of the other tank waste in approximately 20 years. Bulk vitrification has two other advantages. One advantage is the production of a high-quality waste form that is equivalent to or better than the ILAW borosilicate glass. The second advantage is a reduction in the total volume of low-level waste glass for onsite disposal.

Table 5-3. Comparison of Bulk Vitrification with the Original Baseline.

	Original baseline	Bulk vitrification
Tanks processed by WTP	177	109
Tanks processed by supplemental technology	0	68
ILAW glass produced by WTP	205,000 m^3 543,300 MT	94,900 m^3 251,500 MT
Years to process ILAW in WTP at	49.5	23
Years to process ILAW in WTP at 30 MTG/D from 2007 to 2018 and at 60 MTG/D from 2018 to completion	32	17.5
Alternate waste	0	53,300 m^3
Total ILAW volume	205,000 m^3	148,200 m^3

5.4 STEAM REFORMING

This option utilizes a high-temperature fluidized bed to destroy nitrates and, with the help of additives, to incorporate radioisotopes together with sodium, sulfate, chlorine, and fluorine in a granular material that can be placed in containers or grouted. DOE has identified steam reforming for a variety of pretreatment and immobilization applications at the Hanford Site and at other DOE sites. To support the broad application of this technology, DOE has established a team to evaluate deployment and testing of the technology. As their strategy for deployment becomes more detailed, additional information will become available for evaluation.

For this evaluation and recommendation, one of the potential candidate processes for steam reforming is used: the Thermal Organic Reduction (THOR[1]), steam reformer technology developed by Studsvik, AB.

[1] THOR is a service mark held by Studsvik, AB.

5.4.1 Process Description

In the THOR process, waste is fed directly to the steam reformer as slurry or as shredded solids through a lock hopper. The reforming reactor consists of a vertical vessel containing a fluidized bed of alumina sand that is designed to operate at temperatures of up to 800 °C. For safety reasons and to ensure containment of steam-reformed products and gases within the processing equipment, the bed operates at a negative pressure. Heat is supplied to the bed through the injection of superheated steam. Additional energy is supplied by injecting oxygen into the bed where it reacts exothermically with reductant compounds present in the waste or added to the waste. The reformer alumina bed is fluidized and heated with superheated steam. Any organic compounds in the waste are destroyed through pyrolysis and through reaction with hot nitrates, steam, and oxygen. Other reactions include reaction with carbon sources to produce hydrogen, carbon monoxide, carbon dioxide, and water. The temperature of the bed is thus controlled by adjusting the inlet temperature of the fluidizing steam and by regulating the amount of oxygen and reductant injected.

Water fed into the pyrolyzer as a component of the waste is converted to superheated steam. Organic compounds are broken down through pyrolysis and through reaction with the high-temperature steam and oxygen. The gaseous effluent exiting the top of the bed consists primarily of carbon monoxide, carbon dioxide, hydrogen (H_2), and water. Small amounts of organic compounds (e.g. methane) and volatile metals (e.g. mercury) also may be present. The fine solids (<100 μm) entrained in the gas flow resulting from the pyrolysis–reforming reaction are disengaged from the larger alumina particles that constitute the semi-permanent bed in a cyclone at the top of the reactor and are entrained in the top of the reactor. The fine solids include the dried inorganic portion of the injected waste as well as small amounts of fixed carbon and abraded particulates from the bed.

The fluidized bed is designed to be operated such that less than 5 percent of the total bed weight is due to waste solids. This design ensures that the inert part of the bed acts as a large heat sink, thereby avoiding problems with agglomeration caused by the presence of low-melting point salt eutectics in the waste. Recovery from an agglomeration of the bed media involves cooling the bed and washing the media with hot water. The bed is then dried and refluidized through the injection of superheated steam. Alternatively, a water-wash screw conveyor has been designed that could be installed on the bottom of the bed. Operation of the screw would augment the deagglomeration process.

The solids that elutriate from the pyrolyzer–reformer are collected on the surface of ceramic filter elements. The filter elements are periodically back-pulsed with nitrogen to recover the solids. The hot product gases pass through the filter to an oxidation chamber and evaporator where energy is recovered by evaporating excess water from spent scrubber solution. The concentrated scrubber solution is filtered to remove insoluble materials and then dried to produce a salt product for final disposal. The cooled gases pass out of the evaporator to the scrubber where the acid gases (sulfur and halogens) are neutralized by sodium hydroxide (NaOH). The gases then pass through the demister and water-recovery condenser before entering the blower. The blower compresses the gases to atmospheric pressure and forces them through the ceramic thermal converter where the combustible gases (CO, H_2) are oxidized at 1,000 °C to 1,100 °C. Finally the gases are cooled, filtered in the bag house and high-efficiency particulate air filtration, and released through a monitored vent stack.

5.4.2 Technical Analysis

5.4.2.1 Application of the Thermal Organic Reduction Process to Saltcake Waste

The saltcake tank waste, such as that from tank 241-S-112, contains liquid and solids consisting primarily of sodium and aluminum nitrates, nitrites, and carbonates. The process proposed for the treatment of saltcake solids and liquid is similar to the previously described process currently operating at Erwin, Tennessee. In the proposed steam reforming process cations would be converted to a powder of nepheline (Na_2O-Al_2O_3-$2SiO_2$), beta-alumina (Na_2O-Al_2O_3), sodium carbonate (Na_2CO_3) and other mineral and salt forms.

In the proposed treatment process, the hot product gases from the reformer are removed in the scrubber where energy is recovered by evaporating excess water from spent scrubber solution. The concentrated scrubber solution would be filtered to remove insoluble materials and then the slurry recycled to the reformer feed vessel. It is estimated that most of the nitrate and nitrite are reduced to nitrogen while reducing agents would be oxidized to carbon dioxide and water. The off-gas composition under these assumptions would be less than 500-ppm nitrogen oxides and less than 20-ppm chloride, sulfur and fluoride. At this nitrogen compound concentration, ammonia would not be required for the control of nitrogen oxides. Most of the chlorides, sulfur, and fluoride would be retained in the product along with greater than 99 percent of the cesium and technetium. It is estimated that flammable mixtures would be eliminated from the process gases by oxidizing zones in the fluidized bed. Although reliable cooling systems and treatment of hydrogen and ammonia are established technologies in nuclear facilities, preparing the supporting safety basis documentation for the potentially flammable off-gas mixtures may be difficult. As an additional safety factor, the vessels are designed as pressure vessels, which provides explosion resistance. Uncertainties in the process technical basis add to the uncertainty in establishing a safety basis.

5.4.2.2 Salt Agglomeration

Researchers at the Idaho National Engineering and Environmental Laboratory (INEEL) have performed a series of tests on how to process the sodium-bearing waste. This acidic stream has sodium concentrations similar to those considered for the Hanford Site MAI supplemental technology. To overcome plugging in their fluidized beds, INEEL blended the sodium-bearing waste (to less than 5.3 mole percent) with HLW rich in zirconium to dilute the effects of the sodium. Once INEEL completed the processing of the HLW, the site began to explore options for processing the sodium-bearing waste.

The INEEL experience indicates that the high sodium, nitrate, and nitrite concentration in the Hanford Site saltcake waste would require special consideration in the reformer operation. Sodium nitrate exists in a molten undecomposed state over a large temperature range (300 °C to 850 °C) (Newby 1979). Sodium chloride in combination with sodium carbonate forms a eutectic mixture with a melting point as low as 1,172 °F (633 °C) at 62 mole percent sodium carbonate (Wall et al. 1975). Mixtures of sodium chloride and sodium sulfate form a mixture having a low eutectic melting point of 1,154 °F (623 °C) at 65 mole percent sodium sulfate (Wall et al. 1975). When all three of these compounds are present, a mixture with a melting point as low as 1,134 °F (612 °C) is possible (Wall et al. 1975).

When processing sodium saltcake waste, the reformer–fluidized bed tends to form agglomerates over the temperature where sodium salts exists in a molten state. These agglomerates range in size; but regardless of their size, they tend to plug the fluidized bed. To overcome this problem, substances are added to the saltcake feed to (1) lower the decomposition temperature of sodium nitrate or (2) to combine with the nitrate at a low temperature to form a compound that is stable at, and has a melting point above, the reformer operating temperature. The use of additives is proposed in the application of the THOR process to the treatment of saltcake waste.

Sucrose, solid carbon, and kaolin were possible additives suggested in the Studsvik Inc. technical proposal, *Technical Proposal–Denitrification Demonstration Test Utilizing THOR Fluid Bed/Steam-Reforming System to Process Simulated and Actual INTEC Sodium Bearing Waste* (Studsvik 2000), to demonstrate the application of steam-reforming technology to denitrate both surrogate and actual sodium-bearing waste that is temporarily stored in 300,000-gal tanks at INEEL (see *Technical Review of the Applicability of the Studsvik, Inc., Thor Process to INEEL SB* [Gentilucci 2001]). It is presumed that the additives considered for the processing of sodium-bearing waste are among the additives that would be used in the steam reforming of the saltcake, sodium nitrate waste.

The conversion of sodium nitrate to nepheline, Na_2O-Al_2O_3-$2SiO_2$, would require addition of aluminosilicate clay (kaolin) to the steam reformer. The use of sucrose as an additive to enhance nitrate destruction has been tested extensively in related processes. Sugar-additive calcination was attempted at the Hanford Site on a sodium-bearing PUREX process waste stream during the late 1950's (see HW-60584, *Quarterly Progress Report*). Numerous tests have been conducted at INEEL according to the *Status Report for Alternative Calcination Scoping Studies* (Nenni 1997).

Tests on the use of additives in the calcination of the sodium-bearing waste at INEEL, reported by Nenni (1997), may provide some insights into the application of steam reforming for the treatment of saltcake. Some important differences exist between the previously described THOR process and the INEEL calcination tests with the common element being the temperature of the operation in or near regions where the formation of eutectic mixtures are possible.

The INEEL tests were conducted in a fluidized bed calciner with the feed and fuel atomizing nozzles located in a 10-cm-diameter reaction zone. The feed was atomized with air, and the kerosene fuel was atomized with oxygen. The additives used in the calcination tests were aluminum nitrate, calcium nitrate, and sucrose. For the proposed INEEL flow sheet, boron is an additional additive. The INEEL calciner test temperature of 500 °C to 650 °C was lower than the steam reformer temperature of 800 °C. The INEEL sodium-bearing waste was an acidic solution of 1.6 M hydrogen ion and 6.0 M nitrate as compared with saltcake waste, which is dissolved and treated. The dissolved saltcake has a sodium concentration of 5 M with nitrate ion concentration ranging from 1 M to 3 M and hydroxide ion concentration of up to 2 M.

The INEEL calcination tests compared the baseline flow sheet, which involves the addition of aluminum nitrate in a mole ratio of aluminum to alkali metal of 3.5, to a flow sheet with a sucrose addition and a flow sheet in which the calcination temperature is 650 °C. These calcination tests were successful in reducing the aluminum-to-alkali metal ratio required to process the sodium-bearing waste. Lowering the amount of the aluminum nitrate addition reduces the volume of calcine waste produced.

The INEEL tests, with one exception, demonstrated that stable fluidized-bed calcination is achievable with any of the flow sheets. However, the mass mean particle diameters for the calcine generated throughout the test were within the New Waste Calcine Facility acceptance range but had not stabilized by the end of the test for storage.

With respect to storage requirements, varying degrees of hygroscopicity were experienced in the products from the sucrose addition calcination tests and the high temperature calcination test. One test of the former was highly hygroscopic and would be unacceptable for storage. The high temperature calcines were slightly hygroscopic. If the product absorbs too much water, it could lead to free liquids in the waste (e.g., with NaOH or $NaNO_3$).

5.4.2.3 Steam Reformer Waste Product Acceptability for Low-Level Waste Disposal

The waste produced from steam reforming saltcake waste is assumed to be a powder of nepheline, beta-alumina, sodium carbonate, and other minerals and salts. The MAI technology program should verify the expected composition of the steam reformer product through laboratory-scale testing of simulated saltcake waste. The steam reformer product should be tested to verify that the waste meets criteria for disposal. As with the other recommended technologies, this flow sheet and product must be evaluated against regulatory analysis and performance assessment requirements.

5.4.3 Implementation for Demonstration

Currently the DOE ORP in collaboration with DOE INEEL is developing concepts for hot and cold testing of steam reforming concepts. ORP also is supporting BNI to pursue approaches to gather additional data to support decision making regarding steam reforming as an adjunct to the WTP to supplement LAW immobilization.

5.4.4 Implementation for Deployment

The steam reforming capability can serve as a denitration step (supplement to pretreatment). The product may be suitable for packaging for land disposal at the Hanford Site or may require additional immobilization, either through the use of additives during the steam reforming process or the use of subsequent additives to form a compliant grout.

5.4.5 Summary

The steam reforming option is compared with the original baseline in Table 5-4. The information in the table is based on information provided in the May 21-23 workshop. The use of the steam reforming treatment for the waste from 68 SSTs allows the WTP to complete ILAW processing of the other tank waste in approximately 20 years. Steam reforming has two other advantages. The first advantage is that it allows the destruction of nitrates in the wastes and enables a stable mineral waste form to be produced. The second advantage is the elimination of waste recycles between facilities permitting a single-pass operation. The reduction of the WTP mission life for ILAW from 49.5 to 23 years would not allow steam reforming by itself to meet

the completion date of 2028. It would be deployed in conjunction with other MAI to achieve the desired 2028 tank farm mission completion. In addition, steam reforming leads to a 20 percent increase in the total ILAW product disposed of at the Hanford Site.

Table 5-4. Comparison of Steam Reforming with the Original Baseline.

	Original baseline	**Steam reforming**
Tanks processed by WTP	177	109
Tanks processed by supplemental technology	0	68
ILAW glass produced by WTP [a]	205,000 m^3 543,300 MT	94,900 m^3 251,500 MT
Years to process ILAW in WTP at 30 MTG/D	49.5	23
Years to process ILAW in WTP at 30 MTG/D from 2007 to 2018 and at 60 MTG/D from 2018 to completion	32	17.5
Alternate waste	0	154,000 m^3
Total ILAW volume	205,000 m^3	248,900 m^3

[a] Does not include sodium added during WTP pretreatment, which would increase ILAW glass volume 5 to 10 percent.

HLW = high-level waste.
ILAW = immobilized low-activity waste.
LAW = low-activity waste.
MT = metric tons.
MTG/D = metric tons of glass per day.
WTP = Waste Treatment Plant.

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6.0 FLOW SHEET OPTIONS ALSO CONSIDERED

The flow sheets described in this chapter were presented in the April 2-3 workshop and were included in the subsequent flow sheet analysis work to develop material balances and other information. All of these flow sheets were included in the evaluation done by the May 21-23 C3T MAI Subgroup. For various reasons summarized in Chapter 7.0 and described in detail in Appendices A, B, and C of this report, the C3T MAI Subgroup did not recommend that these flow sheets be pursued as part of the MAI in FY 2003. The summary discussion provided in this section is from RPP-11131, *Mission Acceleration Initiative Demonstration Information Package*. Appendix E contains additional discussion on the flow sheet options that were not recommended for further evaluation.

6.1 ACTIVE METAL REDUCTION

The saltcake waste is retrieved and processed through the selective dissolution and solid–liquid separation steps. Both the cesium-rich and separated solids are sent to the DST system for processing through the WTP. The liquid stream from the solid–liquid separation step is the feed for the flow sheet-specific treatment steps. The active metal reduction process uses a stirred tank or a fluidized bed reactor to decompose nitrates and nitrates present in the saltcake waste. The sodium aluminate–aluminum hydroxide product from the active metal reduction reactor is mixed with phosphoric acid or silica to produce a sodium alumino-silicate or alumino-phosphate ceramic waste form.

Based on a preliminary evaluation of the estimated waste inventory in 68 SSTs, this path reduces the WTP total mission ILAW glass volume to 46 percent of the baseline. The volume of the alternate waste form produced is equivalent to 101 percent of the WTP total mission ILAW glass baseline. The total volume of ILAW glass produced by the WTP plus the supplemental waste form (i.e., alumino-silicate or alumino-phosphate ceramic) is equivalent to about 147 percent of the baseline volume of ILAW glass produced in the WTP. Table 7-1 summarizes projected low-level waste production. Sulfate to be treated by WTP as LAW feed is reduced to 10 percent of the baseline. The reduction in waste volume and associated sulfate inventory is an asset to the RPP.

6.2 CLEAN SALT WITHOUT CESIUM ION EXCHANGE

The saltcake waste is retrieved and processed through the selective dissolution and solid–liquid separation steps. Both the cesium-rich and separated solids are sent to the DST system for processing through the WTP. The liquid stream from the solid–liquid separation step is the feed for the flow sheet-specific treatment steps. Cesium and technetium ion exchange columns are not used for this flow sheet option because the radionuclides are inherently separated from the clean salt as part of the process.

The liquid waste stream from the solid–liquid separation step is sent to an acid reactor where it is acidified with nitric acid to pH 2.0. Acidification neutralizes sodium hydroxide and sodium

carbonate, dissolves aluminum hydroxide, and converts all the nitrite to nitrate and nitrogen oxide. The primary form of sodium leaving the acid reactor is sodium nitrate. Crystallization of sodium nitrate is performed in two steps. First, the acidified liquid stream is evaporated at approximately 110 °C at atmospheric pressure until about 50 wt% of the sodium nitrate is crystallized out. Second, the liquid stream is cooled to crystallize another 20 wt% of the sodium nitrate.

The liquid stream, which has a reduced sodium nitrate content, is neutralized by slowly adding the liquid to a sodium hydroxide bath. Once neutralized, the waste stream is sent to the DST system for treatment by the WTP. Because cesium and technetium ion exchange are not performed in this path, the sodium nitrate crystals are processed through a single wash column to remove cesium, technetium, and other soluble radionuclide species. The washed crystals are separated from the filtrate in a solid–liquid separation step that sends the filtrate to the neutralization step and the washed crystals to the immobilization step. A single stage of fractional crystallization is assumed to be adequate to produce sufficient radionuclide decontamination to meet applicable requirements. Waste sodium nitrate is immobilized into a phosphate - bonded ceramic.

6.3 CLEAN SALT WITH CESIUM ION EXCHANGE

The saltcake waste is retrieved and processed through the selective dissolution and solid–liquid separation steps. Both the cesium-rich and separated solids are sent to the DST system for processing through the WTP. The liquid stream from the solid–liquid separation step is the feed for the clean salt with cesium ion exchange-specific treatment steps. For the clean salt with cesium ion exchange flow sheet, a cesium ion exchange column is the first processing step. Technetium is inherently separated from the clean salt and a separate technetium ion exchange column is not needed.

The liquid waste stream from the solid–liquid separation step is sent through a cesium ion exchange column, with the resulting low-cesium solution sent to an acid reactor where it is acidified with nitric acid to pH 2.0. This neutralizes sodium hydroxide and sodium carbonate, dissolves aluminum hydroxide, and converts all the nitrite to nitrate and nitrogen oxide. The primary form of sodium leaving the acid reactor is sodium nitrate. Crystallization of sodium nitrate is performed in two steps. First, the acidified liquid stream is evaporated at approximately 110 °C at atmospheric pressure until about 50 wt% of the sodium nitrate is crystallized out. Second, the liquid stream is cooled to crystallize another 20 wt% of the sodium nitrate.

The liquid stream, which has a reduced sodium nitrate content, is neutralized by slowly adding the liquid to a sodium hydroxide bath. Once neutralized, the waste stream is sent to the DST system for treatment by the WTP. Sodium nitrate crystals are separated from the filtrate in a solid–liquid separation step that sends the filtrate to the neutralization step and the crystals to the immobilization step. A wash column is not used in this path because a cesium ion exchange step is part of the path. A single stage of fractional crystallization is assumed to be adequate to produce sufficient radionuclide decontamination to meet applicable requirements. Waste sodium nitrate is immobilized into a phosphate-bonded ceramic.

6.4 CLEAN SALT AND SULFATE REMOVAL WITHOUT CESIUM ION EXCHANGE

In the clean salt and sulfate removal without cesium ion exchange flow sheet, the saltcake waste is retrieved and processed through the selective dissolution and solid–liquid separation steps. Both the cesium-rich and separated solids are sent to the DST system for processing through the WTP. The liquid stream from the solid–liquid separation step is the feed for the clean salt and sulfate removal without cesium ion exchange-specific treatment steps. For this flow sheet, cesium and technetium ion exchange columns are not utilized because these radionuclides are inherently separated from the clean salt.

The liquid waste stream from the solid–liquid separation step is sent to an acid reactor where it is acidified with nitric acid to pH 2.0. This neutralizes sodium hydroxide and sodium carbonate, dissolves aluminum hydroxide, and converts all the nitrite to nitrate and nitrogen oxide. The primary form of sodium leaving the acid reactor is sodium nitrate. Crystallization of sodium nitrate is performed in two steps. First, the acidified liquid stream is evaporated at approximately 110 °C at atmospheric pressure until about 50 wt% of the sodium nitrate is crystallized out. Second, the liquid stream is cooled to crystallize another 20 wt% of the sodium nitrate. Because cesium and technetium ion exchange columns are not used in this path, the sodium nitrate crystals are processed through a single wash column to remove cesium and other soluble radionuclide species. The washed crystals are separated from the filtrate in a solid–liquid separation step that sends the filtrate to the sulfate removal step and the washed crystals to the microencapsulation immobilization step.

The sulfate removal step is a batch-type process that involves selectively precipitating the sulfate using strontium nitrate. To remove the sulfate as a strontium precipitate, the waste feed is adjusted to pH 1.0 using nitric acid, followed by the addition of excess strontium nitrate. The acidified solution is allowed to digest approximately 1 hour to allow the strontium sulfate to precipitate. Precipitated solids are removed from the liquid stream and sent to a grout step. As was done for the two clean salt flow sheets without sulfate removal described in Sections 6.2 and 6.3, the liquid stream is neutralized by slowly adding the liquid to a sodium hydroxide bath. Once neutralized, the waste stream is sent to the DST system for treatment by the WTP.

The grout immobilization step involves mixing the sulfate precipitate waste stream with grout-forming additives. Waste sodium nitrate is immobilized by microencapsulation using a polyethylene polymer.

6.5 CLEAN SALT AND SULFATE REMOVAL WITH CESIUM ION EXCHANGE

The saltcake waste is retrieved and processed through the selective dissolution and solid–liquid separation steps. Both the cesium-rich and separated solids are sent to the DST system for processing through the WTP. The liquid stream from the solid–liquid separation step is the feed for the specific treatment steps. For the clean salt and sulfate removal with cesium ion exchange flow sheet, a cesium ion exchange column is the first processing step. Technetium is inherently separated from the clean salt and a separate technetium ion exchange column is not needed.

The liquid waste stream from the solid–liquid separation step is sent through the cesium ion exchange column, with the resulting low-cesium solution sent to an acid reactor where it is acidified with nitric acid to pH 2.0. This neutralizes sodium hydroxide and sodium carbonate, dissolves aluminum hydroxide, and converts all the nitrite to nitrate and nitrogen oxide. The primary form of sodium leaving the acid reactor is sodium nitrate. Crystallization of sodium nitrate is performed in two steps. First, the acidified liquid stream is evaporated at approximately 110 °C at atmospheric pressure until about 50 wt% of the sodium nitrate is crystallized out. Second, the liquid stream is cooled to crystallize another 20 wt% of the sodium nitrate. Because a cesium ion exchange column is used in this path, the sodium nitrate crystals are not washed. The crystals are separated from the filtrate in a solid–liquid separation step that sends the filtrate to the sulfate removal step and the sodium nitrate crystal stream to the microencapsulation step.

The sulfate removal step is a batch-type process that involves selectively precipitating the sulfate using strontium nitrate. To remove the sulfate as a strontium precipitate, the waste feed is adjusted to pH 1.0 using nitric acid heated to 60 °C, followed by the addition of excess strontium nitrate. The acidified solution is allowed to digest approximately 1 hour to allow the strontium sulfate to precipitate. Precipitated solids are removed from the liquid stream and sent to a grout step. As was done for the clean salt flow sheets with and without cesium removal described in Sections 6.2 and 6.3, the liquid stream is neutralized by slowly adding the liquid to a sodium hydroxide bath. Once neutralized, the waste stream is sent to the DST system for treatment by the WTP. The grout immobilization step involves mixing the sulfate precipitate waste stream with grout-forming additives. Waste sodium nitrate is immobilized by microencapsulation using a polyethylene polymer.

7.0 CLEANUP CONSTRAINTS AND CHALLENGES TEAM ANALYSIS OF OPTIONS CONSIDERED

A panel of 14 experts convened to evaluate the nine proposed treatment options. The summary information presented in the workshop is shown in Table 7-1. The effect on treatment of waste from 68 SSTs was determined from the preparation of a flow sheet for each supplemental treatment option. The number of years to process all of the tank waste was estimated. The volume of ILAW was estimated.

The flow sheets and the technologies for each option were reviewed using the evaluation criteria in Table 7-2 as guidance. The main categories for evaluation were (1) Compliance and Safety, (2) Project Utility, (3) Operability, (4) Technical Risk, and (5) Programmatic Risk.

The experts used quantitative values to assess the relative merit of the supplement treatment options. The experts ranked the options according to the criteria. The process is described in Appendix A and Appendix B.

7.1 INPUTS TO THE EXPERT PANEL

Inputs to the expert panel consisted of a written report (issued as RPP-11131, *Mission Acceleration Initiative Demonstration Information Package*) with flow sheets and process descriptions for all options except option 3, steam reforming. The information in the written report also was presented verbally at the workshop. The information consisted of the following:

- Mass balances for key radionuclides and chemicals of concern based on the inventory for a representative saltcake tank, tank 241-S-112
- Description of the process equipment and process conditions
- List of relevant laboratory, pilot, and industrial experience
- Order of magnitude cost to deploy the option as a demonstration for processing the waste from one tank
- Estimated reduction of the WTP LAW processing duration based on using the option for processing the waste from 68 tanks (see Appendix D for further discussion of the saltcake waste)
- Estimated total volume of ILAW for the 177 Hanford Site tanks based on using the option for processing the waste from 68 tanks.

Table 7-1. Impact of Each Option on Waste Treatment Plant Low-Activity Waste Processing Duration and Immobilized Low-Activity Waste Total Volume.

Option		Treatment of 68 SSTs					Treatment of other 81 SSTs + 28 DSTs	ORP mission impact		
Path	Option name	WTP ILAW from selective dissolution (m^3) [a]	WTP ILAW unique to path (m^3) [b]	Total path WTP ILAW volume (m^3)	Percent of baseline WTP ILAW	Volume supplemental solid LLW (m^3)	WTP ILAW (m^3)	Total ILAW + alternative solid LLW (m^3)	Percent of baseline WTP ILAW	Years to process ILAW in WTP [c]
NA	Baseline [a]	0	136,000	136,000	100.0%	0	68,700	205,000	100.0%	49.5
1	Bulk vitrification	26,200	0	26,200	19.2%	53,300	68,700	148,000	72.3%	23.0
2	Active metal reduction	26,200	0	26,200	19.2%	207,000	68,700	302,000	147.3%	23.0
3	Steam reforming [d]	26,200	0	26,200	19.2%	154,000	68,700	248,900	121.4%	23.0
4A	Clean salt, no Cs IX	26,200	83,300	110,000	80.3%	47,600	68,700	226,000	110.2%	43.2
4B	Clean salt, with Cs IX	26,200	83,300	110,000	80.3%	47,600	68,700	226,000	110.2%	43.2
5A	Clean salt and SO_4 removal, no Cs IX	26,200	13,300	39,500	29.0%	58,600	68,700	167,000	81.3%	26.2
5B	Clean salt and SO_4 removal, with Cs IX	26,200	13,300	39,500	29.0%	58,600	68,700	167,000	81.3%	26.2
6	Containerized grout	26,200	0	26,200	19.2%	264,000	68,700	359,000	175.2%	23.0
7	Sulfate removal	26,200	55,700	81,900	60.1%	32,800	68,700	183,000	89.4%	36.4

Note: A table in this format was used in the May 21-23, 2002, workshop (see Appendix A). This table contains corrected waste volumes and durations.

[a] Baseline is volume of WTP glass produced from processing all LAW in WTP. Does not include sodium added from process operations conducted in WTP.

[b] WTP ILAW calculated volume is based on the Gimple Rule and density of 2.65 g/c^3. The Gimple Rule is detailed in Appendix D.

[c] WTP ILAW net glass production rate is 30 metric tons of glass per day.

[d] Estimate of steam reforming product is based on the presentation, "THOR Steam Reformer Technology for Hanford Tank Waste Support," made to the Cleanup Constraints and Challenges Team Mission Acceleration Initiative Subgroup by Brad Mason, Studsvik, AB, on May 22, 2002.

Cs IX = cesium ion exchange.
DST = double-shell tank.
LAW = low-activity waste.
ILAW = immobilized low-activity waste.
LLW = low-level waste.
NA = not applicable.
ORP = U.S. Department of Energy, Office of River Protection.
SST = single-shell tank.
WTP = Waste Treatment Plant.

Table 7-2. Evaluation Criteria. (2 sheets)

Compliance and Safety	Project Utility	Operability	Technical Risk	Programmatic Risk
Operational Safety – What are the operational safety impacts of the flow sheet/key process, including ALARA considerations?	**Percent of Waste Applicable To** – To what percentage of the 68 targeted SSTs does the flow sheet apply? Are the flow sheets and key processes potentially applicable to other tank wastes?	**Ease of Operations and Process Control** – Does the flow sheet/key process create difficult operational or operations control situations, including liquid, gas, and solid effluent or waste handling?	**Flow sheet Operations Maturity** – Is the flow sheet/key process based upon mature technologies, equipment, and process control approaches?	**Pathway to Deployment** – Are there any elements in the pathway to full-scale deployment that present unusual challenges or risks that will require special attention or that may not be manageable?
Regulatory Permitting – Would the flow sheet/key process create unusually difficult regulatory permitting issues due to such factors as high temperatures, difficult off-gas treatment requirements, or other flow sheet-specific issues?	**Relative Effect on Waste Volume Disposed of Onsite Including Secondary Wastes** – Will the flow sheet/key process significantly increase or decrease the volume of LAW and secondary waste disposed of onsite?	**Process Stability** – Are any flow sheet elements unstable? Can process control be maintained if any flow sheet process fails? Can the flow sheet accommodate likely variations in waste feed and ambient environmental conditions?	**Susceptibility to Chemistry Risks** – Is the flow sheet/key process susceptible to failure due to low concentrations or buildup of chemicals that may be present in the waste feed?	**Vendor Reliance** – Is the successful deployment of the flow sheet overly reliant on a single vendor? If so, does the vendor have a long and stable business performance history?
Waste Incidental to Reprocessing-Related – How difficult will it be to meet the requirements regarding waste incidental to reprocessing?	**Relative Impact on Mission Completion Date** – Can the flow sheet/key process reduce the time required for mission completion?	**Ease and Frequency of Maintenance** – Does the flow sheet/key process require frequent maintenance or will anticipated maintenance require unusually lengthy shutdowns?	**Deployment History in Other Venues** – Have key flow sheet processes and control approaches been successfully deployed on a commercial scale for other wastes or chemicals that are translatable to the tank wastes?	**Equipment and Parts Availability** – Is the flow sheet dependent on special order equipment or parts such that their availability for testing, initial operations, or continued deployment would create unusually high risks?

Table 7-2. Evaluation Criteria. (2 sheets)

Compliance and Safety	Project Utility	Operability	Technical Risk	Programmatic Risk
Land Disposal Restrictions– Is the waste form likely to meet LDR?	**Compatibility with RPP Integrated Flow Sheet and Operations** – Will the flow sheet/key process create any significant compatibility issues with the overall tank farm and WTP flow sheet? Is the flow sheet/key process compatible with potential technetium removal requirements?	**Number and Complexity of Unit Operations** – How many unit operations are there?	**Susceptibility to Scale-up Issues** – Is the flow sheet/key process likely to encounter significant scale-up issues that could impair performance at the 5-10 gal/min treatment rates anticipated?	**Relative Cost Impact** – Is the flow sheet or key process likely to create significant cost issues or benefits?
Waste Form Performance, Technetium – What is the relative effectiveness of immobilizing technetium?		**Relative Likelihood of Meeting River Protection Project Treatment Needs** – What are the RPP treatment needs? How difficult will it be to pass an operational readiness review? What is the ease of mobility?		
Waste Form Performance, Nitrate – What is the relative effectiveness of immobilizing nitrate?				

ALARA = as low as reasonably achievable.
LAW = low-activity waste.
LDR = land disposal restriction.
RPP = River Protection Project.
SST = single-shell tank.
WTP = Waste Treatment Plant.

7.2 EXPERT EVALUATION

The flow sheets provided to the workshop typically included pretreatment steps for solid–liquid separation and the removal of cesium. The regulators on the expert panel also wanted technetium removal before final treatment and immobilization. The regulators were also more sensitive to the disposal of waste that had not been denitrated.

Cost was a consideration, but the relative cost among options was not a significant discriminator. The cost for disposal of immobilized waste was not included in the flow sheet and descriptive material. This cost can be a significant factor, especially for the higher LAW volume options. The cost estimates were for the initial demonstration for one tank, rather than life-cycle costs for repeated deployments to treat up to 68 tanks. The life cycle cost per tank for multiple tanks would likely be less than the cost estimate for the one tank.

The options that were of most interest to the panel for testing and demonstration were (1) those that could be broadly applied to saltcake waste (Project Utility), (2) those that significantly reduced the volume of LAW that must be processed in the WTP (Project Utility), (3) those that produced a waste form with good performance (Compliance), (4) those that reduced the total volume of ILAW for disposal (Project Utility), (5) those that have had larger scale deployment in industry or within the DOE complex (Operability and Technical Risk), and (6) those that have high deployment potential (Operability and Programmatic Risk). Major reasons for rejection or low interest in options were lack of flow sheet maturity and lack of perceived applicability.

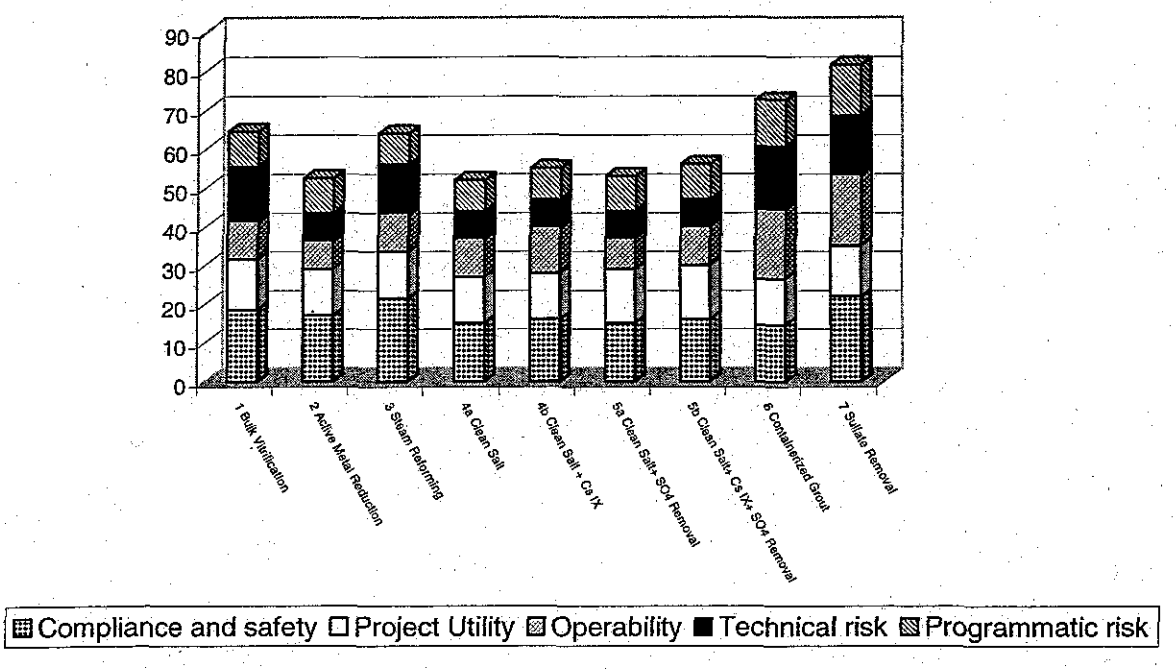
7.3 CONCLUSIONS AND RECOMMENDATIONS

Based on the evaluation of the nine separate flow sheets, four technologies are recommended for additional study:

- Sulfate removal
- Containerized grout
- Bulk vitrification
- Steam reforming.

The experts ranked the options according to the criteria. The options recommended for additional study were those that had the highest accumulated scores. Figure 7-1 is a representation of these results.

Figure 7-1. Comparison of Rating Scores.



The objective of the evaluators was to assess the technology options and to determine those that warranted further investigation because of their potential to meet project objectives for a demonstration in FY 2004 or FY 2005. Further study will be aligned with the needs of each specific option. Both radioactive and nonradioactive tests will be designed for the processes and equipment as required.

These selected options represent a range of trade-offs between process difficulty and performance, ease of achieving regulatory compliance, and benefit to RPP in accelerating the mission. For example, the sulfate removal option is considered a comparatively simple process with less complicated regulatory issues, but the acceleration benefit of removing and disposing of sulfate alone is less than the benefit provided other options with more challenges that do not send any fraction of the treated stream to the WTP.

8.0 OTHER TANK WASTE TREATMENT OPTIONS

Chapters 4.0 through 7.0 described the treatment options and associated technologies considered by the C3T MAI Subgroup that have the potential to maximize WTP throughput through its design life and to provide non-WTP treatment approaches for LAW where it is appropriate and possible to do so. The Performance Management Plan, as noted in Chapter 2.0, also discussed alternatives that could provide parallel non-WTP treatment pathways to accelerate other non-HLW treatment rates. An example cited in the plan is for tank waste that could be treated and disposed of as TRU waste at WIPP at Carlsbad, New Mexico. While alternative treatment of this waste and pathway was not a part of the flow sheet analysis and C3T MAI Subgroup evaluation, it does offer potential for RPP mission acceleration and important advantages for DST space. For that reason, alternative treatments of TRU and low-level wastes that currently are stored in the SSTs and DSTs are discussed in this section.

While additional initiatives are not part of the analyses conducted in this report, it should be noted for completeness that ORP is pursuing additional initiatives as part of its efforts to accelerate tank waste cleanup. ORP, as supported by CHG, is jointly pursuing with the Office of Science and Technology an initiative that could expedite both LAW and HLW immobilization. The goal of this initiative is to significantly increase the throughput of the WTP to enable accelerated cleanup and to achieve balance of mission treatment requirements beyond the current WTP contract. Waste loading improvements to vitrified HLW will significantly increase the capacity of the HLW vitrification plant as well as reduce the volume of immobilized waste requiring disposal. This joint ORP–Office of Science and Technology initiative is investigating alternative HLW forms, modifying the chemistry of the melt, and evaluating alternative melters (e.g., in-can melter and cold crucible) to increase HLW loading in borosilicate glass. Additional technologies will be developed to supplement the capacity of the LAW vitrification facility. This initiative also will look at technologies that will enable a portion of the LAW to be alternatively treated to create a waste form that can meet disposal requirements. DOE also is conducting development and evaluation of additional technologies such as centrifugal separation of plasma that may be applied to treating tank wastes to reduce the RPP mission risks, cost, and schedule while accelerating tank waste cleanup. These initiatives are not discussed further in this document.

8.1 TRANSURANIC TANK WASTE SOLIDIFICATION FOR DISPOSAL AT THE WASTE ISOLATION PILOT PLANT

The Hanford Site underground storage tanks contain approximately 1.3 million gallons of waste that could potentially be classified as TRU waste. These wastes are stored in nine SSTs and three DSTs. Appendix F, Section F1.1, summarizes analyses conducted to determine tanks that contain TRU wastes. The current baseline for treatment and disposal of the Hanford Site tank wastes, including the potentially TRU tank wastes, begins with pretreatment to separate the tank waste into LAW and HLW fractions. The HLW is to be vitrified and disposed of in the spent nuclear fuel–HLW repository. The LAW also is to be vitrified and disposed of at the Hanford Site.

Pretreatment, LAW vitrification, and HLW vitrification processing of tank wastes will be conducted at the WTP. These wastes likely will require blending with HLW sludges before being vitrified in the WTP because they contain components (e.g., bismuth, chrome, and zirconium) that exhibit limited incorporation in borosilicate glass. If processed without blending in the WTP, the TRU tank wastes would produce an estimated 10,900 metric tons (MT) of glass. Instead, if processed in the WTP, these potentially TRU tank wastes would likely be blended with other sludges retrieved from other Hanford Site underground storage tanks. Assuming the potentially TRU tank wastes could be blended with other tank sludges to achieve a non-volatile waste oxide loading of 40 wt%[1] (excluding sodium, potassium, and silicon), the amount of glass produced would be approximately 2,000 MT. Section 8.1.3.1 provides additional information on the estimated mass of glass produced from vitrifying the potentially TRU tank wastes in the WTP.

As an alternative to immobilizing the TRU tank wastes in glass, the TRU tank wastes could be immobilized in a low-temperature waste form and transferred to the WIPP for disposal. A preliminary conceptual flow diagram for alternative treatment of the TRU tank wastes is depicted in Figure 8-1.

8.1.1 Process Description

The TRU tank wastes would first be retrieved from their underground storage tanks and transferred to a facility for separation of supernatants. Solid–liquid separation could be conducted using crossflow filtration as discussed in Section 4.2. Next, the TRU tank wastes would be washed with either water or dilute sodium hydroxide solution to remove soluble salts (such as NaF contained in the neutralized cladding removal waste stored in tanks 241-AW-103 and 241-AW-105) to reduce the mass of TRU tank waste. For the sludges stored in tanks 241-SY-102 and 241-AW-103, washing also separates the HLW supernatant from the TRU sludges. The wash solutions would be transferred to the DST system for treatment in the WTP. The washed TRU tank waste would be immobilized and packaged for disposal in the WIPP. Candidate alternative treatment processes that could be used to prepare the TRU tank wastes for disposal at the WIPP include immobilization in grout, immobilization in phosphate-bonded ceramic, and low-temperature drying.

DOE has determined that TRU waste will be prepared at its place of origin for shipment to WIPP for disposal. TRU wastes are to be segregated into two categories based on the radiation dose rate at the surface of the waste package. Waste packages that exhibit a radiation dose in excess of 200 mrem/h are classified as remote-handled (RH-) TRU waste. Waste packages that exhibit a radiation dose less than 200 mrem/h are classified as contact-handled (CH-) TRU waste. Remote-handled TRU (RH-TRU) waste packages are to be placed in the RH-TRU-72-B radioactive material package to provide shielding.

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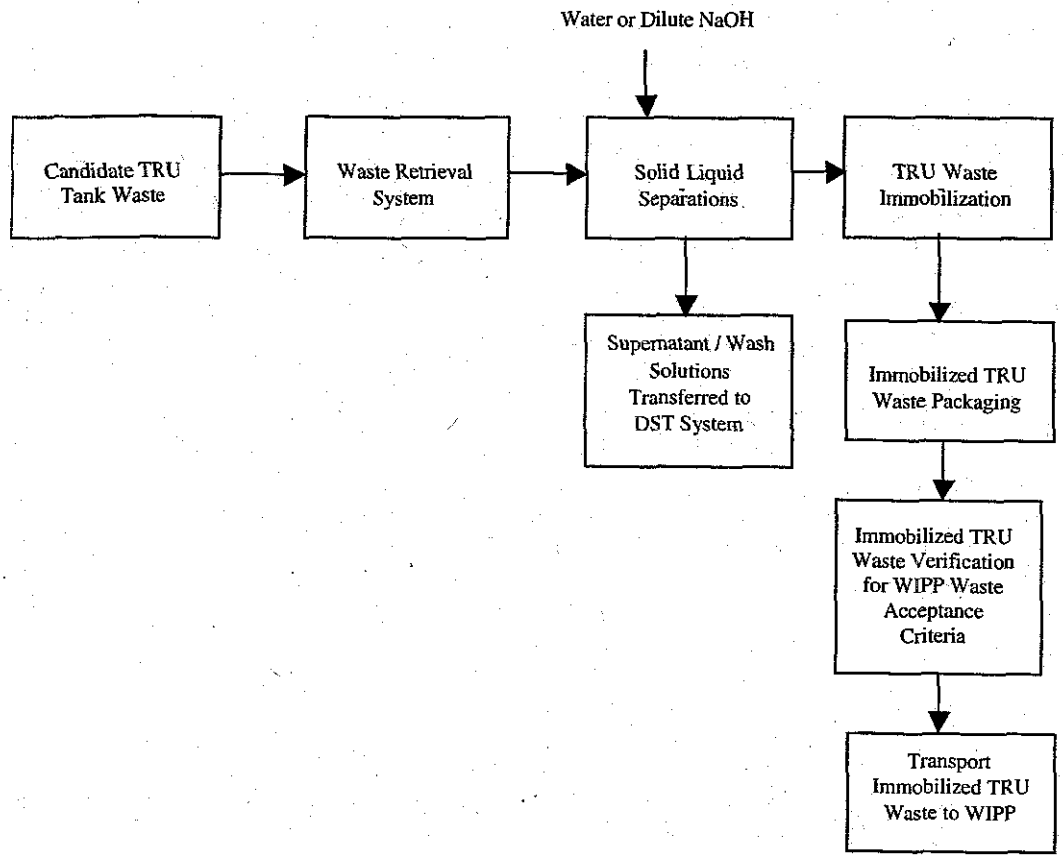
[1]This 40% waste oxide loading is used as an upper bounding value. Typical HLW oxide loadings are in the 25-30% range.

Figure 8-1. Preliminary Conceptual Flow Diagram for Transuranic Tank Waste Treatment.



DOE has established waste acceptance criteria for transfer of contact-handled TRU (CH-TRU) wastes from various sites to WIPP (DOE 1999). Because WIPP presently is not permitted by the New Mexico Environmental Department to dispose of RH-TRU waste, the waste acceptance criteria covers CH-TRU waste only. The DOE Carlsbad Field Office (DOE CFO) is pursuing a modification to the RCRA Part B Permit for WIPP that would allow for the disposal of RH-TRU wastes. Once the RCRA Part B Permit is modified, the DOE CFO will develop waste acceptance criteria for RH-TRU wastes.

The development program for the MAI supplemental technology alternative processes will need to determine whether the TRU tank wastes are CH-TRU or RH-TRU waste and conduct process verification testing to demonstrate compliance with the WIPP waste acceptance criteria for CH-TRU and RH-TRU wastes once the RH-TRU waste acceptance criteria have been developed.

8.1.2 Transuranic Waste Treatment Alternatives

The potentially TRU wastes stored in the SSTs and DSTs consist of precipitated metal hydroxide sludges that include sodium salts, water, and fission products. Additionally, a non-TRU supernatant and saltcake is present along with the potentially TRU waste in some of these tanks.

Treatment alternatives for the potentially TRU tank waste include the following:

- Grout or phosphate-bonded ceramic (an ambient temperature encapsulation process)
- Low-temperature drying (includes addition of stabilizing agents).

These treatment alternatives along with the reference approach of vitrification are representative of the range of treatment alternatives that could be applied to the potentially TRU tank wastes. These treatment alternatives are discussed further in the following sections.

Recommendation: The development program for the MAI supplemental technology processes will need to evaluate waste forms for treatment of the potentially TRU tank wastes.

8.1.2.1 Vitrification

Vitrification of all tank wastes is the current baseline for the RPP. Accordingly, the waste contained in the SSTs and DSTS would be retrieved and transferred to the WTP for treatment. Within the WTP, tank waste sludges are pretreated to remove soluble components such as aluminum, chromium, and PO_4 (sludge washing and caustic leaching) that affect glass composition. Supernatants and sludge wash and leachate solutions are pretreated to separate soluble ^{137}Cs, ^{99}Tc, ^{90}Sr, and TRU radionuclides. The decontaminated supernatants, the LAW fraction, are vitrified in joule-heated melters. The HLW fraction, pretreated sludges combined with the radionuclides that were separated from the supernatants, is vitrified in joule-heated melters that are separate from the LAW melters. The amount of HLW glass produced from the pretreated sludge–radionuclide mixture depends on the composition of waste oxides. The minimum incorporation of HLW oxides in the HLW glass is determined based on specification 1 from the WTP Contract, DE-AC27-01RV14136, *Contract Between DOE Office of River Protection and Bechtel National, Inc., for the Design and Construction of the Hanford Tank Waste Treatment and Immobilization Plant.*

The Hanford Site has conducted sludge leaching and washing tests with samples of tank wastes. In particular, sludge washing and leaching tests were conducted with a core sample from tank 241-T-111. The wastes stored in tanks 241-B-201, 241-B-202, 241-B-203, 241-B-204, 241-T-201, 241-T-202, 241-T-203, 241-T-204, and 241-T-111 are all second-cycle decontamination waste and 224 Building waste. These wastes are assumed to exhibit similar washing and leaching characteristics.

The sludge wash and leaching results from tests with the core sample from tank 241-T-111 were applied to the combined waste inventory to estimate the mass of each waste component after pretreatment to estimate the mass of HLW glass using the minimum waste oxide limits from the WTP Contract. Sludge washing and caustic leaching do not significantly remove bismuth from these sludges. Because of limited bismuth oxide (Bi_2O_3) incorporation in HLW glass, the vitrification of these pretreated sludges would result in the production of 6.68×10^3 MT of HLW glass.

The Hanford Site has not conducted sludge leaching and washing tests with waste samples from tanks 241-SY-102, 241-AW-103, and 241-AW-105. However, the OLI Corporation Environmental Simulation Program was used to estimate the amount of each component that would be removed from these sludges during washing and leaching. The estimated percentage

of each component removed from each sludge was applied to the sludge inventory to estimate the mass of each waste component after pretreatment and to estimate the mass of HLW glass using the minimum waste oxide limits from the WTP Contract. For the sludge in tank 241-SY-102, chrome oxide (Cr_2O_3) is only partially removed during leaching, and because of limited incorporation into HLW glass, this sludge would produce 7.04×10^2 MT of glass. For the sludges in tanks 241-AW-103 and 241-AW-105, zirconium oxide (ZrO_2) is not removed during leaching, and because of limited incorporation into HLW glass, these sludges would produce 3.55×10^3 MT of HLW glass.

Therefore, the estimated quantity of HLW glass produced from processing the TRU tank wastes separately through the WTP is 10,900 MT. However, the TRU tank wastes could be blended together or blended with other tank waste sludges and processed through the WTP. If the TRU sludges stored in all of the previously identified SSTs and DSTs were blended together and the resulting sludge mixture was washed and leached, the mass of HLW glass produced is estimated to be 6,870 MT. If the TRU sludges were washed and leached then blended with other Hanford Site tanks wastes to achieve 40 wt%[2], non-volatile waste oxide loading (excluding sodium, potassium, and silicon oxides) in the HLW glass, the mass of HLW glass produced is estimated to be 2,000 MT, based on the contribution of the waste oxides present in the pretreated TRU sludges only.

8.1.2.2 Grout or Phosphate-Bonded Ceramic

If the TRU wastes were to be immobilized in grout or phosphate-bonded ceramic, wastes would first be retrieved from their underground storage tanks and transferred to a facility for separation of supernatants. Solid–liquid separation could be conducted using crossflow filtration or centrifugal filtration membranes. Next, the TRU tank wastes would be washed with either water or dilute sodium hydroxide solution to remove soluble salts and ^{137}Cs. Washing would reduce the mass of TRU tank waste requiring immobilization. The wash solutions would be transferred to the DST system for treatment in the WTP. The washed TRU tank waste would be immobilized using a specific grout or phosphate-bonded ceramic and packaged for disposal in the WIPP.

8.1.2.3 Low-Temperature Drying

DOE/EIS-0305F, *Final Environmental Impact Statement for Treating Transuranic (TRU)/Alpha Low-Level Waste at the Oak Ridge National Laboratory, Oak Ridge, Tennessee*, was prepared to evaluate treatment alternatives for the Melton Valley Storage Tank legacy wastes and solid wastes at the Oak Ridge National Laboratory. The Melton Valley Storage Tank legacy wastes consist of about 800,000 gal of alpha-contaminated supernatant and about 180,000 gal of TRU sludge. The legacy wastes are similar in waste characteristics to the candidate TRU wastes at the Hanford Site.

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[2]This 40% waste oxide loading is used as an upper bounding value. Typical HLW oxide loadings are in the 25-30% range.

The DOE Record of Decision for the Melton Valley Storage Tank wastes selected the low-temperature drying treatment for the tank waste, and sorting, compaction, and repackaging for the solid waste (65 FR 154). DOE estimates that approximately 180 m^3 of RH-TRU waste will be produced from treating the 900 m^3 of TRU sludge and approximately 588 m^3 of greater than NRC Class C low-level waste will be produced from treating the 800,000 gal of alpha-contaminated supernatant and sludge wash solution (DOE/EIS-0305F). The DOE selected the Foster Wheeler Environmental Corporation to construct, operate, and decommission the required waste treatment facility. The estimated duration for treatment of the Melton Valley Storage Tank legacy wastes is 18 months. The contract value is approximately $225 million. The DOE has options for treatment of additional wastes in the treatment facility.

The low-temperature drying technology could be used to treat the TRU sludges at the Hanford Site. Sludges would be retrieved from their current storage tanks and transferred to a new TRU waste treatment facility. The retrieved sludges would be transferred in a double-contained, pipeline to sludge collection and decant tanks in the new treatment facility. Retrieved sludge would be analyzed and washed with water to remove supernatant and soluble salts. The TRU elements would not dissolve during the sludge washing process. In order to meet RCRA LDR standards and waste acceptance criteria for WIPP, additives would be mixed with the sludge. The sludge–additive mixture would be concentrated for drying. After analysis, the concentrated sludge–additive mixture would be transferred in batches to the sludge dryer. The dried sludge solids would be loaded directly into RH-TRU canisters. Distillate from the sludge dryer would be condensed, sampled and analyzed, then discharged to the 200 East Area Effluent Treatment Facility.

8.2 SOLIDIFICATION OF TANK 241-T-110 LOW-LEVEL WASTE SOLIDS

As part of evaluating whether the SSTs and DSTs contain waste that could be classified as TRU waste, it was identified that the approximately 369,000 gal of waste contained in tank 241-T-110 is potentially low-level waste according to criteria established in DOE M 435.1-1, *Radioactive Waste Management Manual.* Appendix F, Section F2.0, summarizes the analysis conducted to determine that tank 241-T-110 contains low-level waste. The waste stored in some of the other SSTs may also be potentially low-level waste. The treatment alternatives propose for the TRU tank wastes may also be applicable to the tank 241-T-110 waste.

9.0 RECOMMENDATIONS AND PATH FORWARD

This section provides recommendations with respect to ORP acceleration as part of the Performance Management Plan and the path forward for accelerated cleanup of tank waste.

9.1 RECOMMENDATIONS

Four recommendations are presented for the acceleration of cleanup of tank wastes dealing with technology investigation, review of waste treatment and disposal requirements, TRU and low-level waste processing, and denitration. The detailed scopes for implementation of these recommendations are to be developed as part of planning for the target baseline.

9.1.1 Technologies for Investigation Fiscal Year 2003

The pursuit in FY 2003 of the laboratory-scale demonstrations and other investigations that would be required (e.g., follow-on engineering evaluations) for the following supplemental technologies are recommended:

- Sulfate removal
- Containerized grout
- Bulk vitrification
- Steam reforming.

9.1.1.1 Sulfate Removal

Sulfate removal allows for the acceleration of cleanup by reducing the amount of glass produced in the WTP by increasing the waste loading in the LAW. Though this technology could be deployed in conjunction with tank farm operations, it is envisioned that as a pretreatment step, sulfate removal would be best deployed in the WTP. This deployment would offer the potential benefit of not having to neutralize the waste, which would in turn reduce the amount of sodium to be vitrified.

Sulfate removal requires hot and cold laboratory testing to investigate process parameters, separation efficiencies, and waste form acceptability and performance. The process parameter study would define the conditions that would provide a robust region for the operation of the precipitation process. The key for the sulfate precipitation is its acceptability for disposal and the performance of the waste at the Hanford Site either with or without immobilization (e.g., grouting).

9.1.1.2 Containerized Grout

Containerized grout would allow acceleration of tank waste cleanup by reducing the amount of sodium that the WTP needs to process. In deploying this technology, the testing can be conducted independently of the location selected for implementation. Containerized grout could be successfully deployed either in conjunction with tank farm operations or in conjunction with WTP operations.

Containerized grout requires investigations into disposal of nitrates, waste formulation, and container design. Nitrate disposal has been identified as one of the key concerns with respect to grout disposal at the Hanford Site. The need for investigations into waste formulation arises from the fact the previous Hanford Site program had different process requirements than would the containerized grout supplemental technology. Two areas requiring concurrent work are waste formulation and package design. These two areas of investigation are inter-connected because one of the key factors in the formulation work will be the curing temperature. This parameter will in turn be tied to the dimensions of the package.

9.1.1.3 Bulk Vitrification

Bulk vitrification would accelerate tank waste cleanup by reducing the mass of sodium requiring vitrification in the WTP. The technology could be deployed in a variety of configurations based on the module design of the equipment. The investigations for FY 2003 should focus on deployment in conjunction with tank farm operations.

Bulk vitrification requires investigations into waste formulation, off-gas equipment performance, and the retention of radionuclides in the glass both during vitrification and during disposal. The higher temperature and batch processing associated with the bulk vitrification concept may allow significantly higher sodium incorporation rates than currently planned at the WTP. Establishing the sodium loading would be a key parameter for deployment of this technology. The information presented to date shows a robust off-gas system for the bulk vitrification system. Engineering evaluations of the system are necessary to support permitting requirements and to answer concerns raised in review of the technology. In the data provided by the vendor, bulk vitrification showed a high retention of radionuclides both during vitrification and in the disposal system. Confirmation of this radionuclide data would also be key to the successful deployment of bulk vitrification.

9.1.1.4 Steam Reforming

Steam reforming could allow acceleration of the cleanup of tank waste by serving as an additional method for immobilizing the LAW fraction of the waste. By reducing the burden on the WTP melters, the schedule could be significantly accelerated.

Currently the WTP contractor, Bechtel National Inc., is leading this effort. They have performed preliminary cold tests and are evaluating the product. Future plans include BNI developing a technical roadmap, a preliminary flow sheet, and conducting a performance assessment on the product that was produced from the cold tests. These data will enable ORP to evaluate what further investments are required and help them interact with other DOE sites (i.e., Idaho) that

also are interested in steam reforming. The overall evaluation must show a substantial lifecycle cost benefit producing a product that meets the same disposal criteria as the ILAW glass.

9.1.2 Waste Disposal Requirements

Disposal of the supplemental treatment waste at the Hanford Site will require a review of the radionuclide and dangerous waste requirements. It is recommended that these reviews be conducted during FY 2003 to support the down-selection process.

9.1.2.1 Radionuclide Waste Requirements

An evaluation of the proposed supplemental technologies should be conducted to confirm or establish the degree of radionuclide separations necessary for the treated saltcake waste in accordance with waste disposal considerations. Radionuclide separation (i.e. pretreatment) steps common to all of the supplemental technologies (selective dissolution, solid-liquid separation, Cs and Tc separation) should be further investigated, starting in FY 2003, as recommended in Chapter 4. This should include gathering additional selective dissolution data on the tank 241-U-107 test and gathering performance data on solid-liquid separation and Cs and Tc ion exchange starting with maintaining cognizance of the corresponding research and testing by the WTP Project.

9.1.2.2 Dangerous Waste Requirements

Through evaluation of the disposal pathways for the waste from supplemental treatment, the lined low-level waste burial trench was identified as the prime site for disposal of this waste. Further analysis is necessary to determine whether the waste complies with federal regulations for placement on the land such as the LDRs found in Title 40, *Code of Federal Regulations*, Part 268, "Land Disposal Restrictions" (40 CFR 268) and the Washington State regulations found in WAC 173-303-140. In addition, the lined low-level waste burial trench will require an update of its performance assessment.

9.1.3 Supplemental Analysis of Denitration of Tank Waste

The benefits of denitrating the tank waste have been identified at both of the workshops conducted as part of the C3T MAI Subgroup evaluation of supplemental alternatives. The successful denitration of the tank waste would allow for a greater range of supplemental technologies to be explored (e.g., grout, fractional crystallization). A variety of non-thermal alternative technologies such as electro-chemical denitration have been proposed to remove nitrates from the tank waste, but none of these technologies has been deemed adequately advanced in development to be deployed under the requirements for the supplemental technologies (e.g., deploy operational demonstration unit in 2006).

If DOE's current strategy for treatment of the Hanford Site tank waste does not achieve its desired goals, development of one or more backup strategies would be prudent. To increase the range of application for these backup strategies, it would be highly advantageous to investigate means to denitrate the waste. In the evaluation of technologies, the C3T MAI Subgroup found that active metal denitration appears to be promising and warrants further investigation. Thus it

is recommended that the Office of Science and Technology perform investigations of denitration processes.

9.1.4 Transuranic Waste Treatment

TRU waste treatment allows for acceleration of tank cleanup by reducing the amount of waste that requires vitrification as HLW. This treatment system would be deployed in conjunction with tank farm activities to minimize the impact on the WTP.

Preliminary information has been developed for the process and associated costs of this technology. To further advance this concept, it is recommended that an engineering evaluation be conducted for TRU waste disposition alternatives. This evaluation would further develop the waste form, engineering data for the equipment and facility selection, and compliance strategy for disposal of the waste at WIPP.

To support this evaluation of TRU wastes the following tasks should be performed:

- Evaluate the waste contained in the Hanford Site tanks to designate which tanks contain TRU waste suitable for treatment and disposal in the WIPP
- Evaluate waste forms for treatment of the potentially TRU tank wastes (these waste forms may also be applicable to low-level tank waste such as that in 241-T-110 since this waste is chemically similar to the TRU waste present in the SSTs)
- Coordinate with activities planned for the disposition of TRU waste sludges stored in K Basins
- Coordinate with activities planned for the investigation and disposition of the TRU waste in the 618-110 and 618-111 burial grounds.

9.1.5 Continued Development of Office of Science and Technology Initiatives

The continued investigation of promising technologies by ORP together with the Office of Science and Technology should be continued through their jointly agreed-upon projects on immobilization alternatives to expedite cleanup, single-shell HLW tank disposition, and remediation of leaked HLW below Hanford Site tanks. These activities ensure that innovative technologies are available on a continuing basis to support the MAI at the Hanford Site.

9.2 PATH FORWARD

The current RPP path forward includes the following additional steps, which will be completed to implement the Performance Management Plan:

Programmatic Environmental Review Report	7/26/02
Strategy for the revised and mutually agreed to Performance Management Plan for Accelerated Cleanup of the Hanford Site	8/01/02
Draft supplemental analysis to the Environmental Impact Statement	8/30/02
Develop a target baseline	9/30/02
Complete hot laboratory testing of alternative technologies	8/31/03
Complete cold pilot demonstrations of selected technologies	8/31/04

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APPENDIX A

EVALUATION OF LOW-ACTIVITY WASTE FEED SUPPLEMENTAL TREATMENT OPTIONS BY THE CLEANUP CONSTRAINTS AND CHALLENGES TEAM MISSION ACCELERATION INITIATIVE TEAM FOR THE OFFICE OF RIVER PROTECTION

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APPENDIX A

EVALUATION OF LOW-ACTIVITY WASTE FEED SUPPLEMENTAL TREATMENT OPTIONS BY THE CLEANUP CONSTRAINTS AND CHALLENGES TEAM MISSION ACCELERATION INITIATIVE TEAM FOR THE OFFICE OF RIVER PROTECTION

A1.0 INTRODUCTION AND BACKGROUND

The U.S. Department of Energy (DOE), Office of River Protection (ORP), is responsible for the remediation of the Hanford Site tank farms, including the 53 million gallons of highly radioactive mixed waste contained in 149 single-shell tanks (SST) and 28 double-shell tanks (DST). ORP manages the River Protection Project (RPP). Under the RPP, wastes retrieved from the tanks will be partitioned to separate the highly radioactive constituents from the very large volumes of chemical wastes that exist in the tanks. The volume of waste is the result of chemicals used in various Hanford Site processes, chemicals that were added to the tanks to reduce tank corrosion, and chemicals used in reprocessing and extraction of cesium and strontium. The highly radioactive constituents are to be vitrified, stored onsite, and ultimately disposed of as high-level waste (HLW) in the offsite national repository. The less radioactive chemical waste, referred to as low-activity waste (LAW), also would be vitrified and then disposed of onsite in trenches that comply with the *Resource Conservation Act of 1976* (RCRA)[1] and in compliance with DOE O 435.1, *Radioactive Waste Management*.

Under a consent order[2] entered into by the Washington State Department of Ecology (Ecology), the U.S. Environmental Protection Agency, and the ORP, the vitrification of all Hanford Site tank waste is to be completed by 2028. However, meeting the 2028 treatment completion date presents significant technical and fiscal challenges. The current Tri-Party Agreement-compliant RPP baseline is predicated on a phased approach wherein a 30-metric tons of glass per day (MTG/D) LAW vitrification facility and a 1.5 MTG/D HLW vitrification facility will treat at least the first 10 percent of the waste by 2018. HLW treatment capacity will need to be increased to 12 MTG/D and the LAW treatment capacity increased to 120 MTG/D in 2018 in order to complete waste processing by 2028, based on the preferred approach in DOE/EIS-0189, *Tank Waste Remediation System Hanford Site, Richland, Washington, Final Environmental Impact Statement*. According to DOE/EIS-0189, the additional capacity is attained by doubling the capacity of an initial Waste Treatment Plant (WTP) and constructing a second WTP with the same expanded throughput.

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[1] The state of Washington implements a U.S. Environmental Protection Agency-authorized hazardous waste management program via the *Washington Administrative Code*, Section 173-303, "Dangerous Waste Regulations." References to RCRA in this document in the context of Tri-Party Agreement cleanup remedies refer to Washington's Dangerous Waste Regulations.

[2] *Hanford Federal Facility Agreement and Consent Order*, also referred to as the Tri-Party Agreement.

The high capital expense associated with the above approach has resulted in consideration being given to enhancing initial WTP processing capability and eliminating the second WTP. This approach better utilizes the WTP investment capital but will not complete tank waste treatment until 2046.

Accordingly, the Mission Acceleration Initiative (MAI) was developed to allow tank waste treatment to be completed by 2028. Figure 1-1 presents a conceptual pathway to complete waste treatment by 2028. This acceleration would be accomplished through a combination of (1) increasing the HLW and LAW treatment capacities in the initial facilities brought on line in 2007 to 6 MTG/D and 60 MTG/D, respectively,[3] and (2) deploying supplemental treatment technologies to treat wastes determined to be non-HLW.[4] Option 2 may include pretreatment of the waste to produce the non-HLW fraction or may use any excess capacity in the WTP. This accelerated approach enables tank waste treatment to be completed by 2028 with all tank-HLW[5] vitrified. The MAI assumes that LAW treatment in the WTP would increase to 60 MTG/D with LAW immobilization being accomplished by vitrification and a supplemental immobilization technique. Even with the LAW treatment increase, a gap (illustrated by the bracket in Figure 1-1) remains between the quantity of LAW that could be treated in the LAW treatment plant by 2028 and the total quantity.

From May 21 - 23, 2002, the Cleanup Constraints and Challenges Team (C3T) MAI Subgroup, together with invited experts, held a workshop to evaluate flow sheet options for the MAI to close that gap. Although the options assumed skid-mounted treatment units that could ostensibly operate independently of the WTP, the participants were instructed to also consider whether key treatment components would be of value if used in conjunction with the WTP (i.e., waste from pretreatment operations being fed into a supplemental immobilization unit).[6] It was stressed that "skid mounting" could be interpreted in very different ways, from simply constructing "skid-mounted" offsite and transporting to a permanent hosting facility, to total mobility and outdoor operation. Additionally, the options were considered with the objective of a demonstration with radioactive waste in the 5 gal/min throughput range within the next 3 to 5 years. All of the options were targeted for use in closing the LAW treatment gap in a manner that would accelerate cleanup and risk reduction but would maintain cleanup quality.

A LAW treatment gap exists between the MAI conceptual capacity of the WTP and the waste treatment capacity if all tank waste treated by 2028 were predominantly high-sodium saltcake wastes in the tanks. Accordingly, the flow sheets for the supplemental tank waste treatment

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[3] The LAW treatment throughput would be equivalent to 60 MTG/D; however, not all LAW would be vitrified (i.e., alternative waste forms could be used to supplement vitrification).

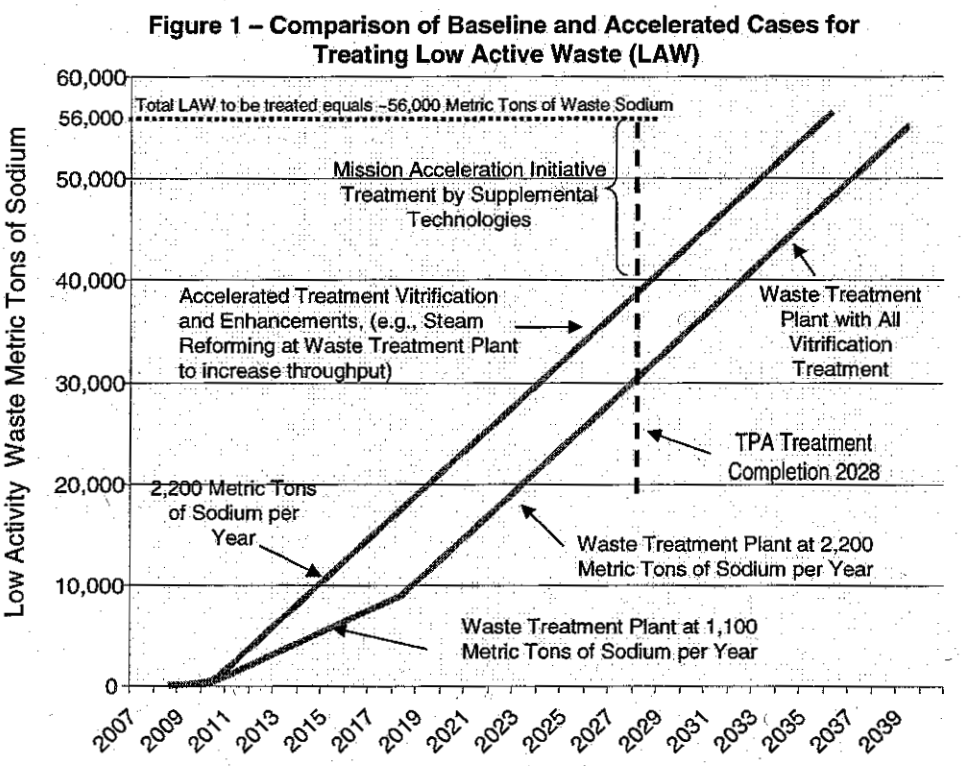
[4] Non-HLW is waste that is deemed not to be HLW due to its origin (e.g., TRU waste from decladding operations) or due to waste incidental to reprocessing determinations in accord with DOE M 435.1-1, *Radioactive Waste Management Manual.*

[5] Hanford Site cesium and strontium capsules were not addressed by this action team.

[6] The flow sheets presented to the workshop participants were intended to facilitate the workshop evaluations, not to limit the ways that treatment technologies could be beneficially deployed to meet ORP's treatment objectives. For example, a 5 gal/min flow rate was used for the flow sheets but a net flow rate of approximately 7 gal/min would be required to close the gap on a 24-7 basis.

options focused on saltcake wastes retrieved from SSTs. For purposes of the workshop evaluations, the flow sheets were focused on treating wastes from 68 SSTs that have been tentatively identified as candidates for such treatment options. Each of the SSTs selected has saltcake inventories of at least 50,000 gal.

Figure 1-1. Mission Acceleration Initiative Cases for Treating Low-Activity Waste.



The combination of accelerated LAW treatment in the WTP and supplemental technologies provides a pathway to complete waste treatment by 2028.

The core LAW treatment technologies used in the flow sheets are the product of prior technology studies by DOE conducted over the past decade (e.g., by the Tanks Focus Area and the DOE Office of Environmental Management) as well as technologies that have been developed and in some cases successfully deployed by private industry. In order to allow the May workshop evaluations to be focused on a manageable number of alternatives, a preliminary screening was conducted by ORP in early April. The screening resulted in selection of nine flow sheet options (options one through seven, plus two variants) for evaluation at the May workshop. The options were based on mass balance and other technical and programmatic data developed for the technologies during April and early May. The evaluator panel included twelve members and two backups. The screening process is described in Attachment A1.

A2.0 OPTIONS EVALUATED AND INFORMATION REVIEWED

Figure 2-1 summarizes the technologies that were used in the nine flow sheet options evaluated. All nine options start with a "Selective Dissolution" step, which would be accomplished as part of the baseline tank retrieval process (salt dissolution). Selective dissolution takes advantage of the high solubility of cesium and technetium to separate the first fraction of the dissolution stream to the WTP, via the DST system, leaving a waste stream with significantly reduced radionuclide content as the feed for supplemental treatment processes. The expected effectiveness of such a separation was discussed among the evaluators, and serious reservations were expressed by a few evaluators regarding the extrapolation of partitioning factors measured in test tubes at equilibrium to phenomena occurring in a tank-size salt bed. The evaluators decided to not include this step in their evaluation and to take no credit for the separations provided by it, although most appeared to believe the technology will work to some extent. CH2M HILL Hanford Group, Inc., will measure the effectiveness of selective dissolution within the next few months during the planned low-volume density gradient proof-of-concept test of salt dissolution retrieval in tank 241-U-107.

In all nine options, selective dissolution is followed by a solid-liquid separation step. This step is expected to effectively separate strontium and transuranics contained in suspended solids as these are essentially insoluble. The saltcake wastes being considered for these options do not have appreciable organic complexants, so there is essentially no soluble strontium or transuranic constituents. The solid-loaded effluent from the solid–liquid separation will be returned to the DST system for treatment by the WTP. Table 2-1 describes the steps specific to each option.

For each option except option 3 (steam reforming), the following information was provided to the evaluators in a written report, RPP-11131, *Mission Acceleration Initiative Demonstration Information Package*, and verbal presentations:

- Mass balance for the main radionuclides and chemicals of concern for the tank 241-S-112 inventory (used as a representative tank) on a 5 gal/min treatment basis (this included, for each unit operation, estimated separations of the main contaminants [e.g., cesium, strontium, technetium, transuranics, nitrates, sulfates] from the stream to be immobilized)
- Description of the primary equipment and process conditions involved
- List of relevant laboratory, pilot, and industrial experience
- Estimated waste form performance toward radionuclides and chemicals of concern
- Order of magnitude of the cost to deploy the option in a skid-mounted unit, to treat the inventory of one tank (e.g., tank 241-S-112) at approximately 5 gal/min (the cost was provided for comparison purposes only, not as a basis for future project planning)

Figure 2-1. Low-Activity Waste Supplemental Treatment Options as Evaluated at the May 21-23, 2002, Workshop.

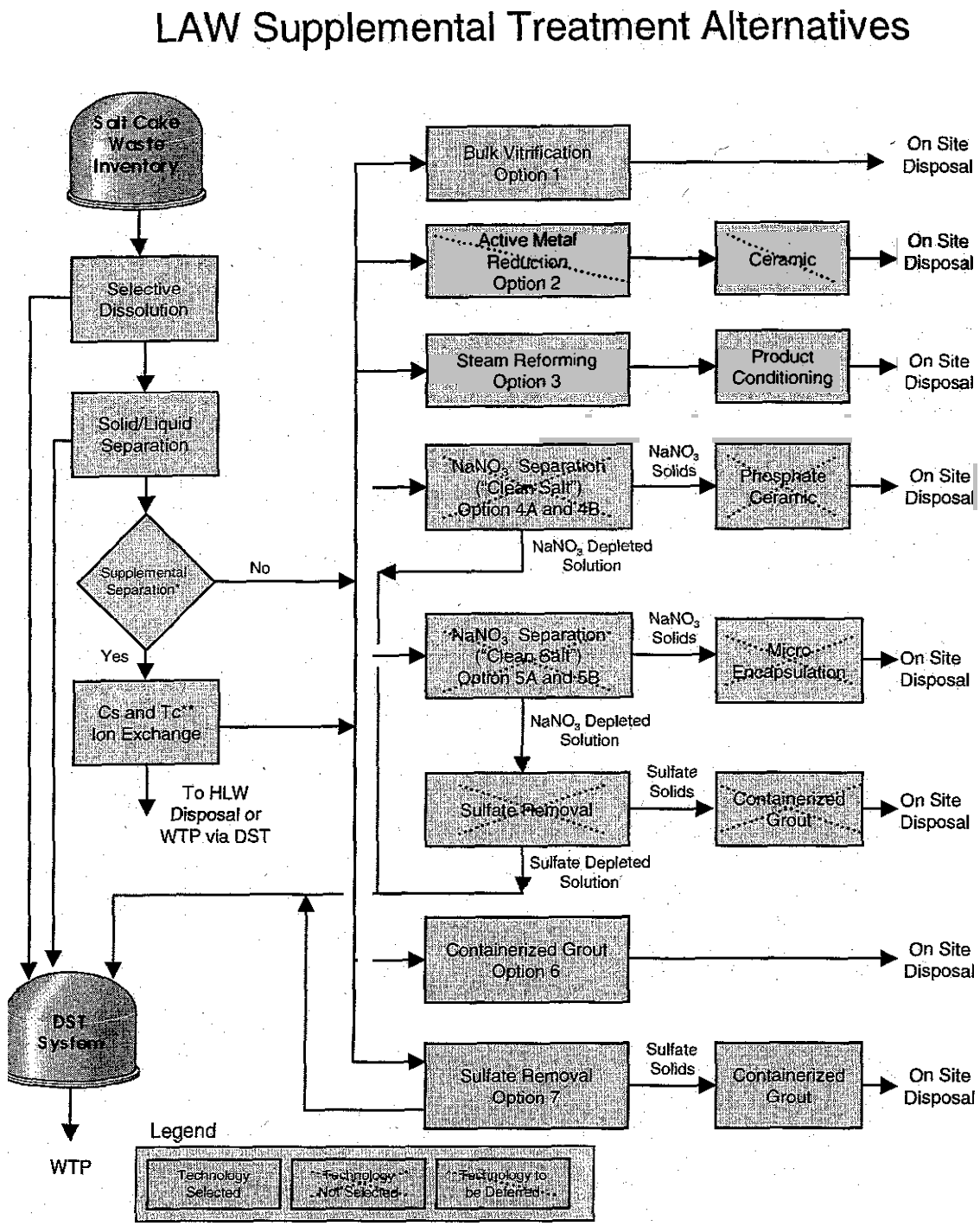


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Table 2-1. Summary Description for Potential Low-Activity Waste Treatment Options. (2 sheets)

Option	Summary description as evaluated
Option 1 – Bulk Vitrification	The LAW stream is passed through a cesium ion exchange column that contains crystalline silicotitanate to remove cesium (technetium removal was assumed when evaluating this option, but no flow sheet calculations were done in advance of the workshop). This results in a waste stream that is expected to require less shielding for subsequent processing steps. The waste stream is processed by a bulk vitrification step that involves the mixture of the waste with inexpensive glass forming materials (clay or sandy soil) followed by vitrification. Vitrification is performed inside of the eventual disposal container through the use of inserted electrodes and the application of electrical power. The resulting vitrified product is disposed of in the container in which it was processed. Final disposition of the ^{137}Cs-laden crystalline silicotitanate for a demonstration has not been determined but could include processing in the WTP HLW vitrification facility. The eluted technetium is returned to the DST system. All larger scale cesium and technetium ion exchange would likely take place in the WTP.
Option 2 – Active Metal Reduction	The LAW stream is passed through a cesium ion exchange column that contains crystalline silicotitanate to remove cesium (technetium removal was assumed when evaluating this option, but no flow sheet calculations were done in advance of the workshop). This results in a waste stream that is expected to require less shielding for subsequent processing steps. The waste stream is processed through two treatment steps. First, the waste stream is reacted with aluminum metal to form a sodium aluminate. This processing step also results in the destruction of sodium nitrate, nitrite, and hydroxide species. The immobilization step involves the reaction of the sodium aluminate with phosphoric acid to create a phosphate-based ceramic waste form that is placed in containers for disposal. The liquid stream not immobilized in the ceramic waste form is placed into a phosphate-based cement. Again, final disposition of the ^{137}Cs-laden crystalline silicotitanate for a demonstration has not been determined but could include processing in the WTP HLW vitrification facility. The eluted technetium is returned to the DST system. All larger scale cesium and technetium ion exchange would likely take place in the WTP.
Option 3 – Steam Reforming	The LAW stream is passed through a cesium ion exchange column that contains crystalline silicotitanate to remove cesium. (Technetium removal was assumed when evaluating this option, but this step was not included in the flow sheet calculations done in advance of the workshop.) This results in a waste stream that is expected to require less shielding for subsequent processing steps. The waste is processed in a high-temperature fluidized bed under a slight vacuum. Superheated steam and additives are injected into the bed creating both reducing and oxidizing zones. The process destroys nitrates and with the help of additives, incorporates radioisotopes together with sodium, sulfate, chlorine, and fluorine in a granular material that can be placed in containers or grouted. Again, final disposition of the ^{137}Cs-laden crystalline silicotitanate for a demonstration has not been determined but could include processing in the WTP HLW vitrification facility. The eluted technetium is returned to the DST system. All larger scale cesium and technetium ion exchange would likely take place in the WTP.
Options 4A and 4B – Clean Salt	Because the clean salt technology separates the cesium and technetium from the stream to be immobilized, evaluations are conducted for one option without a cesium ion exchange column (4A) and one option with the column (4B). For both options, the waste stream is reacted with nitric acid to convert sodium salts to sodium nitrate. The reacted solution is passed through an evaporator and cooler to crystallize out sodium nitrate. For option 4A, the crystals are washed to remove radionuclides and other species from the sodium nitrate crystals. For both options, the sodium nitrate crystals are filtered from the liquid and then immobilized in an appropriate grout. These two options send the sodium nitrate-depleted waste stream to the WTP via the DST system.

Table 2-1. Summary Description for Potential Low-Activity Waste Treatment Options. (2 sheets)

Option	Summary description as evaluated
Options 5A and 5B – Clean Salt with Sulfate Removal	These two options are similar to options 4A and 4B because they react the waste stream with nitric acid to convert sodium salts to sodium nitrate, and crystallize out (through evaporation) sodium nitrate, which is filtered from the liquid, for immobilization. Option 5A involves no upstream cesium ion exchange column, but does include a sodium nitrate crystal wash step, while option 5B includes an upstream cesium ion exchange column but no washing step. In addition, options 5A and 5B include the following features, which are different from options 4A and 4B: (1) the liquid solution (which contains very little sodium nitrate) from the evaporation step is further processed to remove sulfate before being sent to the WTP via the DST system, (2) the removed sulfate is immobilized in an appropriate grout, and (3) the sodium nitrate crystals are immobilized by microencapsulation (as opposed to grout).
Option 6 – Containerized Grout	The LAW stream is passed through a cesium ion exchange column that contains crystalline silicotitanate to remove cesium. (Technetium removal was assumed when evaluating this option, but this step was not included in the flow sheet calculations done in advance of the workshop.) This results in a waste stream that is expected to require less shielding for subsequent processing steps. The waste is processed by an ambient solidification step that involves the mixing of the waste with grout formers (Portland cement, fly ash, and slag) to form a solid grout product. The resulting grout product is placed into containers for disposal. This treatment option does not send any secondary waste stream to the WTP. Again, final disposition of the ^{137}Cs-laden crystalline silicotitanate for a demonstration has not been determined but could include processing in the WTP HLW vitrification facility. The eluted technetium is returned to the DST system. All larger scale cesium and technetium ion exchange would likely take place in the WTP.
Option 7 – Sulfate Removal	The LAW stream is passed through a cesium ion exchange column that contains crystalline silicotitanate to remove cesium. This results in a waste stream that is expected to require less shielding for subsequent processing steps. The waste stream is processed through the following steps. First, the waste stream is reacted with nitric acid to change the stream from alkaline to acidic. Strontium nitrate is added in a subsequent step to precipitate sulfate. The sulfate species are filtered from the liquid and immobilized in a grout. This option sends the sulfate-depleted waste stream that contains technetium and other soluble radionuclides to the WTP via the DST system.

DST = double-shell tank.
HLW = high-level waste.
LAW = low-activity waste.
WTP = Waste Treatment Plant.

- Estimated reduction of WTP LAW processing duration compared with the current baseline for the Hanford 177 tanks if the option were to be applied to all relevant SSTs (68 tentatively identified)

- Estimated total volume of immobilized LAW (ILAW) for the Hanford 177 tanks if the option were to be applied to all relevant SSTs (68 tentatively identified) (this included both the WTP ILAW and the alternative waste forms produced by the option evaluated).

The meeting minutes and verbal presentations have been assembled in RPP-11305, *Three-Day Workshop to Evaluate Alternative Treatment Options for Hanford Site Tank Waste Meeting Minutes*.

Table 2-2 summarizes the potential impact on WTP LAW processing duration and on ILAW total volume.

The evaluators noted that the cost order of magnitude did not include the disposal cost for the immobilized waste, although it could be a significant driver, especially for higher LAW volume options. The evaluators also noted that the cost estimates were for the initial demonstration (5 gal/min basis, 1- to 2-year operation) rather than life-cycle costs for repeated deployments of the same equipment. Deployment for multiple tanks likely would result in lower costs on a per tank basis.

For option 3, steam reforming, three handouts from previous presentations were provided to the evaluators, and a verbal presentation was made by a representative of Studsvik, one of the vendors for this technology. The information provided covered most areas listed above for the other options, except for the following.

- No detailed mass balance was provided. The main process streams were qualitatively discussed, with limited quantitative data provided on some inlet process additives, off-gas streams, and waste products.
- No cost data were developed for a Hanford Site deployment of the technology that would be comparable to the other options.
- The impacts on WTP processing duration and on the total volume of ILAW were estimated by the evaluators based on the limited data provided by the vendor and by extrapolation of the calculations made for the other options.

Table 2-2. Potential Impact of Each Option on Waste Treatment Plant Low-Activity Waste Processing Duration and Immobilized Low-Activity Waste Total Volume. [Note 5]

Option		Treatment of 68 SSTs						Treatment of Other 81 SSTs + 28 DSTs	ORP Mission Impact		
Path	Option Name	WTP ILAW from Selective Dissolution (m^3) [Note 1]	WTP ILAW Unique to Path (m^3) [Note 2]	Secondary Waste Stream to the Waste Treatment Plant	Total Path WTP ILAW Volume	Percent of baseline WTP ILAW	Volume Alternative Solid LAW (m^3)	WTP ILAW (m^3)	Total ILAW + Alt. Solid LAW (m^3)	Percent of baseline WTP ILAW	Years to Process ILAW in WTP [Note 3]
	Baseline [Note 1]	0	9.65E+04	N/A	9.65E+04	100.0%	0	6.18E+04	1.58E+05	100.0%	38.4
1	Bulk vitrification	1.84E+04	0	No	1.84E+04	19.1%	5.56E+04	6.18E+04	1.36E+05	85.8%	19.5
2	Active metal reduction	1.84E+04	0	No	1.84E+04	19.1%	2.27E+05	6.18E+04	3.07E+05	193.9%	19.5
3	Steam reforming	Note 4	Note 4	No	Note 4	Note 4	Note 4	Note 4	Note 4	Note 4	Note 4
4A	Clean salt no Cs IX	1.84E+04	5.96E+04	Yes	7.80E+04	80.8%	4.46E+04	6.18E+04	1.84E+05	116.5%	33.9
4B	Clean salt with Cs IX	1.84E+04	5.96E+04	Yes	7.80E+04	80.8%	4.46E+04	6.18E+04	1.84E+05	116.5%	33.9
5A	Clean salt and sulfate removal no Cs IX	1.84E+04	9.24E+03	Yes	2.76E+04	28.6%	5.53E+04	6.18E+04	1.45E+05	91.4%	21.7
5B	Clean salt and sulfate removal, with Cs IX	1.84E+04	9.24E+03	Yes	2.76E+04	28.6%	5.53E+04	6.18E+04	1.45E+05	91.4%	21.7
6	Containerized grout	1.84E+04	0	No	1.84E+04	19.1%	2.82E+05	6.18E+04	3.62E+05	228.9%	19.5
7	Sulfate removal	1.84E+04	3.98E+04	Yes	5.82E+04	60.3%	3.42E+04	6.18E+04	1.54E+05	97.5%	29.1

[1] Baseline is volume of WTP glass produced from processing all LAW in WTP. Does not include sodium added from process operations conducted in WTP.
[2] WTP ILAW calculated volume is based on the Gimple Rule and density of 2.65 g/cm^3.
[3] WTP ILAW net glass production rate is 30 metric tons of glass per day.
[4] Information on this option was given to the evaluators in a presentation by Brad Mason, Studsvik, AB, entitled "THOR Steam Reformer Technology for Hanford Tank Waste Support," to the Cleanup Constraints and Challenges Team Mission Acceleration Subgroup on May 22, 2002.. To the extent available, this information is contained in RPP-11305, 2002, *Three-Day Workshop to Evaluate Alternative Treatment Options for Hanford Site Tank Waste Meeting Minutes*, CH2M HILL Hanford Group, Richland, Washington.
[5] The information in this table represents summary information from RPP-11131, 2002, *Mission Acceleration Initiative Demonstration Information Package*, Rev. 0, CH2M HILL Hanford Group, Richland, Washington.

Cs IX = cesium ion exchange.
DST = double-shell tank.
ILAW = immobilized low-activity waste.
LAW = low-activity waste.
ORP = Office of River Protection.
SST = single-shell tank.
WTP = Waste Treatment Plant.

A3.0 EVALUATION

A3.1 EVALUATION PROCESS

The 12 evaluators agreed on the evaluation criteria listed and described in Table 3-1. The criteria were grouped into five areas: compliance and safety, project utility, operability, technical risk, and programmatic risk. The criteria were not weighted.

A number of general changes and clarifications were made in the course of evaluating the options, including the following (detailed option-specific changes and clarifications are described later in this section; detailed scores are provided in Table 3-2).

- Selective dissolution, solid–liquid separation, and cesium separation are developed technologies in common to nearly all of the options. Thus, although these technologies were discussed, they were treated as non-discriminators in the evaluation.

- The cesium separation technology was based on non-regenerable crystalline silicotitanate (CST). Although acceptable for the purposes of demonstrating treatment of a cesium-depleted waste stream, the potentially significant adverse impacts of CST on the quantity of HLW glass led to the conclusion that regenerable ion exchange resins could be used in place of CST to minimize these impacts.

- Technetium removal was added to several options to improve overall scoring relative to ease of waste incidental to reprocessing (WIR) determinations and obtaining regulator acceptance of the waste form. The evaluators agreed that adequate proven technology exists for this separation. DOE's ability to make WIR determinations pursuant to DOE O 435.1 is currently in litigation. Ecology expects the WIR process to continue to get great scrutiny by the State and the public. DOE remains accountable for obtaining WIR determinations.

- Although adaptability to skid mounting is a feature that often facilitates cost-effective demonstration of a technology, it was recognized that equipment that generates or has the potential to generate hazardous off-gas streams should be enclosed within a facility designed to accommodate the hazard. Thus, the scoring process considered the use of fixed facilities that enclose process equipment where appropriate. One evaluator pointed out that for most options, temperature control and shielding would require containment of the equipment in a facility but that constructing "skid-mounted" equipment offsite could still lead to some cost savings.

- Two of the project utility evaluation criteria were deleted from the scoring process because they were considered non-discriminators: "Percent of Waste Applicable To," and "Compatibility with RPP Integrated Flow Sheet." Other criteria were clarified before scoring the options. For example, all compliance and safety criteria were noted to imply that any deployment would be safe and compliant but that different options would be more or less challenging to implement in a safe and compliant manner.

Table 3-1. Evaluation Criteria.

Compliance and safety	Project utility	Operability	Technical Risk	Programmatic Risk
Operational Safety – What are the operational safety impacts of the flow sheet or key process, including ALARA considerations?	**Percent of Waste Applicable To** – What percentage of the 68 targeted SSTs is the flow sheet applicable to? Are the flow sheets or key processes potentially applicable to other tank wastes?	**Ease of Operations and Process Control** – Does the flow sheet or key process create difficult operational or operations control situations including liquid, gas, and solid effluent or waste handling?	**Flow sheet Operations Maturity** – Is the flow sheet or key process based upon mature technologies, equipment, and process control approaches?	**Pathway to Deployment** – Are there any elements in the pathway to full-scale deployment that present unusual challenges or risks that will require special attention or that may not be manageable?
Regulatory Permitting – Would the flow sheet or key process create unusually difficult regulatory permitting issues due to such factors as high temperatures, difficult off-gas treatment requirements, or other flow sheet specific issues?	**Relative Effect on Waste Volume Disposed of Onsite Including Secondary Wastes** – Will the flow sheet or key process significantly increase or decrease the volume of LAW and secondary waste disposed of onsite?	**Process Stability** – Are any flow sheet elements unstable? Can process control be maintained if any flow sheet process fails? Can the flow sheet accommodate likely variations in waste feed and ambient environment conditions?	**Susceptibility to Chemistry Risks** – Is the flow sheet or key process susceptible to failure due to low concentrations or buildup of chemicals that may be present in the waste feed?	**Vendor Reliance** – Is the successful deployment of the flow sheet overly reliant on a single vendor? If so, does the vendor have a long and stable business performance history?
Waste Incidental to Reprocessing-Related – How difficult will it be to meet the waste incidental to reprocessing requirements?	**Relative Impact on Mission Completion Date** – Can the flow sheet or key process reduce the time required for mission completion?	**Ease and Frequency of Maintenance** – Does the flow sheet or key process require frequent maintenance or will anticipated maintenance require unusually lengthy shutdowns?	**Deployment History in Other Venues** – Have key flow sheet processes and control approaches been successfully deployed on a commercial scale for other wastes or chemicals that are translatable to the tank wastes?	**Equipment and Parts Availability** – Is the flow sheet dependent on special order equipment or parts such that their availability for testing, initial operations, or continued deployment would create unusually high risks?
Land Disposal Restrictions – Is the waste form likely to meet land disposal restrictions?	**Compatibility with RPP Integrated Flow Sheet and Operations** – Will the flow sheet or key process create any significant compatibility issues with the overall tank farm–WTP flow sheet? Is the flow sheet or key process compatible with potential technetium removal requirements?	**Number and Complexity of Unit Operations** – How many unit operations are there?	**Susceptibility to Scale-up Issues** – Is the flow sheet or key process likely to encounter significant scale-up issues that could impair performance at the 5 to 10 gal/min treatment rates anticipated?	**Relative Cost Impact** – Is the flow sheet or key process likely to create significant cost issues or benefits?
Waste Form Performance, Technetium – What is the relative effectiveness of immobilizing technetium?		**Relative Likelihood of Meeting RPP Treatment Needs** – What are the RPP treatment needs? How difficult will it be to pass an operational readiness review? What is the ease of mobility?		
Waste Form Performance, Nitrate – What is the relative effectiveness of immobilizing nitrate?				

ALARA = as low as reasonably achievable. LAW = low -activity waste. RPP = River Protection Project. SST = single-shell tank. WTP = Waste Treatment Plant.

Table 3-2. Detailed Scores.

	1 Bulk Vit[1]	2 Active Metal Reductn [1,2]	3 Steam Reform[1,2]	4A Clean salt ceramic grout, no cesium removal	4B Clean salt ceramic grout without cesium removal	5A Clean salt sulfate removal, no cesium removal	5B Clean salt sulfate removal with cesium removal	6 Grout[2]	7 Sulfate removal[3]
Compliance and Safety									
Op safety	2	2	2	2	3	2	3	4	4
Reg permit	2[4]	3[4]	2	3	3	3	3	3	4
WIR	2.5	2	3.5	4	4	4	4	3[5]	4
LDR	4	3[5]	3	2	2	2	2	1.5[6]	3
Tc	4	3	3	3	3	3	3	2	3
Nitrate	4	4	4[7]	1	1	1	1	1	4
Project Utility									
Percent waste app	4	4	4	4	4	4	4	4	4
Waste vol disp onsite	3	2	2	3	3	3	3	1	3
Date mission completion	3	3	3	2	2	4	4	4	3
RPP integrated flow sheet compatibility	3	3	3	3	3	3	3	3	3
Operability									
Ease ops and process cont	2	1[8]	25	2	3	1	2	4[9]	3.5
Process stability	3	2	3	2	2	2	2	4[9]	4
Ease maintenance	2	2	2	2	3	1	2	3	4
Number, complexity unit ops	2	1.5	2	2	2	1	1	4	4
RPP treatmt needs	1[10]	1[10]	1[10]	2	2	3	3	3	3
Technical Risk									
Maturity	4	1	3.5	2	2	2	2	4	4
Chem risk	3	2	2	2	2	2	2	4	4
Deployment history	3	1	3	1	1	1	1	4	3
Scale-up	4	3	4[11]	2	2	2	2	4	4
Programmatic Risk									
Path to deployment	2[12]	1[13]	2[11,14]	1	1	1	1	1	3
Vendor rely	2	3	3	3	3	3	3	4	4
Equip avail	3[15]	3	3	3	3	3	3	4	4
Cost impact	2	2	Not rated[16]	1	1	2	2	3	2[17]

[1]Skid-mounted systems are problematic. Scores assume location inside a facility.
[2]This option is not likely to work unless technetium removal occurs before treatment; ratings assume this removal.
[3]This is a WTP enhancement. It will be more cost-effective if applied to DSTs.
[4]Process unit must be housed in a facility, otherwise score drops to 1.
[5]Regulators preferred a lower score than other technical evaluators.
[6]Low because of nitrate issues.
[7]Likely to be required in monolithic form to perform well.
[8]Disagreement among evaluators on ease or difficulty -- many evaluators preferred higher score.
[9]One of the easiest operationally.
[10]Based on mobility criterion only.
[11]Rated on basis of 5-10 gal/min, which requires a 4-ft-diameter reformer similar to that currently operated by Studsvik. Team had reservations about the 9-ft-diameter unit proposed for the WTP due to insufficient information.
[12]DOE administrative policy regarding alternatives to vitrification may exclude this option.
[13]May be promising technology in the long term, but schedule precludes consideration here.
[14]Voting assumed small-scale process unit.
[15]May be patent or royalty issues associated with this option.
[16]Appears to save approximately 19 operating years, but detailed demonstration cost data not were available to make a comparison.
[17]Score if only the 68 tanks are considered.

A3.2 OPTION 1: BULK VITRIFICATION

This option was deemed not viable on a skid-mounted basis due to difficulties in ensuring adequate containment of off-gases even for a limited demonstration rate (5 gal/min basis). Although there is significant vendor experience with skid-mounted treatment of low dose rate wastes, regulator representatives stated that given the very high operating temperature (1,600 °C, which is higher than WTP melters), maximum achievable control technology (e.g., double containment, automatic feed cutoff) will be required, and permitting would only be possible inside a building. Therefore, this option was assumed to be inside a facility.

A3.2.1 Compliance and Safety

The high temperature and possible off-gas system issues drove relatively low scores on operational safety and regulatory permitting despite the relatively low number of unit operations.

The ability to obtain a WIR determination was rated low because the amount of radionuclide separation achieved by this option is lower than that achieved by the WTP; except for cesium separation, the only radionuclide separation performed is by selective dissolution. This is a concern even though the targeted tanks have significantly lower radionuclide contents than DST waste.

The waste form (aluminosilicate glass) may perform better than the WTP ILAW glass (borosilicate) with regards to land disposal restrictions (LDRs) and leachability, especially for technetium, although no Hanford Site waste-specific data are available and a specific waste form qualification process will have to be initiated.

Additionally, this process destroys the nitrates, which eliminates a concern regarding disposal performance assessment of ability to meet drinking water standards.

A3.2.2 Project Utility

Bulk vitrification potentially reduces the WTP LAW treatment duration by as much as any other option (including active metal reduction, steam reforming, and grout), does not send any waste streams back to the DST system and WTP, and should produce a slightly lower ILAW volume than the WTP because high sulfate waste can be accommodated. These factors resulted in high scores on project utility.

A3.2.3 Operability

The concerns mentioned above on temperature and incompatibility with a mobile system resulted in some lower scores in operability. A minority of the reviewers did not agree with these concerns and emphasized the extensive operational experience available. Another concern noted

was the use of consumable graphite electrodes in a strongly oxidizing environment (WTP uses Inconel[7]).

The option received a low score on adequacy of meeting RPP treatment needs based on its assumed inability to be skid-mounted while ensuring adequate off-gas containment.

A3.2.4 Technical Risk

Based on the significant vendor experience available, no significant technical risk was identified.

A3.2.5 Programmatic Risk

Since this option uses a vitrification process, evaluators expressed the concern that it may not be viewed as a true supplemental alternative to WTP. Additionally, some concerns were expressed regarding potential patent and royalty issues, which lead to a reduced score on equipment availability. Finally, the implementation cost was deemed significant despite the positive effect on WTP LAW processing duration. These resulted in relatively low scores in this area.

A3.3 OPTION 2: ACTIVE METAL REDUCTION

This option was deemed not viable on a skid-mounted basis even for a limited processing rate (5 gal/min basis). The process temperature is moderately low (50 °C to 120 °C), but some off-gas compounds (H_2, H_2S, NH_3) include substances that are toxic or could be explosive if process parameters were to deviate significantly from normal. As a result, regulator representatives felt that permitting would be possible only inside a facility. Therefore, for the evaluation, this option was assumed to be inside a facility.

The option was not deemed viable without a technetium separation step upstream. As in bulk vitrification, the only technetium separation from the stream to be immobilized would be at the selective dissolution step. The leachability performance of the waste form (aluminosilicate crystalline form) is unknown but is not expected to be as good as that of glass. Therefore, this option was assumed to include technetium separation upstream.

A3.3.1 Compliance and Safety

The safety concerns regarding toxic and potentially explosive off-gas compounds have been accommodated in highly radioactive environments in the past, as in the case of fuel aluminum cladding dissolution operations. However, they remain significant issues, as they will require narrow control of process parameters; therefore they lead to a relatively low score in operational safety.

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[7] Inconel is a trademark of Inco Alloys International, Inc.

The ability to obtain a WIR determination was rated low for the same reasons as bulk vitrification with less performance expected from the waste form and even though this evaluation assumed a technetium removal step.

Ease of compliance with LDRs was a greater concern to the regulator representatives than to the rest of the evaluators, based on the uncertainties with the waste form performance. The majority scoring did not completely reflect these concerns. Based on the assumed technetium separation step and on the denitration performed by this process, this option rated relatively high on disposal performance assessment regarding technetium and nitrates.

A3.3.2 Project Utility

Active metal reduction, like bulk vitrification, potentially reduces the WTP LAW treatment duration by as much as any other option, which resulted in a high score on mission duration impact.

The estimated waste form volumes provided to the evaluators were based on conservative assumptions and resulted in a significant increase in the total ILAW volume over the WTP-only calculation. An optimized process and waste form (aluminosilicate versus phosphate ceramic) should reduce this volume, but uncertainties are high enough that the score was relatively low on waste volume impact.

A3.3.3 Operability

In general, the option scored very low on operability criteria due mainly to the generation of toxic substances (H_2S, NH_3) and potentially explosive off-gases (H_2, NH_3) and therefore the expected complexity of an off-gas system. Also of concern was the fact that H_2S, even though it could potentially be avoided by close control of the process parameters, could be a poison in catalyzed off-gas treatment reactions. Another concern was the risk of solids accumulation and plugging because the solids generated are essentially insoluble. However, a significant fraction of the evaluators did not agree with the importance given to these concerns.

The option received a low score on adequacy to meet RPP treatment needs based on its assumed inability to be skid-mounted.

A3.3.4 Technical Risk

All evaluators agreed that this is the least mature option, which, when combined with the safety concerns mentioned above, resulted in low scores for most technical risk criteria. The exception to the low scores was for scale-up ability, which was viewed as not very difficult for a 5 gal/min based treatment.

A3.3.5 Programmatic Risk

The path to deployment was scored very low mainly due to the immaturity of the technology. It was noted that the option appears to have promise although further development may expose challenging problems.

The implementation cost of an active metal reduction demonstration was deemed significant despite the potential reduction of WTP LAW processing duration.

A3.4 OPTION 3: STEAM REFORMING

The evaluators noted that the evaluation of this option was based on a level of information inconsistent with the other options because of the limited data provided by the vendor's presentation.

This option was deemed not viable on a skid-mounted basis, even for a limited inventory (5 gal/min basis). The process temperature is relatively high (735 °C), and the fluidized bed contains a potentially explosive mixture should the steam inflow fail, which requires the vessels to be designed to resist an explosion even though the process is run under slight vacuum. As a result, regulator representatives felt that permitting would only be possible inside a facility. Therefore, this option was assumed to be inside a facility.

The option was deemed not viable without a technetium separation step upstream. As in bulk vitrification, the only technetium separation from the stream to be immobilized would be at the selective dissolution step, but unlike bulk vitrification, the leachability performance of the waste form (aluminosilicate crystalline form) is mostly unknown and is not expected to be as good as that of glass. Therefore, this option was assumed to include technetium separation upstream.

Since this option is being proposed by the WTP contractor as a potential addition to the WTP, it was assumed to be implemented downstream of WTP pretreatment. This technology has the potential to be applied elsewhere in the RPP.

A3.4.1 Compliance and Safety

The safety concerns mentioned above with the relatively high temperature and potentially explosive mixture, combined with the fact that the facility will have to include oxygen and steam generation plants and that large quantities of carbon or other reducing agent need to be fed to the bed in order to react with the oxygen for heat generation, led to a relatively low score on operational safety and permitting.

The ability to obtain a WIR determination was rated high based on the assumption that this option would be implemented downstream from the WTP pretreatment.

Ease of compliance with LDR and disposal performance assessment for technetium and nitrate was deemed to be similar to that of the active metal reduction option. The vendor presentation claimed that products from treating Hanford Site waste simulants were successfully tested for compliance with LDR, but the information provided suggested that only a limited number of

contaminants of concern were included in the simulant. The evaluators noted that the granular waste product from the steam reforming process might have to be incorporated in a monolithic waste form to comply with applicable policies.

A3.4.2 Project Utility

Steam reforming, like active metal reduction, potentially reduces the WTP LAW treatment duration by as much as any other option, which resulted in a high score on mission duration impact.

The estimated waste form volumes are high due to the low density of the crystalline waste form. Therefore, the score was relatively low on waste volume impact.

A3.4.3 Operability

In general, the option scored relatively low on operability criteria due to the complexity of the reaction phenomena involved and the need to control closely all feed rates and other process parameters in order to avoid problems such as excessive carbon residues and nozzle pluggage. Regulator representatives typically scored this attribute lower than the majority of evaluators.

The option received a low score on adequacy to meet RPP treatment needs based on its assumed inability to be skid-mounted and the fact that it would require significant support facilities for steam and oxygen generation and reactant handling.

A3.4.4 Technical Risk

The maturity and deployment history were scored relatively high based on the Studsvik experience presented. Virtually no scale-up is needed for a 5 gal/min demonstration, but the evaluators expressed reservations for significantly larger scales (such as the 9-ft-diameter, 40-ft-high unit considered by the WTP project). Evaluators pointed out that the Studsvik commercial steam reforming experience with power plant ion exchange resin wastes is not directly relevant to the Hanford Site high sodium salt content waste, which can cause operational problems such as nozzle pluggage and bed agglomeration. On the other hand, steam reforming is somewhat similar to fluidized bed calcination (although operated under reducing conditions, thereby minimizing the production of NOx, which is an advantage), so it will benefit from the extensive worldwide HLW calcination experience, including experience at the Idaho National Engineering and Environmental Laboratory with high sodium wastes.

A3.4.5 Programmatic Risk

The path to deployment was scored relatively low due to the uncertainties on waste form performance and WTP contractual issues. The evaluators noted that this score was based on a 5 gal/min demonstration but that the score would be even lower for a larger scale.

Vendor and equipment reliability were not viewed as significant issues, as several steam reforming vendors are available.

The cost impact was not evaluated due to lack of data comparable to the other options.

A3.5 OPTIONS 4A AND 4B: CLEAN SALT

A3.5.1 Compliance and Safety

The evaluators discussed the use of clean salt as the cesium separation step for dose rate reduction (option 4A), as opposed to including an ion exchange step upstream (option 4B). One evaluator felt that the implementation of clean salt without prior cesium removal, especially skid mounted, would be "anti-ALARA" and recommended the lowest rating possible for option 4A. Others felt that the loaded cesium ion exchangers from the cesium step also would be a significant source term. Based on this discussion, the majority scored option 4A lower than option 4B but not the lowest score possible.

Based on the fact that this evaporation-based process is not considered a high temperature process, these two options were scored relatively high on permitting.

The ability to obtain a WIR determination was rated very high due to the proven selectivity of the sodium nitrate crystallization, which ensures that nearly all of the radionuclides are immobilized in glass in the WTP processes (supplementing 60 tons per day ILAW glass production).

Ease of compliance with LDR was rated relatively low due to uncertainties regarding the ability of the waste form to effectively treat or immobilize constituents such as nitrates. Disposal performance assessment was rated relatively high since technetium is excluded from the sodium nitrate salt but very low for nitrate since nitrate leachability performance for grout waste forms is generally poor.

A3.5.2 Project Utility

Clean salt slightly increases total LAW volume (as the separated sodium nitrate is assumed not to be delisted and, therefore, needs to be disposed of as a mixed waste) and only slightly reduces the WTP LAW treatment duration. Although clean salt removes the bulk of the salt inventory (sodium nitrate) from the stream to be vitrified, sulfates are not separated, and relatively small quantities of sulfates in this stream require the same level of dilution in glass as in the presence of high sodium quantities. These factors resulted in intermediate scores on mission duration and waste volume impact.

A3.5.3 Operability

In general, these two options scored relatively low on operability criteria due to the complexity of the process for a skid-mounted operation and the difficulty of operating at the very low

temperatures required for crystallization. Option 4A, which will be operated at higher dose rates, was scored lower than option 4B.

The two options received relatively low scores on likelihood of meeting RPP needs due to the difficulty in skid-mounting these options and to the relative complexity of the process.

A3.5.4 Technical Risk

Although this technology is commonly used in commercial applications, and on the relative complexity of the process (acidification, evaporation, cooling, washing), evaluators scored these two options relatively low on technical risk criteria based on the limited experience with Hanford Site waste (only laboratory tests).

A3.5.5 Programmatic Risk

The path to deployment was scored very low due to the predicted waste form qualification issues.

Vendor reliance and equipment availability were not found to be issues, but the cost impact was deemed very unfavorable due to high deployment costs for very little acceleration benefit.

A3.6 OPTIONS 5A AND 5B: CLEAN SALT WITH SULFATE REMOVAL

A3.6.1 Compliance and Safety

The dose rate concerns for the option without cesium ion exchange (option 5A) are identical to those for option 4A, resulting in the same low operational safety score. Additionally, the organic waste form used to immobilize the sodium nitrate could be a safety concern.

The same issues on permitting and WIR determination were identified for these options as for options 4A and 4B.

Ease of compliance with LDRs was rated relatively low due to uncertainties regarding the waste form performance; polyethylene is not expected to perform better than ceramic grout and is known to swell over time when used to immobilize hygroscopic salts. As for options 4A and 4B, disposal performance assessment was rated relatively high since technetium is separated but very low for nitrate due to expected poor nitrate leachability results.

A3.6.2 Project Utility

Clean salt with sulfate separation results in a small decrease in total LAW volume (as the separated sodium nitrate is assumed not to be delisted and, therefore, needs to be disposed of as a mixed waste) resulting in an intermediate score on waste volume impact. These options reduce

significantly the WTP LAW treatment duration, which resulted in a very high score on mission duration.

A3.6.3 Operability

In general, options 5A and 5B scored as low or lower than options 4A and 4B on operability criteria. The issues as for options 4A and 4B apply, with the additional concern of a heat-processed waste form (polyethylene) and of an even higher process complexity (more unit operations).

The two options received relatively low scores on likelihood of meeting RPP needs because of the difficulty in skid-mount these options and the relative complexity of the process.

A3.6.4 Technical Risk

The same technical risk issues as for options 4A and 4B apply to these two options.

A3.6.5 Programmatic Risk

The same considerations and scores for options 4A and 4B apply to these two options except for the cost impact, which was scored higher for these two options due to their significantly higher acceleration benefit despite high implementation costs.

A3.7 OPTION 6: CONTAINERIZED GROUT

The option was not deemed viable without a technetium separation step upstream due to the expected high leachability of technetium from grout. As in bulk vitrification, the only technetium separation from the stream to be immobilized would occur during selective dissolution, but in this case, the leachability performance of the waste form is expected to be low. Therefore, this option was changed to include technetium separation downstream of selective dissolution.

A3.7.1 Compliance and Safety

No significant issue was identified regarding operational safety and permitting of this low temperature process with relatively few unit operations.

The ability to obtain a WIR determination received a relatively high score due to the separation of cesium and technetium. The regulator representatives rated this option slightly lower than other evaluators due to the expected continued stakeholders concerns with grout. These concerns include poor durability, high leachability, and increase in waste volume compared to vitrified waste.

Ease of compliance with LDRs was rated very low due to uncertainties regarding the waste form performance, especially in meeting State-only toxicity criteria. Disposal performance assessment was rated slightly higher since technetium is separated but very low for nitrate since nitrate leachability performance for grout waste forms is generally poor.

A3.7.2 Project Utility

Containerized grout, like bulk vitrification, potentially reduces the WTP LAW treatment duration by as much as any other option, which resulted in a very high score on mission duration impact.

The estimated waste form volumes are very high, which resulted in the lowest score possible in waste volume impact.

A3.7.3 Operability

Containerized grout received high scores on all operability criteria because it is a low temperature, well known-process, with a small number of unit operations.

A3.7.4 Technical Risk

Technical risk scores were also high for the same reasons as in operability and because extensive experience with LLW grouting exists worldwide.

A3.7.5 Programmatic Risk

The path to deployment was scored very low due to stakeholder concerns and waste form performance uncertainties.

This well-proven technology received high scores on all other programmatic risk criteria with one caveat on cost impact; the evaluation did not take into consideration the immobilized waste disposal cost, which could be more significant for this options than for others due to the high waste volume.

A3.8 OPTION 7: SULFATE REMOVAL

A3.8.1 Compliance and Safety

No significant issue was identified regarding operational safety, permitting, and WIR determination for this low temperature, simple process.

Ease of compliance with LDR was rated relatively high, as were performance assessments for technetium and nitrates (not precipitated with sulfate to be grouted).

A3.8.2 Project Utility

Sulfate separation slightly reduces the total ILAW volume and reduces significantly the mission duration, which resulted in relatively high ratings on waste volume and mission duration impacts.

A3.8.3 Operability

This simple process scored high on all operability criteria. No issue was identified; the sulfate precipitate is not expected to be gelatinous or difficult to handle as it is formed under acidic conditions.

A3.8.4 Technical Risk

High to very high scores were given for technical risk criteria. This process is very similar to the strontium recovery operations conducted in the past at B Plant where strontium sulfate precipitation was performed under acidic conditions. The added tank waste volume caused by the need to reneutralize the acidified sulfate-depleted solution prior to storage in the DST system is estimated to be 30 percent of the initial waste volume.

A3.8.5 Programmatic Risk

This option rated high to very high on programmatic criteria, except for cost impact, since the acceleration benefit is limited and the implementation cost is significant (although among the lowest). A much higher acceleration benefit could be obtained if the option were applied not only to SST salt waste but also to high sulfate DSTs. Overall, this option is viewed as best suited within the WTP flow sheet where the sulfate-depleted acidified waste stream could be sent to the melter without neutralizing the waste.

A4.0 CONCLUSIONS AND RECOMMENDATION

Based on the evaluation of the nine separate flow sheets, four are recommended for additional study based on consideration of the scores shown in Table 3-2. Ranking of the options was done by totaling the raw scores. The four options according to rank (highest to lowest) that are recommended for further study are the following:

- Sulfate removal (sulfate separation)
- Containerized grout
- Bulk vitrification
- Steam reforming.

The objective of the evaluators was to assess potential technology options to determine those that warranted further investigation. Further study will be aligned with the needs of each specific option. Both radioactive and non-radioactive tests will be designed for the processes and equipment as required.

These selected options represent a range of trade-offs between process difficulty and performance, ease of achieving regulatory compliance, and benefit to the RPP in accelerating the mission. For example, the sulfate removal option is considered a comparatively simple process with less complicated regulatory issues, but the acceleration benefit of removing and disposing of sulfate alone is less than the benefit provided by other options with more challenges that do not send any fraction of the treated stream to the WTP.

The grout option also is comparatively simple but has the most difficult regulatory issues, particularly disposal issues for nitrates and technetium. Primary advantages of this option are its ability to accelerate the mission by disposing of a LAW fraction including the bulk salts and the comparatively simple and well-proven status of the technology. However, the disposal cost for the large immobilized waste volume generated is likely to offset some of these benefits.

Steam reforming represents a different set of tradeoffs. The process is more complex than the other options and has more complex off-gas permitting issues since it is considered a thermal treatment process. Two key advantages are that the steam reforming process denitrates the waste and accommodates high sulfate waste. Technetium removal requirements may be less stringent with this waste form than for grout. Some of the evaluators were uncomfortable with the lack of data regarding steam reforming.

Bulk vitrification represents yet a different mix of trade-offs. It is a relatively mature process that will denitrate the waste, will provide a comparatively robust waste form, and is capable of accelerating the mission by treating bulk LAW waste salts and sulfate. However, as within the WTP, the off-gas treatment will be technically challenging and will have complex permitting issues.

This recommendation is made recognizing open issues associated with waste acceptance criteria and disposal cost.

Additionally, active metal reduction is recommended for further evaluation by DOE Office of Science and Technology because it is a low temperature process that destroys nitrates and would likely produce a waste form that is superior to grout.

All options involving clean salt are recommended for removal from further consideration as they involve significant deployment challenges for very little acceleration benefit.

Nuclear safety and regulatory requirements may require most or all processing equipment to be placed inside suitable facilities.

Regulator participation in the workshops and in the development of this report was useful and appreciated. However, the participation is not construed as an endorsement by Ecology of any supplemental waste treatment options other than vitrification as identified in the Tri-Party Agreement, TPA M-62-00, for the treatment of the tank waste.

A5.0 REFERENCES

DOE M 435.1-1, 2001, *Radioactive Waste Management Manual*, Change 1, U.S. Department of Energy, Washington, D.C.

DOE O 435.1, 2001, *Radioactive Waste Management*, Change 1, U.S. Department of Energy, Washington, D.C.

DOE/EIS-0189, 1996, *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement*, Washington State Department of Ecology, Olympia, Washington, and U.S. Department of Energy, Washington, D.C.

RCRA, *Resource Conservation and Recovery Act of 1976,* Pub. L. 94-580, 90 Stat. 2795, 42 USC 6901 et seq.

RPP-11131, 2002, *Mission Acceleration Initiative Demonstration Information Package*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-11305, 2002, *Three-Day Workshop to Evaluate Alternative Treatment Options for Hanford Site Tank Waste Meeting Minutes*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

Tri-Party Agreement, 1989, *Hanford Federal Facility Agreement and Consent Order*, Washington State Department of Ecology, Olympia, Washington; U.S. Environmental Protection Agency, Washington, D.C.; and U.S. Department of Energy, Washington, D.C.

WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, as amended.

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ATTACHMENT A1

PROCESS USED TO IDENTIFY TREATMENT OPTIONS EVALUATED AT THE WORKSHOP

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ATTACHMENT A1

PROCESS USED TO IDENTIFY TREATMENT OPTIONS EVALUATED AT THE WORKSHOP

Technologies for treating the Hanford Site tank wastes, including the salt fraction, have been researched and evaluated for a number of years. A systematic review of all possible technologies was conducted in the early 1990's and resulted in the issuance of DOE/EIS-0189, *Tank Waste Remediation System Hanford Site, Richland, Washington, Final Environmental Impact Statement*, and subsequent Record of Decision (62 FR 8693). These studies were reviewed in January and February of 2002, and vendors, national laboratories, and universities were consulted for additional technologies, as time allowed, in order to establish a list of all possible technologies for treating the low-activity waste.

During the month of March 2002, the technologies were grouped into families that employed the same basic principles but differed only in their implementation (e.g., all calcination technologies were grouped together, all polymer-based microencapsulations were grouped together). Single-shell tank 241-S-112 was selected as a good representative for the targeted low-activity waste source single-shell tanks. Technology experts were asked to prepare short briefings on their technologies and how they could be applied to tank 241-S-112-type waste with the objective of a tank-scale demonstration with real waste between 2005 and 2006. Additionally, separation technologies were combined with immobilization technologies to constitute complete treatment options.

This relatively high-level information was presented to a group of 35 technical and programmatic experts from the DOE complex during a two-day workshop on April 2 and 3, 2002. The group discussed the feasibility of the proposed treatment options and added a few options, leading to a total of 25 options to be considered. They used the nominal group rating technique to screen out treatment options or technologies that were unlikely to provide adequate treatment or to be deployable in the desired time frame.

The results of the April 2 and 3 workshop are documented as an appendix in RPP-11131, *Mission Acceleration Initiative Demonstration Information Package*. They were reviewed by Office of River Protection representatives, who selected six treatment options for a more detailed evaluation, with the purpose of submitting these for evaluation by the Cleanup Constraints and Challenges Mission Acceleration Initiative Subgroup by the end of May 2002. The options selected were either those with the highest scores in the workshop or options built around technologies that had received the highest scores when scores from all options, including the particular technology, were added. Two technologies were included in selected options despite relatively low scores: active metal reduction and micro-encapsulation with polymers because there was a concern that they may have been scored low because most workshop participants were very unfamiliar with them.

During April and early May 2002, mass balances and other technical and programmatic data were developed for the six selected treatment options and two variants. A seventh option — sulfate separation by strontium precipitation in acidic conditions —was added during that period. Sulfate separation had not been considered during the previous months, mainly because a relevant production reference had not been identified.

REFERENCES

RPP-11131, 2002, *Mission Acceleration Initiative Demonstration Information Package*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

APPENDIX B

THREE-DAY WORKSHOP TO EVALUATE ALTERNATIVE TREATMENT OPTIONS FOR HANFORD SITE TANK WASTE MEETING MINUTES

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APPENDIX B

THREE-DAY WORKSHOP TO EVALUATE ALTERNATIVE TREATMENT OPTIONS FOR HANFORD SITE TANK WASTE MEETING MINUTES

B1.0 SUMMARY

A panel of 14 experts convened to evaluate nine proposed alternative treatment options for Hanford Site tank waste. The evaluators heard presentations on each of the options under consideration (viewgraphs may be found in Attachment B4), determined suitable criteria for judging the options (Attachment B2), and scored the options according to the criteria. The results of the evaluation process may be found in Attachment B3.

Workshop Dates: May 21-23, 2002

Panel of Evaluators:

Jimmy Bell, Independent Consultant
Robbie Biyani, Washington State Department of Ecology
Joel Case, DOE – Idaho (attended and voted days 1, 2 only)
Suzanne Dahl, Washington State Department of Ecology
Bill Hewitt, YAHSGS LLC
Bill Holtzscheiter, Westinghouse Savannah River Co./Savannah River Testing Co.
Kenneth Lang, DOE Headquarters, EM-42
Vince Maio, Mixed Waste/INEEL (voted day 3 only)
Billie Mauss, DOE Office of River Protection
Richard Raymond, CH2MHill Hanford Group
Roger Stanley, Washington State Department of Ecology
Russ Treat, Dade, Moeller & Associates
Nancy Uziemblo, Washington State Department of Ecology
Don Wodrich, Independent Consultant (voted day 3 only)

Other Attendees:
See Attachment B1

B2.0 DISCUSSION

The following is a summary of the May 21–23 meeting of the Cleanup Constraints and Challenges Team (C3T) Mission Acceleration Initiative Subgroup.

- Bill Hewitt presented a conceptual overview of the supplemental technology approach showing the gap between low-activity waste treatment capacity and Tri–Party Agreement milestones. He also discussed the modular concept behind the supplemental technologies.

- Kayle Boomer, CHG, presented the Hanford Site tank waste treatment background. The largest gap between treatment capacity and tank inventory is the soluble salts in single-shell tanks.

- Roger Stanley presented regulatory and compliance considerations. Roger emphasized a need to keep in mind tank retrieval and closure, DOE O 435.1, *Radioactive Waste Management*, waste incidental to reprocessing determination, and overlay of *Resource Conservation and Recovery Act of 1976* closure when considering the treatment alternatives.

- Janet Badden, CHG, presented onsite disposal protocols. She covered waste pathways and Hanford Site facilities for disposal of various types of waste.

- Ken Gasper, CHG, presented selective dissolution, solids–liquids separations, and cesium ion exchange. These technologies are a necessary pretreatment step before applying the other treatment options.

- George Reddick, CHG, presented the flow sheet for bulk (ex situ) vitrification. In this technology, 5M sodium feed is mixed with silicates, dried, and heated to 1,600 °C.

- Richard Brouns, PNNL, presented the flowsheet for active metal reduction. In this technology, aluminum metal is added to the waste, which is denitrated and converted into either aluminosilicate or aluminophosphate waste forms.

- Michael Johnson, CHG, presented the four clean salt options as follows:

  - Acidify 5M sodium feed, evaporating the acidified waste, cooling the slurry to crystallize sodium nitrate and aluminum phosphate; mix with MgO and KH_2PO_4 forming Ceramicrete

  - Same as above, except add a cesium removal step

  - Similar to above, except add excess strontium nitrate to precipitate strontium sulfate, strontium chromate, and some aluminum phosphate (metals become

chemically bound, and clean salt is solidified in polyethylene to encapsulate sodium nitrate)

- Use strontium precipitation process and add cesium removal step.

- Michael Johnson, CHG, presented the flow sheet for sulfate removal. In this process, 5M sodium from the cesium ion exchange is adjusted with HNO_3 to pH 1.0, heated to 60 °C, and subjected strontium nitrate precipitation. Metals are chemically bound. Waste form is incorporated into grout.

- Jeff Voogd presented the flowsheet for containerized grout. In this process, 5M sodium feed is mixed with Portland cement after selective dissolution, solids–liquids separation and cesium ion exchange. Metals are chemically bound; the challenge is to bind alkali metals and nitrates.

- Duane Smoker, Washington Group, and Brad Mason, Studsvik, presented steam reforming. In this technology, waste feed plus additives and steam at 600 °C are processed in a pressure vessel. This technology is based on a fluidized bed process. It eliminates nitrates and destroys organics.

- The panel decided on judging criteria (Attachment B2) and scored the technologies according to the criteria (Attachment B3).

- A report of the panel's findings, including recommendations, will be prepared by the C3T Balance of Mission Team in early June 2002.

- Some evaluators provided additional written comments after the meeting; these can be found in Attachment B5.

B3.0 ACTION ITEMS

Action Items:

- **Due 5/23/02**: Jimmy Bell is to write dissenting remarks on operational safety of clean salt processes without cesium removal. These remarks are to be included in write-up (completed 5/23/02).

- **Due 5/24/02**: Nancy Welliver is to issue draft minutes (completed 5/24/02).

- **Due 5/28/02**: Anne-Marie Choho is to summarize issues for the five broad criteria for judging technologies (compliance and safety; project utility; operability; technical risk; and programmatic risk.) She is to e-mail the summary to reviewers Billie Mauss, Russ Treat, Nancy Uziemblo, Phil Gauglitz, and Bill Hewitt.

- **Due 5/28/02**: Individual members of the Alternative Treatment Workshop panel are to e-mail additional comments, if any, to Anne-Marie Choho.

- **Due 5/29/02**: Reviewers (Mauss, Treat, Uziemblo, Gauglitz, Hewitt) are to meet to verify and consolidate comments and summary. Billie Mauss to organize the meeting.

- **Due 5/30/02**: C3T team is to meet and discuss the write-up and the path forward to meeting commitment to deliver the write-up. Meeting set for 10:00 a.m. to 12:00 noon, Thursday, May 30. Bill Hewitt is to send out meeting notices.

Attachments:

1 – List of attendees
2 – Condensed evaluation factors for possible River Protection Project technologies
3 – Evaluation results for possible River Protection Project technologies
4 – Presentation viewgraphs
5 – Evaluators post meeting comments.

Prepared by Nancy Welliver, DMJMH+N, 5/24/02

ATTACHMENT B1

LIST OF ATTENDEES AT THE MAY 21-23, 2002, CLEANUP CONSTRAINTS AND CHALLENGES TEAM MISSION ACCELERATION INITIATIVE SUBGROUP SUPPLEMENTAL TECHNOLOGIES WORKSHOP

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ATTACHMENT B1

LIST OF ATTENDEES AT THE MAY 21-23, 2002, CLEANUP CONSTRAINTS AND CHALLENGES TEAM MISSION ACCELERATION INITIATIVE SUBGROUP SUPPLEMENTAL TECHNOLOGIES WORKSHOP.

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ATTACHMENT B2

CONDENSED EVALUATION FACTORS FOR POSSIBLE RIVER PROTECTION PROJECT TECHNOLOGIES

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ATTACHMENT B2

CONDENSED EVALUATION FACTORS FOR POSSIBLE RIVER PROTECTION PROTECT TECHNOLOGIES

Compliance and Safety	Project Utility	Operability	Technical Risk	Programmatic Risk
Operational Safety – What are the operational safety impacts of the flow sheet or key process, including ALARA considerations?	**Percent of Waste Applicable To** – What percentage of the 68 targeted SSTs does the flow sheet apply to? Are the flow sheets and key processes potentially applicable to other tank wastes?	**Ease of Operations and Process Control** – Does the flow sheet or key process create difficult operational or operations control situations including liquid, gas, and solid effluent or waste handling?	**Flowsheet Operations Maturity** – Is the flow sheet or key process based upon mature technologies, equipment, and process control approaches?	**Pathway to Deployment** – Are there any elements in the pathway to full-scale deployment that present unusual challenges or risks that will require special attention or that may not be manageable?
Regulatory Permitting – Would the flow sheet or key process create unusually difficult regulatory permitting issues due to such factors as high temperatures, difficult off-gas treatment requirements, or other flow sheet-specific issues?	**Relative Effect on Waste Volume Disposed of Onsite Including Secondary Wastes** – Will the flow sheet or key process significantly increase or decrease the volume of LAW and secondary waste disposed of onsite?	**Process Stability** – Are any flow sheet elements unstable? Can process control be maintained if any flow sheet process fails? Can the flow sheet accommodate likely variations in waste feed and ambient environmental conditions?	**Susceptibility to Chemistry Risks** – Is the flow sheet or key process susceptible to failure due to low concentrations or buildup of chemicals that may be present in the waste feed?	**Vendor Reliance** – Is the successful deployment of the flow sheet overly reliant on a single vendor? If so, does the vendor have a long and stable business performance history?
Waste Incidental to Reprocessing Related – How difficult will it be to meet the requirements for waste incidental to reprocessing?	**Relative Impact on Mission Completion Date** – Can the flow sheet or key process reduce the time required for mission completion?	**Ease and Frequency of Maintenance** – Does the flow sheet or key process require frequent maintenance or will anticipated maintenance require unusually lengthy shutdowns?	**Deployment History in Other Venues** – Have key flow sheet processes and control approaches been successfully deployed on a commercial scale for other wastes or chemicals that are translatable to the tank wastes?	**Equipment and Parts Availability** – Is the flow sheet dependent on special order equipment or parts such that their availability for testing, initial operations, or continued deployment would create unusually high risks?
Land Disposal Restrictions – Is the waste form likely to meet land disposal restrictions?	**Compatibility with RPP Integrated Flow Sheet and Operations** – Will the flow sheet or key process create any significant compatibility issues with the overall tank farm–WTP flow sheet? Is the flow sheet or key process compatible with potential technetium removal requirements?	**Number and Complexity of Unit Operations** – How many unit operations are there?	**Susceptibility to Scale-up Issues** – Is the flow sheet or key process likely to encounter significant scale-up issues that could impair performance at the 5-10 gal/min treatment rates anticipated?	**Relative Cost Impact** – Is the flow sheet or key process likely to create significant cost issues or benefits?
Waste Form Performance, Technetium – What is the relative effectiveness of immobilizing technetium?		**Relative Likelihood of Meeting RPP Treatment Needs** – What are the RPP treatment needs? How difficult will it be to pass an operational readiness review? What is the ease of mobility?		
Waste Form Performance, Nitrate – What is the relative effectiveness of immobilizing nitrate?				

ALARA = as low as reasonably achievable.
LAW = low-activity waste.
RPP = River Protection Project.

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ATTACHMENT B3

EVALUATION RESULTS FOR POSSIBLE RIVER PROTECTION PROJECT TECHNOLOGIES

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ATTACHMENT B3

EVALUATION RESULTS FOR POSSIBLE RIVER PROTECTION PROJECT TECHNOLOGIES

	1 Bulk Vit[1]	2 Metal Reductn[1,2]	3 Steam Reform[1,2]	4a Clean Salt Ceramic Grout no Cs removal	4b Clean Salt Ceramic Grout w/Cs removal	5a Clean Salt sulfate removal no Cs removal	5b Clean Salt sulfate removal w/Cs removal	6 Grout[2]	7 Sulfate Removal[3]
Compliance and Safety									
Op Safety	2	2	2	2	3	2	3	4	4
Reg Permit	2[4]	3[4]	2	3	3	3	3	3	4
WIR	2.5	2	3.5	4	4	4	4	3[5]	4
LDR	4	3[5]	3	2	2	2	2	1.5[6]	3
Tc	4	3	3	3	3	3	3	2	3
Nitrate	4	4	4[7]	1	1	1	1	1	4
Project Utility									
% waste app	4	4	4	4	4	4	4	4	4
Waste vol disp on-site	3	2	2	3	3	3	3	1	3
Date misson completion	3	3	3	2	2	4	4	4	3
RPP integrat flowsheet compatibilty	3	3	3	3	3	3	3	3	3
Operability									
Ease ops & process cont	2	1[8]	2[5]	2	3	1	2	4[9]	3.5
Process Stability	3	2	3	2	2	2	2	4[9]	4
Ease Maint	2	2	2	2	3	1	2	3	4
#, complex unit ops	2	1.5	2	2	2	1	1	4	4

[1] Skid-mounted systems are problematic. Scores assume location inside a facility.
[2] This option not likely to work unless technetium removal occurs before treatment; ratings assume this removal.
[3] This is a Waste Treatment Plant enhancement. It will be more cost-effective if applied to double-shell tanks.
[4] Process unit must be housed in a facility, otherwise score drops to 1.
[5] Regulators preferred a lower score than other technical evaluators.
[6] Low because of nitrate issues.
[7] Likely to be required in monolithic form to perform well.
[8] Disagreement among evaluators on ease/difficulty – many evaluators preferred higher score.
[9] One of the easiest operationally.

	1 Bulk Vit[1]	2 Metal Reductn [1,2]	3 Steam Reform[1,2]	4a Clean Salt Ceramic Grout no Cs removal	4b Clean Salt Ceramic Grout w/Cs removal	5a Clean Salt sulfate removal no Cs removal	5b Clean Salt sulfate removal w/Cs removal	6 Grout[2]	7 Sulfate Removal[3]
RPP treatmt needs	1[10]	1[10]	1[10]	2	2	3	3	3	3
Technical Risk									
Maturity	4	1	3.5	2	2	2	2	4	4
Chem risk	3	2	2	2	2	2	2	4	4
Deployment history	3	1	3	1	1	1	1	4	3
Scale up	4	3	4[11]	2	2	2	2	4	4
Programmatic Risk									
Path to deployment	2[12]	1[13]	2[11,14]	1	1	1	1	1	3
Vendor rely	2	3	3	3	3	3	3	4	4
Equip avail	3[15]	3	3	3	3	3	3	4	4
Cost impact	2	2	Not rated[16]	1	1	2	2	3	2[17]

GENERAL COMMENTS

- Voting was done informally by having voters call out their scores. The scores were tallied. If there was good agreement on a score (fewer than four dissenters), that score was used. If the voters were evenly divided between scores, a score halfway between the two was assigned. If the regulators voted differently than other technical evaluators, this was noted in the table.
- Disposal costs were not included in the evaluations but could be a driver.
- One must assume that the cesium ion exchange step works for all of these technologies. This step was not scored separately.

[10] Based on mobility criterion only.
[11] Rated on basis of 5-10 gal/min. Team had reservations with Waste Treatment Plant requirement of diameter vessel due to insufficient information.
[12] DOE administrative policy may exclude this option.
[13] Promising technology for long term, but schedule precludes consideration here.
[14] Voting assumed small-scale process unit.
[15] There may be patent or royalty issues associated with this option.
[16] Appears to save approximately 19 operating years, but detailed cost data are not available.
[17] Score if only the 68 single-shell tanks are considered

- The sulfate removal process should not be considered a complete processing alternative. Rather, it is a beneficial additional step for the Waste Treatment Plant pretreatment.

- Many of these technologies are not suitable for modularity.

- All technologies are expected to be applied to all 68 single-shell tanks under consideration. The ranking criterion for "Percent Waste Applied To" therefore became a non-discriminator.

- In some cases, assumptions such as cesium removal or lack of mobility became a requirement for the technology. These are noted in the scoring table.

- The evaluators devoted much time to discussion of questions and concerns regarding technetium. One of the evaluators (Bell) wrote a recommendation after the meeting. His recommendation was to conduct a study to better determine (1) the volatility of technetium at temperatures greater than 1,000 °C from a matrix that initially includes the technetium-VII oxidation species; (2) human body retention rates for the technetium-VII species; and (3) potential biohazards of human ingestion of technetium-VII species in drinking water.

- Some evaluators were disappointed that low radiation was not more heavily factored into the rankings.

- One evaluator noted that it would be helpful if the Waste Treatment Plant low-activity waste vitrification baseline were adjusted to the 5 gal/min rate assumed for the alternate technologies and included in the analysis for comparison purposes.

- The regulators stated that, although the 68 single-shell tanks under consideration were considered "benign" from the standpoint of curies of cesium and strontium, they were among the most risky with respect to groundwater. The concern is with technetium and iodine removal.

- Bulk vitrification and all four of the clean salt processes were evaluated on the second day of the workshop. Metal reduction, steam reformation, and grout were evaluated the last day of the workshop.

PRESENTATIONS AND EARLY DISCUSSION BEFORE SCORING:

DOE Perspective: Presented by Bill Hewitt, YAHSGS LLC

- Drivers for supplemental technologies include Waste Treatment Plant capacity and whether steam reforming is successful. Low-activity waste treatment capacity needs to be increased to meet DOE commitments.

- Technologies may be skid mounted within the Waste Treatment Plant or in their own facilities; new buildings may be needed.

Hanford Tank Waste Background: Presented by Kayle Boomer, CH2MHill Hanford Group

- Supplemental technologies were to be demonstrated on the tank inventory from tank 241-S-112. For calculation purposes, tank 241-S-112 contains Envelope B waste, high sulfate content. Sixty-eight single-shell tanks have been determined to be represented by this inventory.

Regulator Perspective: Presented by Roger Stanley, Ecology

- C3T meetings have been going on for about a year. The focus of the meetings has been to find ways to process low-activity waste faster.

- Regulators have been reviewing tank treatment about 10 years. Treatment plans have changed over this period. The push in the last year has been to look for alternatives. When determining alternatives, one must keep in mind retrieval; closure; DOE O 435.1, *Radioactive Waste Management*; waste incidental to reprocessing determination; and overlay of *Resource Conservation and Conservation Act of 1976* (RCRA) closure.

On-Site Disposal Protocols: Presented by Janet Badden, CH2MHill Hanford Group

- Issues with liquid effluents and air release appear to be minimal.

- Thermal treatment is sometimes considered an incinerator for permitting purposes. It is more difficult to get a permit in this case; it does not make air release standards harder to achieve.

- Disposal of immobilized low-activity waste must meet waste acceptance criteria. Waste acceptance criteria are not yet fully defined.

- All tanks contain mixed waste. No technologies have yet been ruled out for RCRA non-compliance issues.

- Immobilized low-activity waste disposal is intended to be permitted. Conceptual design and application are needed and planned for 2003 with construction assumed to start in 2005.

- Category III waste is similar to Class C waste but higher in some radionuclides.

- Technetium inventory confidence is needed. Tank 241-S-112 was sampled and found to be lower in technetium than originally thought. The ORIGEN computer code is used to model the technetium inventory, and it tends to overestimate technetium. Some technologies may be unnecessary if the inventory is refined. The inventory uncertainty is high in single-shell tanks, for example, for transuranics.

- Immobilized low-activity waste performance assessment is calculated at 1,000 years and also at 10,000 years.

- Only three flow sheets denitrate the waste. This affects the performance assessment.

- RCRA trenches did not include a requirement for nitrate leachability. This is still an open question.

Selective Dissolution, Solids–Liquids Separations and Cesium Ion Exchange: Presented by Ken Gasper, CH2MHill Hanford Group

- The process is assumed to have one selective dissolution run, not multiple runs.
- TRIAD (solids–liquids separation system) processed 300 kgal of waste.
- The 68 single-shell tanks under consideration contain about 85 percent of the Hanford Site saltcake inventory.
- There is uncertainty in the tank inventories.
- Waste incidental to reprocessing determination may be questionable.
- Gunite tank waste was treated at Oak Ridge National Laboratory.
- Dan Herting provided data on this process for well-mixed waste. One evaluator questioned whether the data were applicable to unretrieved tanks. To maximize effect of selective dissolution, waste would need to be mixed after retrieval to double-shell tanks.
- The vision was to segregate after 25 percent of the waste went through the process. Without much sodium nitrate dissolution, we could get cesium and technetium. There is a minimum impact on saltcake dissolution activity.
- This process does not stand alone but is an integral part of other technologies.

Bulk Vitrification: Presentation by George Reddick, CH2MHill Hanford Group

- Very hot processing temperatures of 1,600 °C may be expected.
- An off-gas system is used to mitigate NO_x and sulfur components.
- The final product characteristics determine the limiting factor for sodium loading.
- Sulfur goes to solid–liquid streams from the off-gas and will need to be disposed of.
- The process is in a unit independent of the Waste Treatment Plant.
- This process presents challenges from a safety basis viewpoint.
- The process uses graphite electrodes.
- This is a batch process; metal settling must be monitored.
- The Waste Form Qualification process is similar to that of the Waste Treatment Plant.

- The amount of cesium removed determines potential remote maintenance requirements of the process.

Active Metal Reduction: Presentation by Richard Brouns, Pacific Northwest National Laboratory

- Denitration may produce hydrogen sulfide, which is poisonous and needs treatment.
- Chromium and technetium are reduced to insoluble aluminates.
- Product is one of a few mineral compounds that hold sodium very well.
- Vessel of 1,000 L is required.
- With excess aluminum, more gibbsite is generated than Na Al O_2.
- Waste containing aluminate does not make good grout.
- The economic analysis for this process was favorable when compared with past baselines.
- Phosphate has the advantage of faster reactions.
- Aluminum causes reduction to sodium aluminate, which is then caged on silicon.

Clean Salt Variations: Presentation by Mike Johnson, CH2MHill Hanford Group

- Sulfate separation is achieved by adding strontium nitrate.
- Without sulfate separation, sulfate goes to double-shell tanks; the double-shell tank waste is processed by the Waste Treatment Plant.
- Acid recovery was not studied.
- Shielding requirements are very different between clean salt with cesium removal and clean salt without cesium removal (options 4A and 4B).
- Technetium goes back to double-shell tanks.
- A 40 ton/day implementation rate was achieved in Russia.
- Capacity for 68 single-shell tanks in 10 years is about 10 gal/min.
- If nitric or phosphoric acid is added to reduce NaOH to be added back, it could reduce Waste Treatment Plant processing time by about 3 years.
- Ceramicrete and microencapsulation yields higher waste loading.

Sulfate Removal:

- The Waste Treatment Plant had sulfate removal in its original design, but it was deleted; the decision was to make more immobilized low-activity waste glass (20 percent increase.) Sulfate removal is being reconsidered because best-basis inventory has changed since 1998 when the decision was made. It is showing more sulfate and less sodium, hence greater impact on immobilized low-activity waste volume. Contract structure with BNFL made acidification, sulfate removal, and caustic addition unwise from a business point of view.

- "Rule of 5" shows higher sulfate loading when sodium loading is low, giving reduction in immobilized low-activity waste production.

- An evaluator asked about the pH of 5M sodium feed. The single-shell tank saltcake is probably lower in free hydroxide than double-shell tank feed (10M sodium is 2 or 3M free hydroxide).

Grout: Presentation by Jeff Voogd, CH2MHill Hanford Group

- Key point is that focus on key product qualities is needed; then one must develop a process to achieve that product quality.

- With previous grout formulation, an asphalt barrier and Hanford Site barrier were needed for technetium and nitrate. Better grouts can be made. Smaller containers are better but perhaps still not good enough. An adiabatic cure for the grout does not work well. Even small boxes are nearly adiabatic.

- Savannah River Site grout formulation is not used at the Hanford Site because slag helps with technetium, but pore structure helps with nitrate.

- The cost estimate for immobilized low-activity waste is very simplistic: every year the Waste Treatment Plant does not need to operate saves one billion dollars.

- One evaluator stated that it was hard to show from risk analysis that technetium should be as big a driver as it is.

Steam Reforming: Presentation by Duane Smoker, Washington Group, and Brad Mason, Studsvik.

- A vendor gave the presentation for steam reforming, whereas CHG and PNNL staff gave presentations for the other technologies. No test data or calculations were provided to support the performance described.

- Process is being used in radioactive environment.

- Samples of product were shown.

- Presenters are prepared to talk about result but cannot present data for business sensitivity reasons.

- There are 6-in., 18-in., and 45-in. beds in Erwin, Tennessee, processing radioactive waste from power plants. The feed is polystyrene beads.
- Studsvik is not licensed to process sludges. They are using ion exchange resins, which contain a lot of sludge.
- The final waste form is sodium aluminate as powder; it is not stabilized.
- The process can handle 7 wt% sulfur at a rate of several tons per year.
- The current process is not handling transuranic compounds. The main radionuclides are cesium, cobalt, nickel, manganese, and iron.
- More than 99.95 percent of the incoming cesium stays in the final product.
- Pyrolysis did not reduce organics volume enough; steam reforming was developed to gassify product.
- The 15-in. fluid bed test facility was used for a test for BNI in December with double-shell tank waste simulant. One-ninth production scale, process control, off-gas verification, and metallurgy and corrosion verification were tested.
- In 1999, the Tennessee facility started commercial pyrolysis and steam reforming in a 45-in. fluid bed, under 400 R/h, and heavily shielded. Contact maintenance was performed by flushing. Fluidized bed and off-gas system do not significantly accumulate cesium (100-150 mR/h). The semi-permanent bed of alumina is emptied at intervals of approximately once per year. The facility performs denitration and sodium immobilization by changing additives. The product is sodium oxide and aluminum oxide in Tennessee. At the Hanford Site, it would be a mix of oxides of sodium, aluminum, and silicon.
- An evaluator asked whether there was an excess amount of additive. The vendor replied that the additive was close to stoichiometry and that other species that can form are insoluble.
- There is a need to grout the waste form to produce a monolith. The granular material meets ultimate tensile strength.
- Sodium is not in the pores; it is part of the crystalline structure, which forms cages that trap larger ions such as cesium. There is not enough experience with the process to know what the maximum sodium loading is.
- The process operates at no lower than 735 °C; the process is too slow if a lower temperature is used.
- There is less than 500 ppm total NOx in the off-gas, and less than 20 ppm also is Cl. F caught in the solid. Concentrations are so low that there is no need to neutralize scrubber solution.

- Vendor has not done enough work to know where the sulfate is. There is less 0.1 percent in the off-gas. It is slightly soluble, but mostly insoluble. Clay bonds with the sulfate in the bed.

- Process is not RCRA-licensed. Tests have been conducted with chromium, lead, cadmium, nickel, and aluminum that were contained within solids and were non-leachable. The product passed the toxicity characteristic leaching procedure by a factor of 100.

- Finer material was elutriated and recycled. It passes toxicity characteristic leaching procedure as well. A majority of material comes out at the bottom of the bed.

- Oxygen plus superheated steam generates heat at the bottom of the bed, which is oxidizing. The middle of the bed is reducing, leading to denitration. The metals are all bound. Oxygen is added to the top to finish organic destruction. Some metals could be oxidized, but they would still be insoluble.

- There is no incomplete combustion. The fluidized bed is excellent at mixing. Chlorine is bound, so it is harder to form dioxins. There are no direct data, but data from similar processes are available. Some data on DOE organic waste are available. One needs proof for regulators.

- Steam is at 600 °C, under a slight vacuum (~20 in. water column.) the steam head must be 4 to 5 lb/in^2 to inject.

- The black coating on the samples shows that a lot of carbon is burned. Work on removal of carbon in fines is needed.

- A 9-ft-diameter vessel is needed for low-activity waste treatment at the Hanford Site in the Waste Treatment Plant. Thirty-six tons per day of product would be processed.

- Pretreatment depends on customer preference.

- The highest radiation ever processed by Studsvik is 395 R/h.

- The volume of product, based on tank 241-S-112, is 4,180 m^3, or 3,610 metric tons. It is a low-density product.

- With additives, the feed is about 3M sodium. Feed may need to be evaporated.

- The nozzle was fouled at times; vendor changed the nozzle tip orientation to resolve the problem.

- A "non-incinerator" designation on the permit means no public comment period. Maximum achievable control technology applies, so designation may not matter here.

- No known catalyst poisons are in the waste feed.

- Cost for a 45-in. bed process in Tennessee was thirty-five million dollars.
- Height of vessel is 25 to 28 ft.

SCORING DISCUSSIONS

1- Bulk Vitrification

- **General**: A fixed facility must be assumed for secondary containment. One evaluator remarked that it does not seem worthwhile to pursue since it is so similar to the vitrification process now being built and cannot be safely skid mounted.
- **Operational safety**: Some wanted to rate this lower than 2 because of lack of modularity.
- **Regulatory permitting**: Regulators believe permitting will be difficult because higher temperatures cause more off-gas. RCRA is also an issue. One must assume a fixed building to have any chance of permitting.
- **Waste incidental to reprocessing**: Cesium ion exchange and solid–liquid separation may not be as good as Waste Treatment Plant pretreatment. This makes it hard to argue that radionuclides have been removed to the standard of the best that is technically and reasonably possible. Ecology rated this lower than other evaluators. The waste incidental to reprocessing ranking would be lower than Waste Treatment Plant glass. The cost per curie to process waste by this method is expensive. Waste already has been processed through B Plant and does not need to be processed by the Waste Treatment Plant. There is a problem with the high-level waste definition in DOE O 435.1; it is horrible to work with. Technetium removal is not likely to meet requirements for waste incidental to reprocessing.
- **Land disposal restrictions**: There was little discussion and good agreement on score of 4.
- **Waste form performance, technetium**: Glass is durable and the best option. Separation of technetium is small based solely on selective dissolution.
- **Waste form performance, nitrate**: Nitrate is removed and is not an issue.
- **Percent waste applicable to**: There was little discussion and good agreement on score of 4. All tanks will get this score making this criterion a non-discriminator. One can apply all technologies to all 68 single-shell tanks.
- **Effect on waste volume**: Waste volume will change by not more than 20 percent. Score 3.
- **Mission completion date**: There was little discussion and good agreement on score of 3.

- **Compatibility with flow sheet**: There was little discussion and good agreement on score of 3
- **Ease of operations**: Evaluators expressed concern about graphite electrodes being corroded (consumable). Score 2.
- **Process stability**: Score 3.
- **Ease and frequency of maintenance:** Score 2.
- **Number and complexity of unit operations:** Process temperature is 1,600 °C for bulk vitrification versus 5,000 °C at Allied Technology Group. Allied Technology Group processes different kind of waste. Score 2.
- **River Protection Project treatment needs:** Score of 1 due to lack of mobility.
- **Flow sheet compatibility:** Glass chemistry is known earning a score of 4.
- **Susceptibility to chemistry risks:** There was little discussion and good agreement on score of 3.
- **Deployment history**: Score 3.
- **Scale-up issues**: Score 4.
- **Pathway to deployment:** DOE administrative policy may effectively exclude this option. Score 2.
- **Vendor reliance**: Score 2.
- **Equipment and parts availability**: Score 3.
- **Relative cost impact**: Score 2.

2 – Active Metal Reduction

- **Operational safety**: Temperature of process is not high (50 °C - 120 °C). If water is added to control temperature, there is a 7-to-1 evaporation rate. Testing was done at 50 °C. Hydrogen, hydrogen sulfide, and ammonia could come off in potentially explosive concentrations. For batch reactions, it is difficult to control the rates; a way is needed to make it continuous. Also, nitrate-aluminum reaction could be extremely explosive if powdered aluminum were used. It is less risky if bead-like material is used. If beads are used, the temperature could reach 400 °C. On the other hand, this processing is similar to the aluminum cladding dissolution done for many years at DOE sites, so these issues can presumably be controlled. Safety is no worse than that of bulk vitrification, which has a temperature of 1,600 °C. The evaluators scored this as a 2.

- **Regulatory permitting**: Permitting will be complex if process equipment is skid-mounted. The process must be done in a building. One must consider low-temperature denitration and recycling of aluminum scraps. Active metal reduction is easier than bulk vitrification and steam reforming but harder than sulfate removal. All agree on a score of 3.

- **Waste incidental to reprocessing**: Technetium will be reduced and will be retained in glass. Reducing technetium has not happened in short-term tests. Hanford Site soil is oxidizing, so technetium could be reoxidized over time. Release mechanism from glass is surface corrosion. If technetium is in porous material, the release mechanism depends on where technetium is in the material matrix. Steam reforming product will be porous. Here, product is less porous because it was formed in a liquid environment. Evaluators guess that quality will be better than grout and worse than glass but not much worse. No certain data exists. Aluminosilicates will take some nitrate if needed and will yield a much higher performance than phosphate-bonded material. All agree on score of 2.

- **Land disposal restrictions**: Score 3 (regulators tended to vote lower than others). This waste form might be better than glass, but a lot of uncertainty exists.

- **Waste form performance, technetium**: Good waste form to lock technetium, but there is much uncertainty about performance. Score 3.

- **Waste form performance, nitrate**: Nitrate is separated. If there is any nitrate, the waste form will hold it. It needs to meet a 500 lb/in^2 requirement. All agreed on a score of 4.

- **Percent waste applicable to**: Score 4.

- **Waste volume disposed of onsite**: Flow sheet shows phosphate ceramic, but voting was based on aluminum silicate flow sheet. Stoichiometry could be optimized. Product may need to be compacted. Score 2.

- **Mission acceleration impact**: Evaluators had little confidence in time saving of 19 years. Score 3.

- **Flowsheet compatibility**: Little discussion occurred. Score 3.

- **Ease of operations**: Unfavorable aspects include toxic compound in off-gas, mixed ammonia and nitrate, and organics. The process has lots of steps, mixed ammonia and nitrates, and hydrogen sulfide poisons catalysts, which render it not very favorable. Process is not as hard as clean salt. Score 1 with dissenters voting for a 2.

- **Process stability**: Process has narrow operation parameters. There could be unknown poisons. On the other hand, this is a type of process DOE has done before. One needs a lot of control to get the right mineral and to minimize hydrogen gas emissions. Score 2.

- **Ease of maintenance**: No unusual equipment needed. Process is not as easy as grout. With clean salt, all is soluble and one can redissolve any precipitation. There is a long curing time. Radiation levels have been taken down before processing. There are issues with potential solids accumulation in the system, more solids that are insoluble, and gunky aluminum hydroxide precipitate. Score 2.

- **Number and complexity of unit operations**: The process is roughly equal to clean salt and sulfate removal. There are off-gas issues. Evaluators felt information was insufficient to discriminate among these options. Process is complex as written but could be simplified. Flow sheet is more detailed than others but not the off-gas system. Score 1.5 (evenly divided between 1 and 2).

- **River Protection Project treatment needs:** The process must be in a building as for bulk vitrification. Score of 1 due to this mobility issue.

- **Technical maturity**: This is the least mature of the options. Score 1.

- **Chemistry risk**: Hydrogen sulfide can poison the off-gas treatment. Score 2.

- **Deployment history**: Score 1 (little discussion).

- **Scale-up**: This is a batch process. Process rates of 5 to 10 gal/min are achievable, but two units may be needed. Score 3.

- **Pathway to deployment**: Process would require arduous developmental work but produces a great waste form. Off-gas will be hard to handle within the DOE system. At the Savannah River Site, a solvent extraction process was eliminated 2 years ago because of technical immaturity and is now the process of choice. This process is penalized for our purposes because of immaturity combined with an aggressive schedule but is promising over the long term. Score 1.

- **Vendor reliability**: Score 3 (little discussion).

- **Equipment availability**: Score 3 (little discussion).

- **Cost impact**: Score 2 (little discussion).

3 – Steam Reforming

- **General**: The presentation was in a different format than the others and was made by a vendor (Studsvik, sponsored by BNI). Some parts of the process were not revealed for business sensitivity reasons. Evaluators did not have a flow sheet to use for the evaluation. One must assume process is housed in a building. It may be used at Idaho National Engineering and Environmental Laboratory as well as at the Hanford Site. BNI is trying to get funding to move forward and will send out a request for proposals to do the testing. Process is good for organic waste, and its reducing environment is good. Testing did not include RCRA constituents and was a short-duration test.

- **Operational safety**: Process is at a relatively high temperature, 700 °C. Potentially explosive mixture results from the process, so the vessel is designed to resist explosion. Fluidized bed is under combustible gas conditions. NOx is under negative pressure. It must be assumed that this process is housed in a building and that cesium and technetium are removed as required. Process requires oxygen storage and steam plant. Source of carbon in process is suspected to be activated carbon or sugar.

- **Regulatory permitting**: Feed uncertainty combined with flow sheet uncertainty make this option hard to evaluate. No big concerns were expressed, but regulators questioned what would be gained by declaring that the facility is not an incinerator. Score 2.

- **Waste incidental to reprocessing**: The waste will need to go through pretreatment. Voting was evenly divided so score of 3.5 was assigned.

- **Land disposal restrictions**: Process is expected to have good performance on metals; however, data are lacking. The vendor said that one sample passed the toxicity characteristic leaching procedure, but he did not say what happened to other samples. Not all RCRA metals were used in the tests. We need more tests with good simulants. Process makes a similar waste form to active metal reduction. Toxicity characteristic leaching procedure tests of product appear to be limited at best, based on the *Steam Reforming Thirty-Day Scoping Effort Report*. Score 3.

- **Waste form, technetium**: Technetium performance is expected to be same as that for active metal technology. Score 3.

- **Waste form, nitrate**: Grout would perform better on monolithic basis but worse on a particulate basis. Waste form will likely need to be monolithic (causing an additional process step). This is to be noted on scoring table. Nitrates will be destroyed. Score 4.

- **Percent of waste applicable to**: Score 4.

- **Waste volume**: Score 2.

- **Mission acceleration**: Similar to bulk vitrification. Score 3.

- **Flowsheet compatibility**: Score 3.

- **Ease of operations**: Industry has lots of fluidized bed experience. There is a need to fine tune the mix of elements (e.g., oxygen–carbon–steam–catalyst).

- **Ease of maintenance**: Experience with treating ion exchange resins at Erwin, Tennessee, is not directly applicable to Hanford Site waste. The Hanford Site waste has a high salt content that can cause operating problems, such as feed nozzle plugging and bed agglomeration in the steam reformer, that are due to formation of a molten mixture of sodium hydroxide and sodium carbonate that is mastic. The vendor acknowledged nozzle plugging with sodium. There is an issue with carbon pollution on the product. Test reformer could not run at steady state, but some panel

members felt problems could likely be corrected. There will be some clinker formation in beds. Score of 2.

- **Number and complexity of unit operations**: Score 2.
- **River Protection Project treatment needs**: Score 1 (based on lack of mobility [i.e., needs to be in a building]). Based on initial information, the process requires facilities to generate steam and oxygen.
- **Maturity**: Process is working in commercial and nuclear industries. Score 3.
- **Chemical risk**: Score 2 (worse than bulk vitrification)..
- **Deployment History**: Score 3 (little discussion).
- **Scale up:** There are issues if more than 10 gal/min are processed. Insufficient information is available to understand how rate and tank size are correlated. Score of 4 based on a 5 to 10 gal/min processing rate. One person had concerns with the ability to control the process with a 9-ft vessel as assumed for the WTP. Score 4.
- **Pathway to deployment:** Issues must be resolved (e.g., waste form). It is difficult to rate because of lack of information from the vendor. Vendor initially thought this technology would be put in a melter cell but is now considering a separate facility. Score of 2 for the 5-10 gal/min rate.
- **Vendor reliability:** Multiple vendors and bidders expected. Score of 3 based on lack of information.
- **Equipment availability:** Score 3.
- **Cost:** Costs will be influenced by the large volume of secondary waste. No cost estimates were presented to panel. Thirty-five million dollars of capital expense were incurred to start facility in Erwin, Tennessee. The facility would need a big off-gas system, a big pressure vessel, and a building approximately three stories high. The process appears to save 19 years, but data are not available. Not rated.

Clean Salt Options 4A, 4B, 5A, and 5B were ranked as a group.

4A – Clean Salt (Ceramic grout, no cesium removal)

- **Operational safety**: Option 4A is rated as unsafe, and 4B is okay. In option 4A, 90,000 Ci of cesium are processed; in option 4B, 900 Ci of cesium are processed. In both cases, there is a remotely operated step. The loaded cesium ion exchangers are a big source term. Without cesium ion exchange, there is still an accumulation point in an accumulation tank but a smaller source term. In remote operations, things go wrong 10 times more often than they do with hands-on operations. In safety, one looks for big problems like pressurization and spills. It would be a drawback to have to go to a shielded facility to repair a skid-mounted system. Voted, score of 2. One strong dissenter (Bell) felt this process was anti-ALARA. He was concerned that not

using cesium ion exchange would create shielding issues. These were no big release concerns. He wrote a formal dissent as follows: "Operations safety of a process for treating radioactive materials is a strong function of the rad levels of the material. A total process generally includes a number of unit operations, and when these unit operations are physically separated, the operations safety can be directly related to the number of unit operations that have rad levels that require high shielding and remote operations. A process that includes remote operations rather than contact operations when contact operations are within a reasonable grasp should be rated at the lowest level. This conclusion would apply to both the 4A and 5A process flow sheets. These processes could be called anti-ALARA."

- **Regulatory permitting**: This process uses an evaporator-like aspect compared with WTP, which is considering evaporators as miscellaneous units. Some thermal treatment standards apply but not 4/9s. All low temperature evaporation is not thermal treatment. The LAW evaporator has some thermal treatment features for permitting as a "miscellaneous" facility. The Hanford Site 242A Evaporator was not permitted as thermal. Agreed, score 3.

- **Waste incidental to reprocessing**: Easy, permanent process that works. Score 4.

- **Land disposal restrictions**: Process is likely to meet ultimate tensile strength for metals and toxicity. Organics are not treated and will not be with $NaNO_3$; rather they will be in solution and go to the DST system. Waste streams will not be more than 5 percent organic, mostly oxalates, not listed waste. The issue will at least need study in a public forum. Whether technologies fall under the ultimate tensile strength definitions (needing land disposal restrictions variance) has not been analyzed. No one has done a leach test on the waste form. Score 2.

- **Waste form performance, technetium:** Waste form is likely good for phosphate-bonded ceramic considering that the removal of technetium has occurred. Waste form is very low in technetium. Waste form will not hold as well as aluminum silicate, but it is better than polyethylene and still very good. All agree on a score of 3

- **Waste form performance, nitrate**: Performance is poor; there is no mechanism to retain nitrate, which will leach. Score 1.

- **Mission completion date**: There is some concern that the sulfate goes to WTP.

- **Ease of operability**: Crystallization is considered difficult to operate. Operating at freezing point is risky. All agree on a score of 2.

- **Process stability**: Crystallization is hard for modular system. Score 2.

- **River Protection Procect treatment needs**: There is no ease of mobility. Score 2.

- **Flow sheet operation maturity**: Mostly laboratory-scale testing has been done. Technology development is in early stages. All agree on a score of 2.

- **Chemistry risks**: Precipitation is vulnerable to low concentration species. Evaluators concluded that there will be no chemical reaction except during acidification. Sometimes things cannot be made to dissolve and other surprises occur with acidificaton. Score 2.

- **Deployment history:** The process worked in Russia, but there is no parallel to commercial standards, especially since Russia used the process in the 1960s. Crystallization is used in the industry, but acidification is not easy. Score 1.

- **Scale-up issues**: Score 2.

- **Pathway to deployment:** The pathway to deployment is scary; there are many issues with the waste form. It does not appear to be totally unsuitable and may be manageable for a demonstration. Score 1.

- **Vendor reliability**: INEEL experience shows equipment is available but does not work well. Score 3.

- **Equipment and parts availability**: Score 3.

- **Cost**: Process is costly and does not reduce burden of glass. This process yields the worst cost for ILAW reduction ration. Score 2.

4B – Clean Salt (ceramic grout, with cesium removal)

Option 4B is the same as 4A, except for more favorable ratings on operational safety, ease of operations, and ease of maintenance because of the cesium removal step.

5A – Clean Salt (with sulfate removal, no cesium removal)

Option 5A is the same as 4A, except for more favorable ratings on mission completion date and RPP treatment needs and less favorable on ease of maintenance and operations and on number and complexity of unit operations (with sulfate removal step). DST volume reduction is good.

5B - Clean Salt (with sulfate removal, with cesium removal)

Option 5B is the same as 5A, except for more favorable ratings on operational safety, ease of operations, and ease of maintenance because of the cesium removal step.

6 – Grout

- **General:** This option is likely not viable unless technetium is removed. It will be trapped and reduced to TcO_2. Reducing agents can be put in the grout; the research has been done, but reducing is only partially effective. A panel member asked whether the reductant would work if the waste were dried first. The answer is that the waste will not be dried. In bulk vitrification, the technetium is bound but the inventory is still there. There is a volatility concern. One would have to separate technetium from chlorine and fluorine to recycle. The state regulators have concerns regarding the WIR determination. At the Savannah River Site vitrification facility,

technetium is not in the off-gas, but conditions there are different; the technetium is reduced in the sludge, and the process temperature is lower.

- **Operational safety:** Score 4.
- **Permitting:** Score 3.
- **Waste incidental to reprocessing:** Regulators tended to rate this process lower than other evaluators due to ^{99}Tc and ^{129}I issues. Technetium is the most mobile followed by ^{129}I and ^{14}C. Other radionuclides are much less significant. There is a lot of information on technetium. It is probably much lower in the tanks, having been volatilized, than the best-basis inventory would indicate, and if removed, it will be much less important. So technetium is a good representative. But the process will get a lot of scrutiny, even with technetium separation, as shown in the 1993 WIR determination. In 1997 DOE did a WIR determination for all SSTs and DSTs that determined that it was not economical to remove technetium unless required for performance assessment. Cesium ion exchange is needed. Mixed waste is not made part of the WIR. Waste coming into the WTP is worse as far as radionuclides, so it goes to glass. The ^{129}I and ^{14}C do not go into glass; ^{129}I is trapped in the off-gas system, but there is no way to immobilize it. The ^{14}C goes into the air. With this option, it is at least somewhat immobilized. Voting was split, with regulators voting for a score of 2 and others voting 3. Score of 3 with a footnote indicating the split.
- **Waste form performance, technetium**: Score of 2 because technetium must be removed.
- **Waste form performance, nitrate**: Score 1.
- **Percent of waste applicable to**: Without technetium removal, the process cannot apply to all 68 tanks. If one assumes technetium removal, the score is 4.
- **Effect on waste volume**: Score 1.
- **Mission completion**: Score 4.
- **Compatibility with River Protection Project flow sheet:** Score 3.
- **Ease of operations**: Off-gas is minimal; there may be some volatile organic compounds. Technetium removal adds one unit operation; still score of 4.
- **Process stability**: Very stable. Score 4.
- **Ease of maintenance**: Score 3.
- **Number and complexity of unit operations**: Comparable to sulfate removal except for acidification. Score 4.
- **River Protection Project treatment needs:** Score 3.

- **Flow sheet maturity:** Score 4.
- **Susceptibility to chemical risk:** Only a few chemicals, some organics and aluminum, can perturb grout. Nitrate is not really tied up. Score 4.
- **Path to deployment**: Unlikely to get stakeholder buy-in. Score 1.
- **Vendor reliability**: Score 4.
- ***Equipment availability***: Score 4.
- **Cost**: Cost is very favorable. Years are cut off the WTP process and relatively cheaply. Life cycle cost for disposal is likely to rise. Score 3.

7 – Sulfate Removal

- **Operational safety**: This is a simple operation. Score 4.
- **Regulatory permitting**: This is probably the simplest of the options. Score 4.
- **Waste incidental to reprocessing**: Sulfate removal is relatively easy, similar to nitrate crystallization. Score 4.
- **Land disposal restrictions**: Sulfate removal should meet the toxicity characteristic leaching procedure, but fluorine-listed waste is an administrative issue. Score 3.
- **Waste form performance, technetium**: Score 3.
- **Waste form performance, nitrate**: There are no nitrates. Score 4.
- **Mission completion date**: Sulfate still goes to WTP. Score 3.
- **Ease of operations**: Sulfate step is relatively simple. Acid step is the only complicating factor. Score 3.5.
- **Pathway to deployment**: It only makes sense to do this in WTP with the acidified stream sent to melter. Score 3.
- **Cost**: This technology is a lower cost process that solves a real problem, but it does not solve the whole problem, and it adds wash water. Score 2.

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ATTACHMENT B4

PRESENTATION VIEWGRAPHS
HANFORD SITE TANK WASTE BACKGROUND

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ATTACHMENT B4

PRESENTATION VIEWGRAPHS

Hanford Tank Waste/Treatment Background

Hanford Tank Waste/Treatment Background

RPP Alternative Technology Workshop

May 21, 2002

Kayle Boomer, CHG

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Hanford Group, Inc.

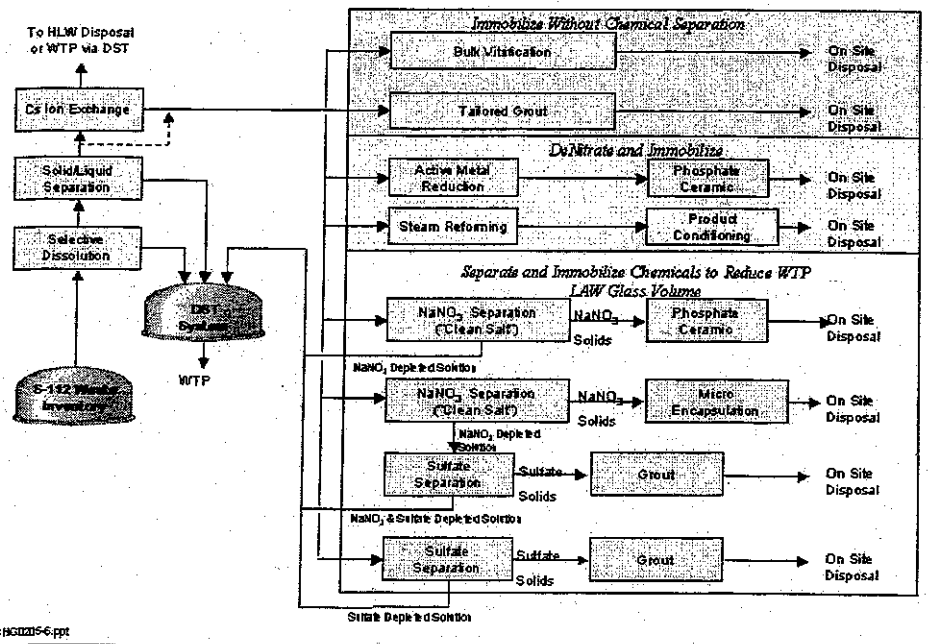
Background

- Largest gap between WTP current capacity and tank inventory is soluble salt inventory ("Low Activity Waste")
- ⇨Mission Acceleration Initiatives near term focus is selection of LAW treatment alternatives to WTP for demonstration within four years with tank waste
- April 2-3 workshop reviewed available technologies
- Seven LAW alternative treatment paths for flowsheet and performance data development: Results will be presented today

Background (Cont'd)

- WTP capacity drivers for LAW are:
  - Sulfates: reduce possible waste loading in glass
  - Non-radioactive sodium salts: are the majority of the waste
- All treatment options include:
  - Selective dissolution to reduce Cs/Tc content
  - Solid-liquid separation
  - Cs ion exchange (optional for some) to reduce dose rate
- Three categories of alternative treatment options
  - Immobilization without chemical separation
  - Denitration and immobilization
  - Separation and immobilization of chemicals to reduce WTP LAW glass volume

LAW Treatment Alternatives



Enabling Assumptions for MAI Technologies

- Feed Selection, Tank S-112
  - Saltcake Tank, high in sulfate
  - Sound Tank, characterized
  - Planned for near term retrieval
- Pretreatment to Reduce Radionuclides to MAI Technologies
  - Selective Dissolution applies to all paths
  - Solid/Liquid Separation applies to all paths
- Feed Processing
  - 5 GPM at 5 M Na

Enabling Assumptions for MAI Technologies (Cont'd)

- General
  - No Waste Retrieval Issues
  - Must be Class C or better
  - Waste consistent with site disposal requirements
- Technology Information
  - Based on available vendor information and laboratory data

On-Site Disposal Protocols

On-Site Disposal Protocols

J. W. Badden

May 21, 2002

CH2MHILL

Waste Pathways

- Liquid Effluents Treatment/Disposal
  - Effluent Treatment Facility (ETF)
  - Permitted Facility
  - Liquid effluents must meet ETF waste acceptance criteria
  - Not a discriminator between treatment options
- Air Releases
  - Consider in design
  - Obtain Notice of Constructions (NOCs)
  - Thermal treatments may be more problematic, however not considered a discriminator between treatment options
- Solid Waste Disposal
  - On-Site facilities are available
  - Must meet waste acceptance criteria

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Hanford Site Solid Waste Facilities

- Lined Low-Level Burial Grounds (LLBG) (Mixed Waste Trenches)
  - Mixed low activity waste (LAW) should be able to meet current waste acceptance criteria (WAC)
  - Assumption: WAC could be expanded to allow other waste forms
- Immobilized Low Activity Waste (ILAW) Disposal Facility
  - Disposal of vitrified LAW only
- Environmental Restoration Disposal Facility
  - Not currently available to RCRA process waste - not considered further
- Central Waste Complex
  - Interim storage ability for mixed LAW – for information purposes

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Solid Waste Facility Descriptions

- Lined Low-Level Burial Ground
- Immobilized Low-Activity Waste Facility
- Central Waste Complex (CWC)

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Lined Low-Level Burial Grounds

- Trenches 31 and 34 of the 218-W-5 Burial Ground
- Lined, RCRA compliant disposal units
- Accepts LAW designated D001-D043, tank listed wastes, and state-only dangerous waste
- Interim status permits; air permits in place

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Immobilized Low-Activity Waste Facility

- RCRA compliant landfill incorporating double lined trench with leachate collection system and surface/subsurface barriers
- Located in unused portion of 200 East Area
- Configured to hold 81,000 ILAW packages in 6 separate disposal cells
- Each cell consists of large trench containing 3 layers of ILAW packages separated vertically by soil
- ILAW packages positioned with crane
- Currently intended for disposal of vitrified waste only (accepted method of achieving ILAW status)
- Not permitted

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Central Waste Complex

- Storage unit for low level mixed, TRU, TRU mixed, and other waste types requiring treatment before disposal
- Potential back-up facility for temporary storage of Mission Acceleration Initiative (MAI) ILAW or other secondary solid waste
- Waste stored at CWC will be treated and repackaged as required for disposal as treatment capabilities become available
- Accepts characteristic waste numbers D001-D043, certain listed wastes, and state-only dangerous waste

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Solid Waste Facility Waste Acceptance Criteria

- Radiological
- Chemical
- Packaging

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Lined Low-Level Burial Ground Acceptance Criteria Radiological Requirements Summary

- Transuranic content ≤ 100 nCi/g of the ILAW
- Waste category shall not exceed Category 3 without analysis
- Category 3 waste shall satisfy one of the following stabilization requirements: 1) packaging in high integrity container; 2) placement in monolith in the LLBG; 3) stabilization in concrete or other agent
- Stabilization of mobile radionuclides
- Performance assessment (PA) doesn't allow for >1 Ci Tc (higher would require amending PA)
- Waste must meet the LLBG interim safety basis limits
- Surface contamination shall not exceed the limits in HNF-5173, Table 2-2
- Dose rate shall be ≤ 200 mrem/hr on contact and ≤ 100 mrem/hr at 30 cm

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Lined Low-Level Burial Ground Chemical Composition Requirements Summary

- All free liquids must be absorbed, stabilized or removed
- Residual liquids shall be sorbed or removed
- ILAW form shall be acceptable for land disposal under WAC 173-303
- ILAW form shall meet applicable land disposal restrictions treatment standards and requirements (40 CFR 268, WAC 173-303-140)
- Waste disposed in trenches 31 and 34 must be compatible with the landfill liner system (HNF-5841)
- Chelating compounds exceeding 1 wt % of waste must be solidified or stabilized
- If heat generation from radiological decay exceeds 3.5 watts/m^3, a container integrity evaluation is required
- Container vents shall be provided if potential exists for pressurization or flammable/explosive gas generation

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Lined Low Level Burial Ground Packaging Requirements Summary

- Containers other than metal drums must be evaluated for structural stability and containment on a case-by-case basis
- Integrity of outer containers shall not be compromised
- Containers shall comply with LLBG Fire Hazards Analysis
- Containers shall be compatible with waste and maintain containment and integrity during handling and storage
- Container compatible with forklift or crane lifting device
- Packaging shall minimize settling and subsidence in trenches 31 and 34

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Lined Low Level Burial Ground Packaging Requirements Summary

- Containers other than metal drums must be evaluated for structural stability and containment on a case-by-case basis
- Integrity of outer containers shall not be compromised
- Containers shall comply with LLBG Fire Hazards Analysis
- Containers shall be compatible with waste and maintain containment and integrity during handling and storage
- Container compatible with forklift or crane lifting device
- Packaging shall minimize settling and subsidence in trenches 31 and 34

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ILAW Facility Acceptance Criteria Radiological Requirements Summary

- Documentation of radionuclide inventory of each ILAW package
- Transuranic content ≤ 100 nCi/g of the ILAW
- Radiological concentrations shall not exceed applicable Class C low level waste concentration limits
- Maximum contaminant release rate shall be less than the limiting value for protection of groundwater during the compliance period
- Release rate in PA based on vit form; e.g., grout would not be expected to meet

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ILAW Facility Acceptance Criteria Chemical Composition Requirements Summary

- ILAW form shall be acceptable for land disposal under WAC 173-303
- ILAW form shall meet applicable LDR treatment standards and requirements (40 CFR 268, WAC 173-303-140)
- Sodium leachability index greater than 6 (ANSI/ANS 16.1)
- ILAW form shall not be pyrophoric, reactive with water, or capable of explosive decomposition at normal temperature and pressure
- ILAW form shall not contain or generate explosive or toxic gases
- ILAW package shall not contain detectable free liquids

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ILAW Facility Acceptance Criteria Packaging Requirements Summary

- Sealed, stainless steel, right circular product container enclosing a poured glass waste form with a sand or glass fill material
- Container compatible with crane lifting device and amenable to vertical stacking
- Welded lid
- Package integrity and compressive strength requirements shall be met
- Mass of each package ≤ 10,000 kg
- Surface dose rate ≤ 1,000 mrem/hr
- Void space volume ≤ 10% of total internal volume at time of filling
- After cooling, filler may be added such that void space does not exceed 5%

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Central Waste Complex Acceptance Criteria Radiological Requirements Summary

- Must meet fissile and fissionable material content limits in CPS-SW-149-00002
- Up to 35 DE-Ci per container for routine shipments; Up to 150 DE-Ci per container subject to evaluation
- Waste exceeding Category 3 (except TRU) requires DOE-RL approval
- Surface contamination shall not exceed the limits in HNF-5173, Table 2-2
- Dose rate shall be ≤ 200 mrem/hr on contact and ≤ 100 mrem/hr at 30 cm

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Central Waste Complex Acceptance Criteria Chemical Composition Requirements Summary

- All wastes placed in a given outer container shall be chemically compatible (WAC 173-303-630)
- Liquid sorption is allowed, if compatible with treatment methods anticipated for disposal
- Sufficient sorbent shall be added to sorb any expected condensate
- If heat generation from radiological decay exceeds 3.5 watts/m^3, a container integrity evaluation is required
- Container vents shall be provided if potential exists for pressurization or flammable/explosive gas generation

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Central Waste Complex Acceptance Criteria Packaging Requirements Summary

- Packages shall meet applicable 49 CFR container requirements for the hazard class of the waste
- Outer containers shall be constructed of noncombustible materials
- Packaging shall include coatings and/or liners to maintain containment integrity
- Integrity of outer containers shall not be compromised
- CWC container size and floor loading limits shall be met or otherwise approved
- Packages must withstand the weight of two layers of 55-gallon drums weighing 1,000 lbs stacked on top

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Selective Dissolution, Solids/Liquids Separations and Cesium Ion Exchange

Mission Acceleration Initiative Flow Sheet

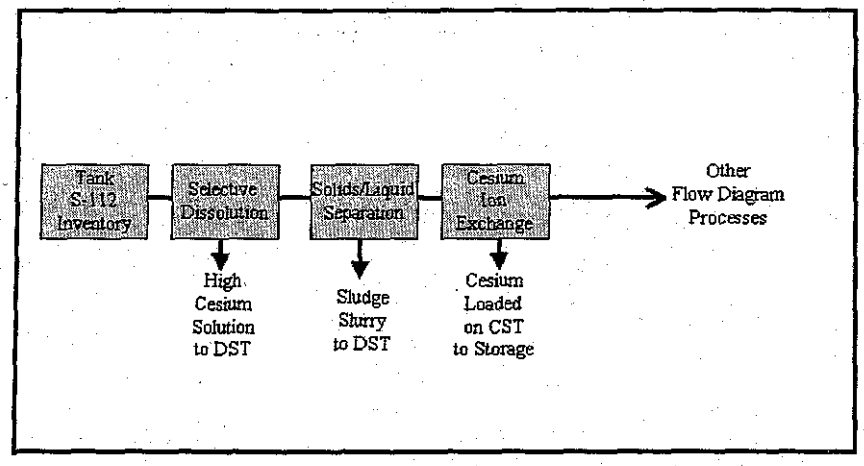
Selective Dissolution, Solids/Liquids Separations, and Cesium Ion Exchange

May 21, 2002

K. A. Gasper

CH2MHILL
Hanford Group, Inc.

FLOW DIAGRAM



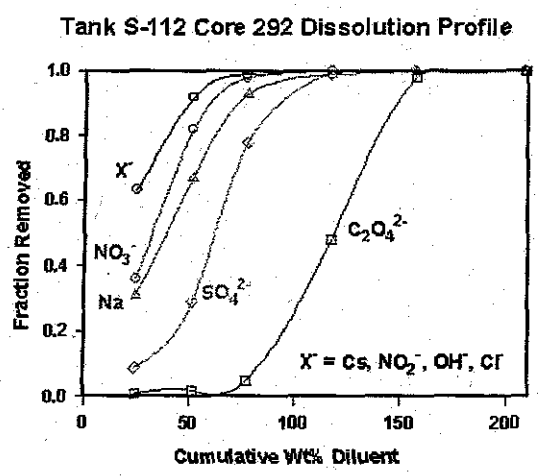
2

Process Description

- Process Chemistry
  - Step 1: Selective Dissolution
    - Premise:
      - Salt cake dissolution during retrieval may lead to "fractions" based on differential solubilities
      - Fractions may be diverted to different disposal pathways

3

Selective Dissolution



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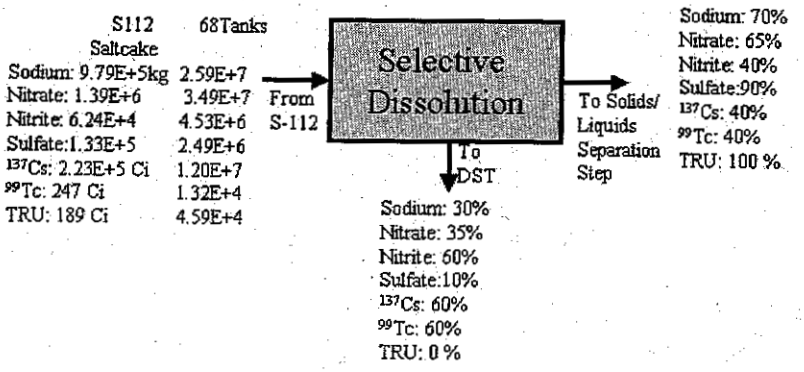
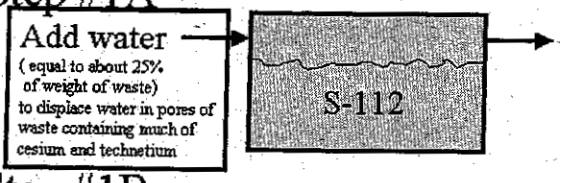
Selective Dissolution: Separation Information



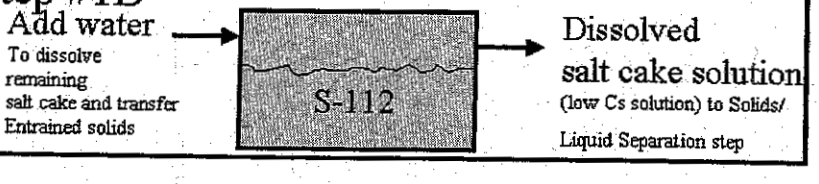
5

Selective Dissolution Process Equipment/Approach

- After salt well pumping
- Step #1A

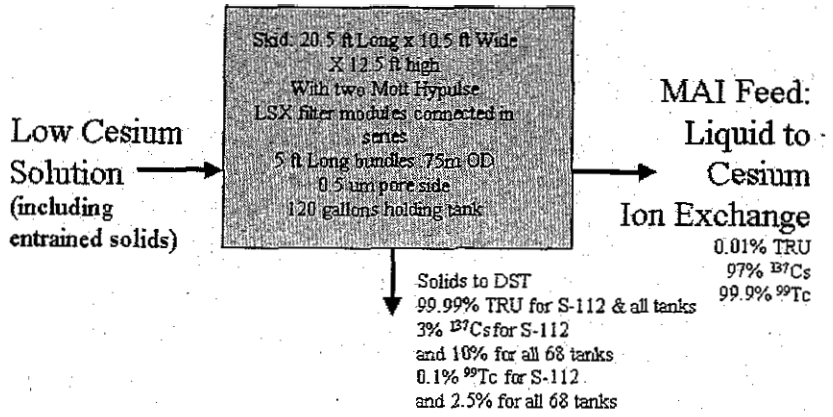


- Step #1B



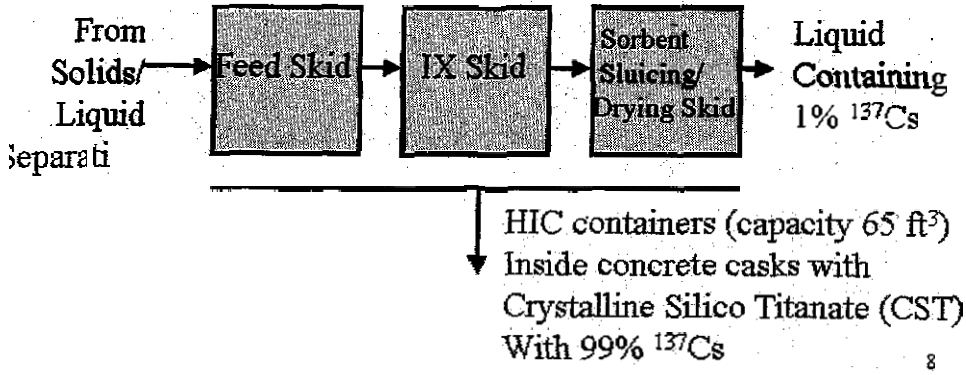
6

Process Description
Step 2: Solids/Liquids Separations



7

Process Description
Step 3: Cesium Ion Exchange



8

Process Flexibility

- Ease of Handling Variation of Waste Feed assumes:
  - All Sr and TRU are non-soluble for solids/liquid separation
  - Non-equilibrium conditions can be approximated by equilibrium conditions for selective dissolution predictions
  - Sulfate separation is greater when sulfate concentration is higher

9

Regulatory Compliance

- Is Technetium Removed?
  - Some technetium is removed by selective dissolution step and sent to DST; whether additional technetium is removed depends on additional pretreatment steps associated with different flow sheets

10

Investment Driver

- Cost: The costs for carrying out demonstrations for these pretreatment processes are included with the individual flow sheets
  - Solid/liquid separations and cesium ion exchange processes are baseline pretreatment processes in the Waste Treatment Plant
  - Selective dissolution could be an incremental step for planned retrieval of salt cake from single-shell tanks

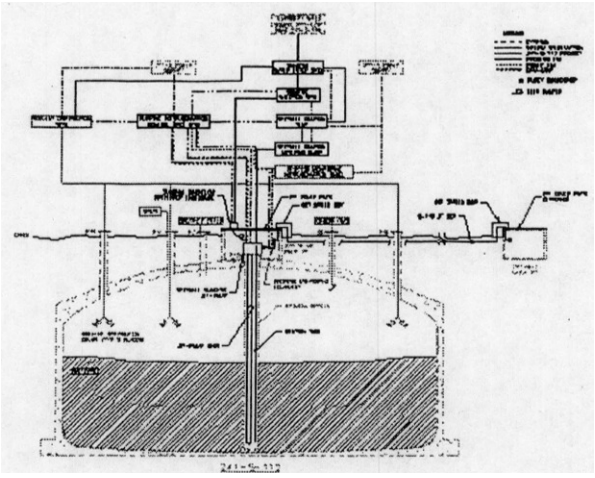
11

Investment Driver

- Reduced burden on DST space: critical first steps enabling more than half of the waste retrieved from a single shell tanks to be diverted from DSTs to alternate waste form immobilization.

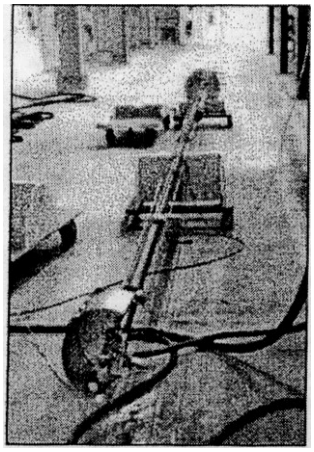
12

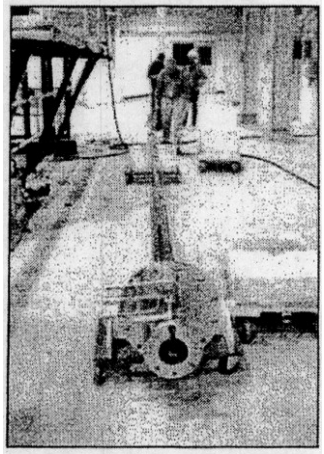
Selective Dissolution



13

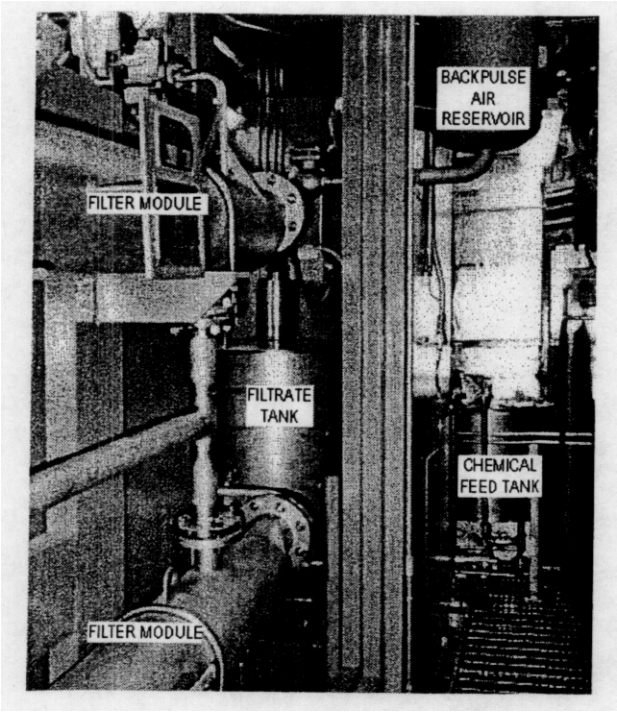
Selective Dissolution





Fabrication of Riser #2 Nozzle Assembly for U-107

14

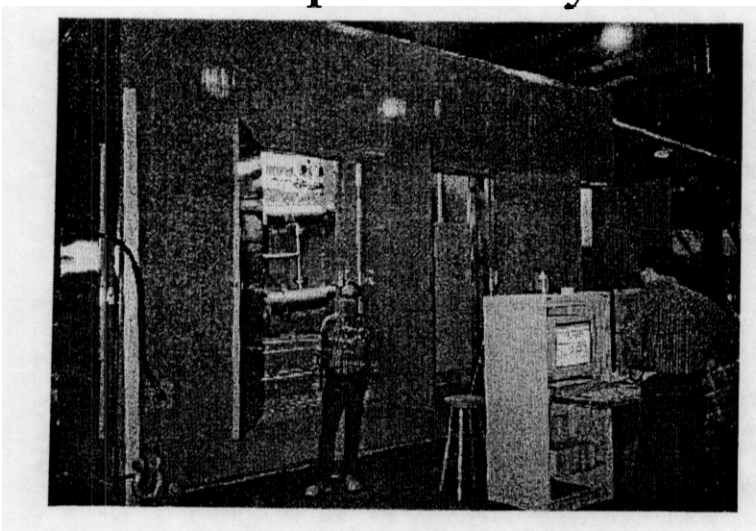


TRIAD Solids/Liquids Separation System

Components inside shielded container

15

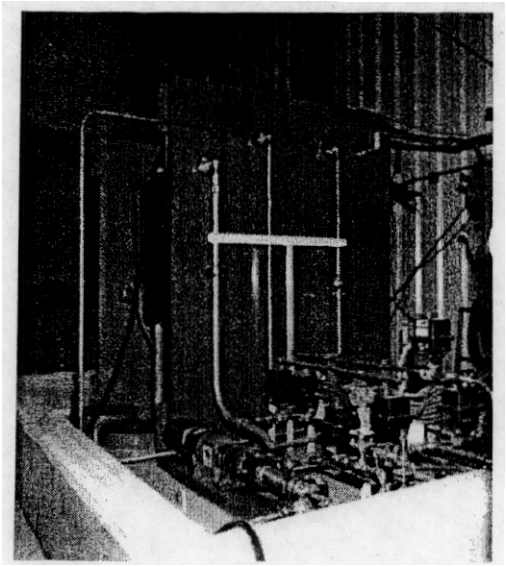
TRIAD Solids/Liquids Separation System



SLS system during acceptance testing at the NUMET facility

16

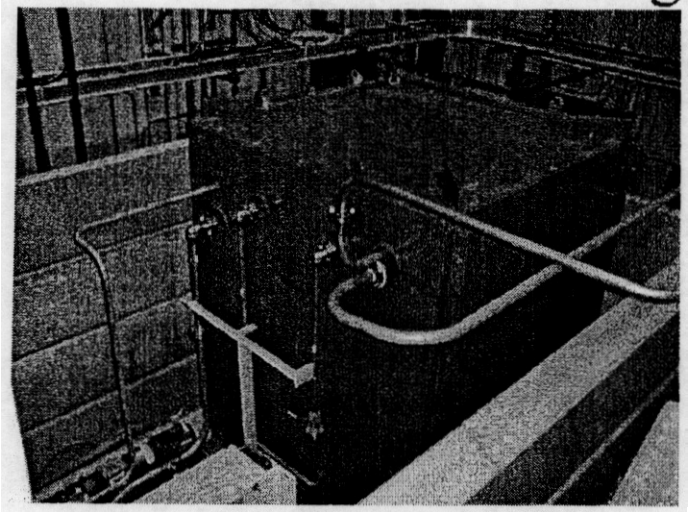
TRIAD Cesium Ion Exchange



Cesium
Removal
System
Modular
Shielding

17

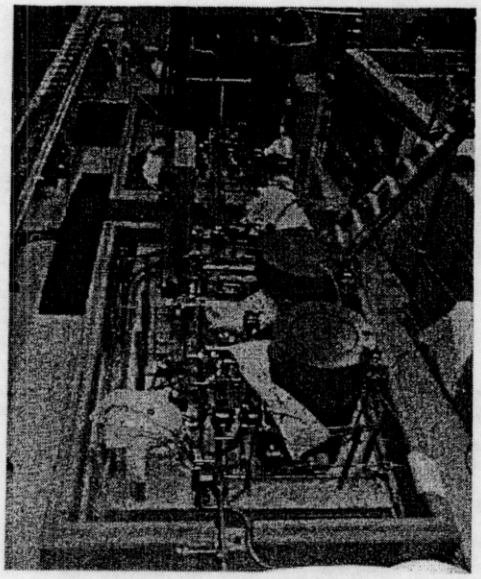
TRIAD Cesium Ion Exchange



CsR System Feed Tank Modular Shielding

18

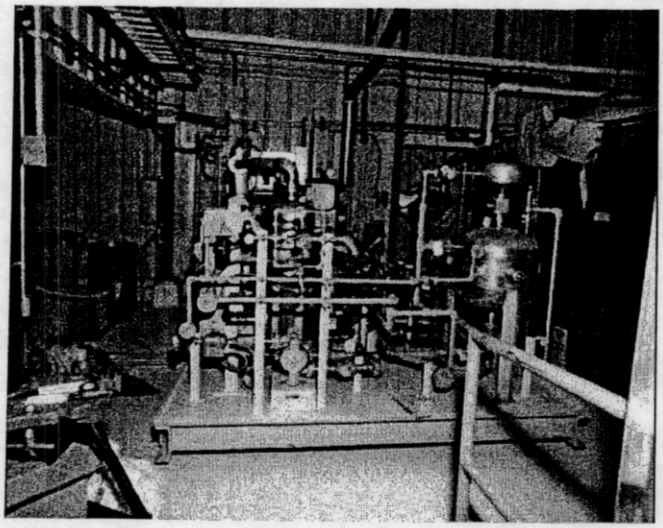
TRIAD Cesium Ion Exchange



Cesium Removal System Ion Exchange Skid with Modular Shielding

19

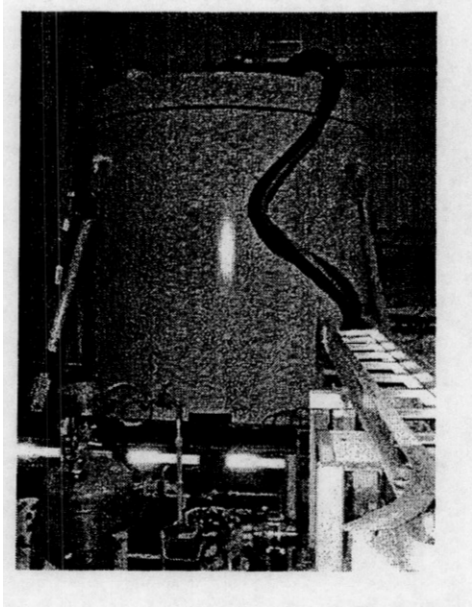
TRIAD Cesium Ion Exchange



Cesium Removal System Sorbent-Sluicing/ Drying Skid

20

TRIAD Cesium Ion Exchange



Concrete cask used to shield the high integrity container (HIC) containing the ^{137}Cs loaded sorbent

21

Ease of Building Modular Process

- Experience demonstrated with ORNL "TRIAD" project for
  - Solids/Liquid Separation
  - Cesium Ion Exchange with CST
- Experience to be demonstrated for Selective Dissolution with Tank U-107 Proof of Concept Test

22

Acceleration

- See individual flow sheets

23

Technical Maturity

- Pretreatment
  - Selective Dissolution: demonstrated on Hanford waste in lab with S-112, U-107 and BY-102 waste; to be tested in tank U-107 at Hanford in summer of 2002.
  - Limited flush to selectively remove ^{137}Cs planned for Tank 41 at Savannah River in summer of 2002 to produce "low curie salt"

24

Technical Maturity

- Pretreatment
  - Solids/Liquid Separation: much work with this approach carried out in lab to support Hanford Initial Pretreatment Module (1993-1995) design and Waste Treatment Plant baseline; approach already in Savannah River baseline; ORNL Triad Project included a Solids/liquid separation skid mounted unit (same scale: 5 gpm)

25

Technical Maturity

- Pretreatment
  - Cesium Ion Exchange: much work with this approach carried out in lab to support Hanford Initial Pretreatment Module (1993-1995) design and subsequent RPP work
    - Lab testing includes dissolved saltcake waste from Tanks A-101, U-108, U-109 (SESC-EN-RPT-006); AN-107 (SESC-EN-RPT-005); AW-101 Double Shell Slurry Feed (DSSF) (WHC-SD-RE-TRP-018)

26

Technical Maturity

- Pretreatment (continued)
  - Cesium Ion Exchange (continued): extensive evaluation of CST and development of data as part of SRS Salt Alternatives Disposition down selection; ORNL Triad Project included a cesium ion exchange skid mounted unit that operated at 2-2.5 gpm to remove 7700 Ci of ^{137}Cs from 267,000 gallons of waste using CST over an 11 month period.
- Immobilization: See individual flow sheets

27

Regulatory Compliance

- Temperature: all processes are room temperature
- Off-gas Treatment: no off-gases generated
- Ease of gaining a permit: all processes are consistent with other operations being used at Hanford or a part of Waste Treatment Plant baseline
- Ease of gaining a Waste Incidental to Reprocessing (WIR) ruling: dependent on particular flow sheet for further pretreatment and immobilization

28

Condensed Evaluation Factors

- Operational Safety and Process Safety/Stability
  - Selective Dissolution: no operations different than normal saltcake or saltcake/sludge retrieval
  - Solids/Liquids Separation: TRIAD SLS had no incidents; WTP will also utilize Cross-flow filter in Pretreatment plant
  - Cesium Ion Exchange: TRIAD IX had no incidents; WTP will utilize elutable IX. No decision has been made on how to process CST from Hanford demo.

29

Condensed Evaluation Factors

- Operability: Process Stability
  - Selective Dissolution: no operations different than normal saltcake or saltcake/sludge retrieval
  - Solids/Liquids Separation: TRIAD SLS had required backflushes when solids content approached 10%; WTP will also utilize Cross-flow filter in Pretreatment plant
  - Cesium Ion Exchange: TRIAD IX had no incidents; WTP will utilize elutable IX. No decision has been made on how to process CST from Hanford demo.

30

Condensed Evaluation Factors

- Operability: Ease of Maintenance
  - Selective Dissolution: no operations different than normal saltcake or saltcake/sludge retrieval
  - Solids/Liquids Separation: TRIAD SLS had provisions for expected maintenance; WTP will also utilize Cross-Flow Filter in Pretreatment plant
  - Cesium Ion Exchange: TRIAD IX had difficulties; WTP will utilize elutable IX. No decision has been made on how to process CST from Hanford demonstration.

31

Bulk (Ex Situ) Vitrification

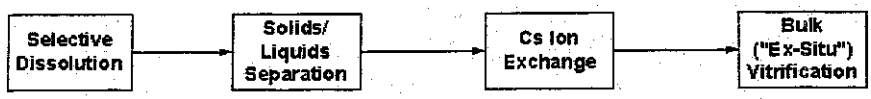
Mission Acceleration Initiative Flowsheet for Bulk (Ex Situ) Vitrification

May 21, 2002

George Reddick

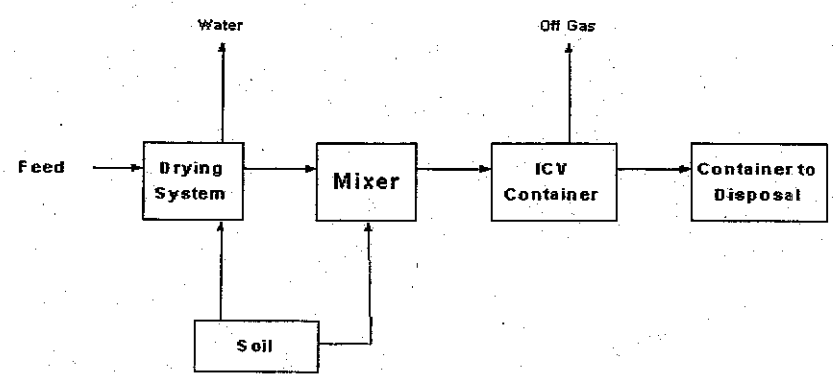
CH2MHILL
Hanford Group, Inc.

Flow Diagram



2

ICV Flow Diagram



3

Process Description

- Process Chemistry
  - 5M sodium feed
  - Mixed with soil (silicates) and dried
  - Mixed with more soil and fed to container
  - Soil mixture heated to 1600°C
  - Sodium oxide loading is 20% in glass
- Process Equipment
  - Staging tank and Dryer
  - Vitrification feed mixer
  - Disposable container with electrodes
  - Off-gas system

4

Process Flexibility

- Ease of Handling Variation of Waste Feed
  - Salt solutions from each tank are uniform
  - Soil mass controls handling of feed
  - Equipment designed to handle solids
  - Vitrification effective over a broad waste feed range
- Ease of Building Modular Process
  - Process and equipment designed for modular service
  - Equipment unit operations have been demonstrated
  - Equipment exists and is available

5

Acceleration

	Original Baseline	Bulk Vitrification Flow Path #1
Tank Processed by WTP	177	109
Tanks Processed by Alternative	-0-	68
ILAW Glass Via WTP	157,900 m^3 420,000 MT	80,200 m^3 213,000 MT
Years to Process ILAW in WTP @ 30 MTG/day	38.4 yrs	19.5
Alternate Waste	-0-	55,600 m^3
Total ILAW Volume	157,900 m^3	136,000 m^3

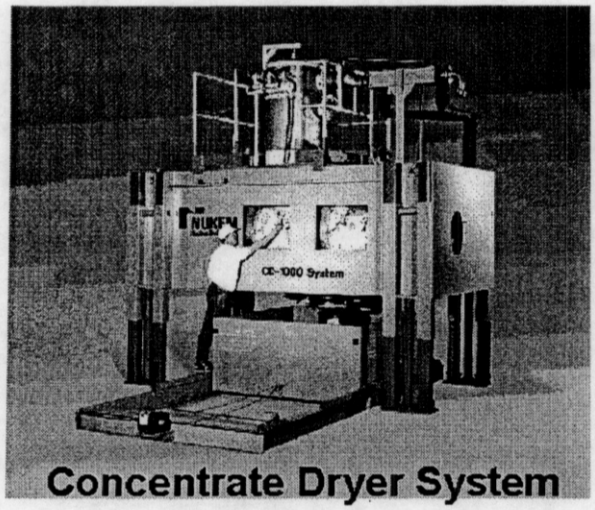
6

Technical Maturity

- Pretreatment
  - Retrieval and Solids separation for all options
  - Cesium IX is the same for all options
- Immobilization
  - Same container sizes have been used commercially
  - No scale up required for feed system, electrodes, or off gas system

7

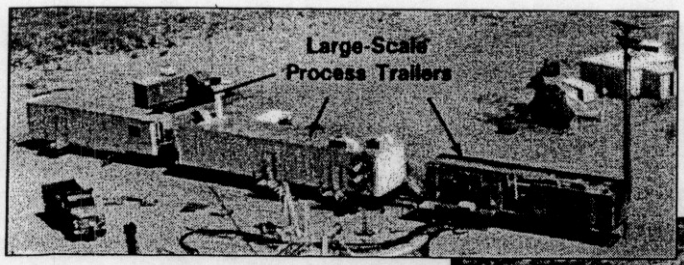
RWE NUKEM Sludge Processing Equipment

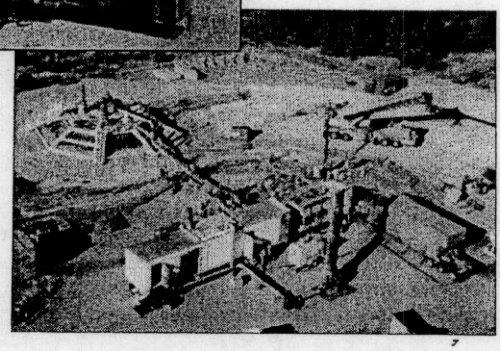


Concentrate Dryer System

8

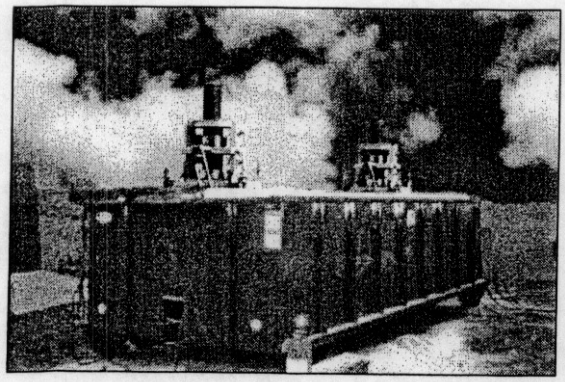
AMEC's GeoMelt Equipment





- 2 Full-scale systems
- Over 20,000 tons processed
- Mobile, located in Richland
- Proven on radioactive and hazardous waste sites
- Each can process two ICV containers in parallel

In-Container Vitrification (ICV)



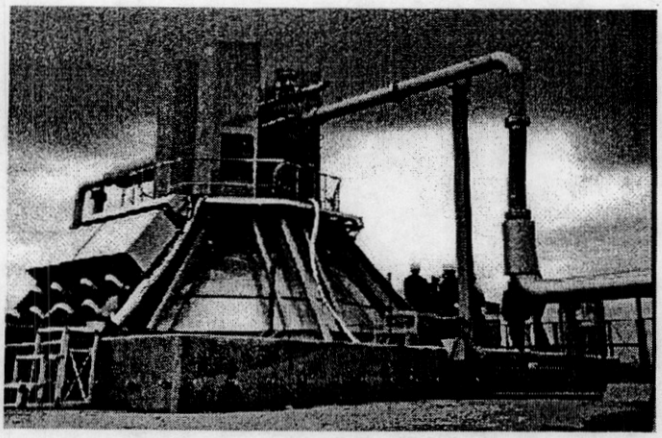
Batch treatment in a 20 cubic yard roll off box (Box can vary in size and shape)

- Waste mixture staged in insulated box

  Hood & electrodes installed
- Wastes treated
- Melt allowed to cool and solidify

  Hood removed, lid installed
- Box transported to burial ground for disposal

10



AMEC GeoMelt-Japan's 30TPD ICV Facility

11

Regulatory Compliance

- Performance typically 10X better than borosilicate glass
- Off Gas Treatment may generate solid and liquid waste
- Ease of Gaining a Permit
  - High temperature process (1600 °C)
  - Qualification of waste form
- Ease of Gaining Waste Incidental to Reprocessing
  - Solids separated and Cs removed
  - Compliant with existing WIR determination
- Is Technetium Removed?
  - Some Tc is removed in selective dissolution
  - Tc is retained in the glass

12

Investment Driver -Cost

Description	Cost $M
Development	25
Infrastructure & Facilities	48
Process Systems	47
Selective Dissolution	11
Liquid/Solid Separation	11
Cs Ion Exchange	14
Bulk (Ex-Situ) Vitrification	**11**
Other Project Costs	14
Operations	21
Closure	7
Sub Total	**161**
Contingency	48
Escalation	14
Total	**223**

13

Active Metal Reduction

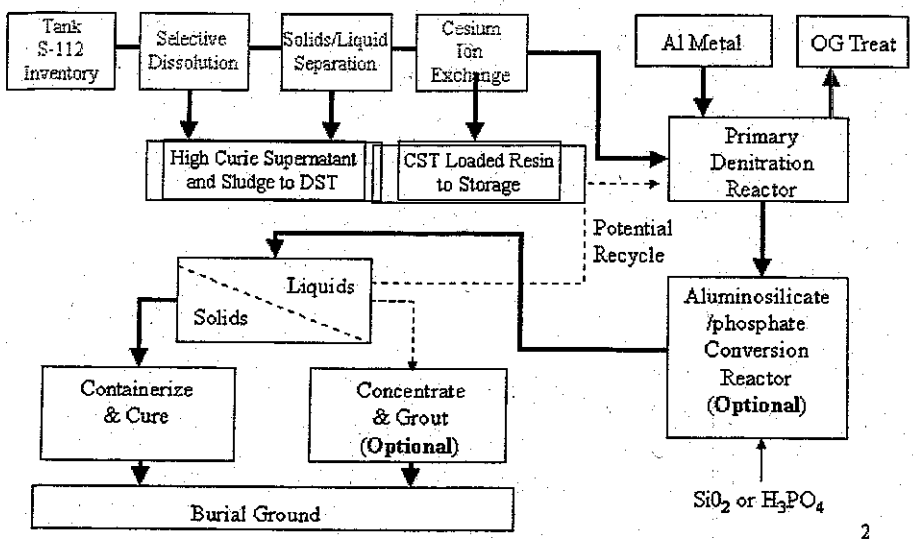
Mission Acceleration Initiative Flowsheet For Active Metal Reduction

May 21, 2002

Rick Brouns

CH2MHILL
Hanford Group, Inc.

Path #2
Active Metal Reactor Flow Diagram



2

Process Description

- Process Chemistry
  - Nitrate solutions converted to $NH_{3\,(g)}$, $NaAlO_2$ (Sodium Aluminate), and $Al(OH)_3$ (Gibbsite).
  - Low temperature (50-120° C) and pressure (atmospheric),
  - Excess heat of reaction removed by cooling coils or distilling H_2O
  - NH_3 and H_2 off gas catalytically oxidized to N_2 and H_2O
  - Metals react with aluminates to produce insoluble spinels
  - Optional 2nd stage reaction produces **extremely insoluble** aluminosilicates/phosphates that bind many alkali metals & earths
  - Reaction residence time is roughly 30 min at solution boiling point (~110 -120° C), and >1 hour at 50-80° C.
  - Fate of sulfate requires further study. Assumed to evolve as H_2S.

3

Process Description (cont'd)

- Process Equipment
  - Continuous stirred tank or fluidized bed reactor (1000 gal.)
  - Aluminum shot solids feeder
  - Offgas condenser, filter and catalytic oxidation system
  - Optional 2nd stage reactor for enhanced waste form development (~1000 gal. stirred tank)
  - Solids/liquid separator (potentially optional)
  - Evaporator and grout mixer for liquid fraction (optional), or return to ETF
  - Extruder or grout pump transfer to drums or standard burial boxes
  - Storage area for curing prior to disposal

4

Process Flexibility

- Ease of Handling Variation of Waste Feed
  - Insensitive to waste composition over wide nitrate range (e.g. 0.1 to 6 M)
  - Gibbsite/Aluminate ratio in the final product is a function of hydroxide/nitrate ratio of feed. Impacts curing and product durability.
  - Optimal product formulation and predictability requires additional R&D
  - Fate of minor constituents and their role in product quality is not well understood. No surprises anticipated.
- Ease of Building Modular Process
  - Low temperature and pressure process uses commercially proven unit operations
  - Exothermic reaction with large excess heat drives process (no energy)
  - Significant process simplification appears feasible. ORNL tests with a single stage denitration reaction and no secondary separation or treatment produced a durable cured product

5

Acceleration

	Original Baseline	Active Metal Reduction Product
Tanks Processed by WTP	177	109
Tanks Processed by Alternative	-0-	68
ILAW Glass Via WTP	157,900 m^3 420,000 MT	*80,200 m^3 213,300 MT
Alternate Waste	-0-	**227,000 m^3 383,600 MT
Years to Process ILAW in WTP @ 30 MTG/day	38.4 yrs	19.5 yrs
Total ILAW Volume	157,900 m^3	307,200 m^3

*Volume of both products

**Base assumption: Aluminophosphate with separate concentration and grouting of liquid phase.

6

Technical Maturity

- Scale of Previous Deployment(s)
  - Bench scale R&D
  - Process studied by ORNL and Florida International University starting in 1993 (> 10 publications)
  - Engineering plans for a pilot scale system completed in 1995. EM cancelled construction due to shifting priorities and funding shortfalls
  - Economic analysis and technology comparisons done for Savannah River Site and by EM-50 for Hanford in 1997 and 1994 respectively.

7

Technical Maturity (cont'd)

- Scale Up Required
  - Reaction kinetics and mechanisms as a function of temperature, feed composition, solution concentration and particle size require additional study
  - Limited study in understanding range of end products that are possible, and the impact of feed variability
  - Waste form: Aluminosilicates are prevalent in nature and a highly studied class of materials. Their performance should be easily predicted. A much more limited understanding of aluminophosphates exists.

8

Regulatory Compliance

- Alternate Waste Form Product Performance
  - Sodium aluminosilicates (NAS), such as the natural zeolites and nephaline minerals, are thermodynamically stable and highly insoluble.
  - Unreacted sodium aluminates are highly soluble and could leach. In contact with silica in the environment, they will slowly convert to NAS.
  - Aluminophosphates require further study
- Temperature – 50 to 120° C
- Off Gas Treatment
  - Treatment of ammonia, hydrogen and possibly hydrogen sulfide may require some special attention.
  - VOCs distilled with steam

9

Regulatory Compliance

- Ease of Gaining a Permit
  - Destruction of nitrate and immobilization of alkali species achieves major benefits of vitrification
  - Non-thermal process with low pressure operation simplifies permitting
  - Flammable gas safety concerns are mitigated by process control, dilution by steam, and inherent safe system design.
- Ease of Gaining WIR
  - Agreement reached in 1993
  - Probably requires update with NRC
- Is Technetium Removed?
  - Selective dissolution

10

Investment Driver - Cost

Description	Cost $M
Development	28
Infrastructure & Facilities	57
Process Systems	56
Selective Dissolution	11
Solid/Liquid Separation	11
Cs Ion Exchange	14
Active Metal Reduction	14
Phosphate Bonded Ceramic	7
Other Project Costs	16
Operations	20
Closure	9
Sub Total	186
Contingency	74
Escalation	17
Total	**$277 M**

11

Summary

Simple reaction system:

- Low temperature and pressure process
- Energy supplied by exothermic reaction
- Easily modified, scaled and modularized vessels
- Aluminum metal and water are only major additives
- Silica or phosphoric acid may be added for improved waste form if required. Silica potentially added directly with waste feed in single step process.
- Byproducts of ammonia and hydrogen safely oxidized catalytically at the vessel vent.

12

Summary (cont'd)

- Gas inventories in reaction vessels remain small due to continual purging
- The reaction is exothermic and requires only mixing/agitation and active water-cooling of outside of vessel for temperature control.
- Excess process water is boiled off and could be condensed and reused.
- Reaction rate is controlled by rate of waste or Al addition, dilution and temperature control.
- Emergency shut down is easily achieved by draining the reaction vessel.
- Reactors are easily stopped and re-started, even after an emergency shutdown.

13

Summary (cont'd)

- Reaction can handle a wide range of concentrations, including that pumped directly from a tank.
- Many components are reduced (e.g. metals such as Cr) to low oxidation states, which are insoluble, and form part of the solid product.

14

Clean Salt

Mission Acceleration Initiative Flowsheet Paths #4A/4B and 5A/5B Clean Salt

May 21, 2002

Michael E. Johnson

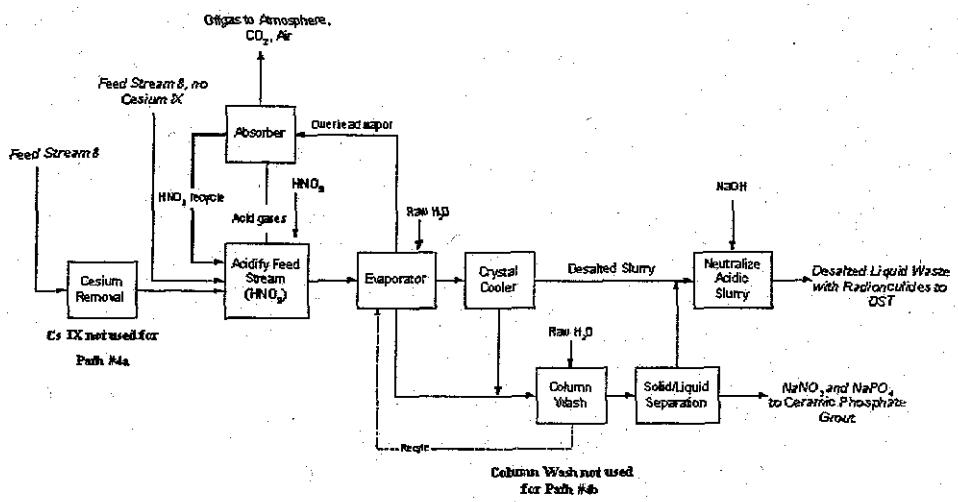
CH2MHILL
Hanford Group, Inc.

Why are Sodium and Sulfate a Problem?

- Sodium and Sulfate are limited in glass
  - Average Na_2O loading in WTP ILAW glass is 11 to 12 wt%
- A separate, molten sulfur layer forms in the joule-heated melter if sulfate solubility in glass is exceeded
  - Steam explosion is possible
  - Off-gas treatment needed for volatilized sulfur compounds

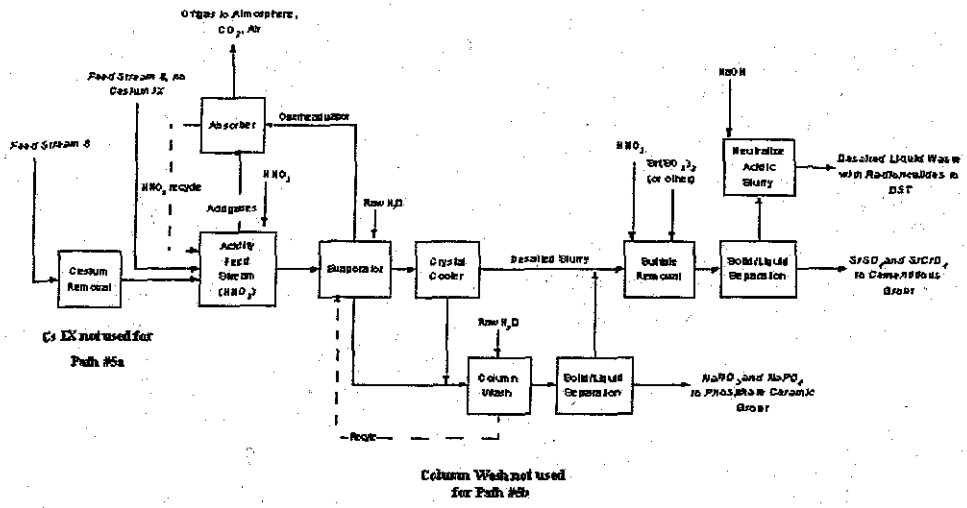
2

Path #4A and 4B Flow Diagram



3

Path #5A and 5B Flow Diagram



4

Process Description – Paths #4A/4B

- Process Chemistry - Clean Salt
  - 5M Sodium Feed
  - Acidify waste with HNO_3 to pH 2.0
  - Evaporation at 110°C (atmospheric)
  - Slurry cooled to crystallize $NaNO_3$ and $AlPO_4$
  - Simple off-gas system to treat acid gases, remove NO_x
- Process Chemistry – Ceramicrete
  - $NaNO_3$ and $AlPO_4$ are mixed with MgO powder and KH_2PO_4 to form Ceramicrete
  - Exothermic reaction (maximum temperature 80°C)
  - Metals chemically bound
  - Alkali metals (Na, K, Cs) and nitrate not chemically bound

5

Process Description – Paths #5A/5B

- Process Chemistry - Clean Salt
  - Same as Paths #4A/4B
- Process Chemistry - Sulfate Extension
  - Feed is acidic supernate from Clean Salt, adjusted with HNO_3 to pH 1.0
  - Add excess $Sr(NO_3)_2$ to precipitate $SrSO_4$, $SrCrO_4$, (and some $AlPO_4$)
  - Same off-gas system as Clean Salt
- Process Chemistry – Grout / Polyethylene
  - $SrSO_4$ / $SrCrO_4$ (and $AlPO_4$) precipitates incorporated into Grout;
  - Metals chemically bound (similar to Path #6)
  - Clean Salt solidified in Polyethylene to encapsulate sodium nitrate

6

Process Description (cont'd)

- Process Equipment - Clean Salt (Preliminary Estimates)
  - Feed Acidification Tank (400 gallons)
  - Off-gas Absorber (not sized)
  - Evaporator/Cooler (2,000,000 BTU/hr)
  - Wash Column (Path 4A/5A only) (100 gallons)
  - Solid/Liquid Separation (700 gallons)
  - Waste Neutralization (2 tanks, 100 gallons)

  Process Equipment - Sulfate Extension (Paths #5A/B)
  - Feed Acidification Tank (100 gallons)
  - Feed Precipitation Tank (100 gallons)
  - Solids/Liquid Separation (not sized)
  - Neutralization Tank (100 gallons)

7

Process Flexibility

- Ease of Handling Variation of Waste Feed
  - Capable of processing all dissolved saltcake
  - Quantity of Al in acidic waste solution affects amount of NaOH needed to neutralize waste to DSTs
    - Increases amount of ILAW Glass produced at WTP
  - Organic compounds are decomposed during acidification of the dissolved saltcake
    - Off-gases generated during acidification
    - Waste foaming may occur
  - Ceramicrete, grout, or polyethylene waste formulations optimized with additional development

8

Process Flexibility

- Ease of Building Modular Process
  - Modules similar to Solids/Liquid Separations and Evaporator modules constructed / operated for ORNL Wastewater Triad
  - Clean Salt unit operation complexity based on radionuclide concentration in feed and allowable contamination in salt product
    - Determines number of evaporation / crystallization and wash cycles
  - Minimal complexity in Ceramicrete and other waste form equipment

9

Acceleration

	Original Baseline	Path #4A/4B	Path #5A/5B
Tanks Processed by WTP	177	109	109
Tanks Processed by Alternative	-0-	68	68
ILAW Glass Via WTP	157,900 m^3 420,000 MT	139,800 m^3 371,900 MT	89,400 m^3 273,800 MT
Alternate Waste	-0-	44,600 m^3 82,500 MT (Ceramicrete)	55,300 m^3 93,500 MT (Polyethylene and Grout)
Years to Process ILAW in WTP @ 30 MTG/day	38.4 yrs	33.9 yrs	21.7 yrs
Total ILAW Volume	157,900 m^3	184,400 m^3	144,700 m^3

10

Technical Maturity

- Pretreatment
  - Scale of Previous Deployment(s)
    - Clean Salt: Lab-scale with radioactive waste samples
    - Strontium Sulfate precipitation: Full-scale (1,400-gallon / batch) in Hanford B Plant (1974 – 1985)
  - Scale Up Required ~ yes
- Immobilization
  - Scale of Previous Deployment(s)
    - Ceramicrete (Paths 4A/4B): Lab-scale with Hanford simulants
    - Micro Encapsulation (Paths 5A/5B): Bench-scale with simulants
    - Grout (Paths 5A/5B): $SrSO_4$ in grout has not been demonstrated
  - Scale Up Required ~ yes

11

Regulatory Compliance

- Alternate Waste Form Product Performance
  - Nitrate leaching from Ceramicrete and Polyethylene
  - Ceramicrete and Polyethylene should comply with UTS for metals
- Temperature
  - Waste Evaporation at 110°C;
  - Ceramicrete at 80°C; Polyethylene at 120°C to 180°C
- Off Gas Treatment
  - NO_x and organic vapor abatement
- Ease of Gaining a Permit
  - Engineered disposal system needed to comply with drinking water standards for nitrate
- Ease of Gaining WIR
  - Compliant with existing WIR determination
- Is Technetium Removed? Yes, transferred to WTP

12

Investment Driver - Cost

Description- Path #4A	Cost K$
Development	26
Infrastructure & Facilities	54
Process Systems	53
Selective Dissolution	11
Liquid/Solid Separation	11
Clean Salt	25
Ceramic Grout	6
Other Project Costs	15
Operations	21
Closure	8
Subtotal	176
Contigency	70
Escalation	16
Total	**262**

Description- Path #4B	Cost K$
Development	26
Infrastructure & Facilities	68
Process Systems	67
Selective Dissolution	11
Liquid/Solid Separation	11
Cs Ion Exchange	14
Clean Salt	25
Ceramic Grout	6
Other Project Costs	17
Operations	22
Closure	10
Subtotal	209
Contingency	84
Escalation	19
Total	**312**

13

Investment Driver - Cost

Description- Path #5A	Cost K$
Development	28
Infrastructure & Facilities	76
Process Systems	75
Selective Dissolution	11
Liquid/Solid Separation	11
Clean Salt	25
Micro-Encapsulation	8
Sulfate Removal	14
Waste Specific Grout	6
Other Project Costs	18
Operations	23
Closure	10
Subtotal	231
Contingency	115
Escalation	23
Total	**368**

Description- Path #5B	Cost K$
Development	32
Infrastructure & Facilities	90
Process Systems	89
Selective Dissolution	11
Liquid/Solid Separation	11
Cs Ion Exchange	14
Clean Salt	25
Micro-Encapsulation	8
Sulfate Extension	14
Waste Specific Grout	6
Other Project Costs	21
Operations	24
Closure	12
Subtotal	267
Contingency	134
Escalation	26
Total	**427**

14

Sulfate Removal

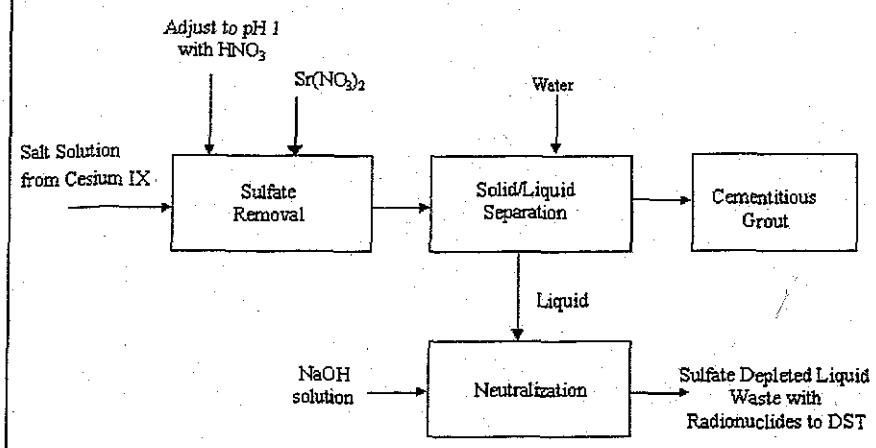
Mission Acceleration Initiative
Flowsheet Paths #7
Sulfate Removal

May 21, 2002

Michael E. Johnson

CH2MHILL
Hanford Group, Inc.

Path #7 Flow Diagram



2

Process Description

- Process Chemistry – Sulfate Precipitation
  - 5M Sodium solution from Cs IX
  - Adjusted with HNO_3 to pH 1.0
  - Heat to 60°C and add excess $Sr(NO_3)_2$ to precipitate $SrSO_4$, $SrCrO_4$, (and some $AlPO_4$)
  - Simple off-gas system to treat acid gases, remove NO_x
- Process Chemistry – Grout
  - $SrSO_4$ / $SrCrO_4$ (and $AlPO_4$) precipitates incorporated into Grout
  - Metals chemically bound (similar to Path #6)

3

Process Description

- Process Equipment (Preliminary Estimates)
  - Feed Acidification tank (100 gallons)
  - Feed Precipitation Tank (100 gallons)
  - Solids/Liquid Separation (not sized)
  - Neutralization Tanks (two tanks, 100 gallons each)
  - Off-gas treatment (not sized)

4

Process Flexibility

- Ease of Handling Variation of Waste Feed
  - Capable of processing all dissolved saltcake
  - Quantity of Al in acidic waste solution affects amount of NaOH needed to neutralize waste to DSTs
    - Increases amount of ILAW Glass produced at WTP
  - Organic compounds are decomposed during acidification of the dissolved saltcake
    - Off-gases generated during acidification
    - Waste foaming may occur
  - Grout formulations optimized with additional development

5

Process Flexibility

- Ease of Building Modular Process
  - Modules similar to Solids/Liquid Separations module constructed / operated for ORNL Wastewater Triad
  - Minimal complexity in Grout
    - $SrSO_4$ / $SrCrO_4$ (and $AlPO_4$) precipitates may not require solidification in Grout for disposal

6

Acceleration

	Original Baseline	Path #7
Tanks Processed by WTP	177	109
Tanks Processed by Alternative	-0-	68
ILAW Glass Via WTP	157,900 m^3 420,000 MT	*120,000 m^3 319,200 MT
Alternate Waste	-0-	34,200 m^3 51,000 MT (Grout)
Years to Process ILAW in WTP @ 30 MTG/day	38.4 yrs	29.1 yrs
Total ILAW Volume	157,900 m^3	154,200 m^3

*ILAW glass volumes could be further reduced by treating DST supernate and not conducting selective dissolution.

7

Technical Maturity

- Pretreatment
  - Scale of Previous Deployment(s)
    - Strontium Sulfate precipitation: Full-scale (1,400-gallon / batch) in Hanford B Plant (1974 – 1985)
    - Lab-scale testing of waste acidification using AN-102 and AN-107 radioactive waste sample
  - Scale Up Required
    - Yes
- Immobilization
  - Scale of Previous Deployment(s)
    - Grout treatment facility an order of magnitude larger
    - Used internationally for waste immobilization
  - Scale Up Required
    - None

8

Regulatory Compliance

- Alternate Waste Form Product Performance
  - Should comply with UTS for metals and drinking water standards for nitrate
- Temperature
  - Ambient to 60°C (sulfate precipitation)
- Off Gas Treatment
  - NO_x and organic vapor abatement
- Ease of Gaining a Permit
  - Engineered disposal system *not* needed to comply with drinking water standards for nitrate
- Ease of Gaining WIR
  - Compliant with existing WIR determination
- Is Technetium Removed? Yes, transferred to WTP

9

Investment Driver - Cost

Description/Path #7	Cost $K
Development	22
Infrastructure & Facilities	50
Process Systems	50
Selective Dissolution	11
Liquid/Solid Separation	11
Cs Ion Exchange	14
Sulfate Removal	14
Cementitious Grout	6
Other Project Costs	14
Operations	22
Closure	8
Sub Total	166
Contingency	58
Escalation	15
Total	**$239**

10

Containerized Grout

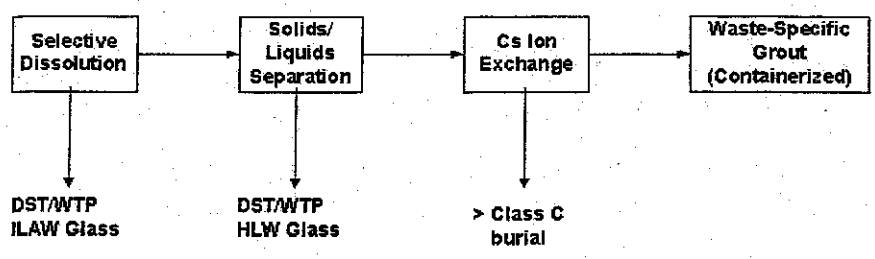
Mission Acceleration Initiative Flowsheet For Containerized Grout

May 21, 2002

Jeff Voogd

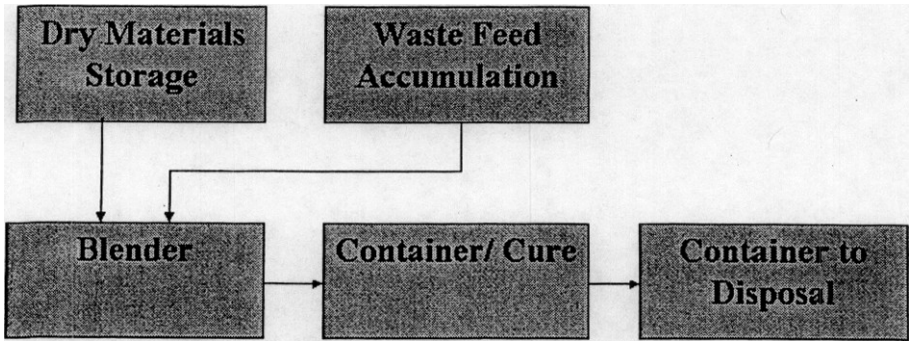
CH2MHILL
Hanford Group, Inc.

Path #6 Flow Diagram



2

Grout Flow Sheet



3

Process Description

- Process Chemistry
  - 5M Sodium in feed mixed with Portland Cement (for scoping)
  - Ambient temperatures, simple process off-gas system
  - Metals chemically bound (Cr, Hg, U, etc.)
  - Challenge to bind alkali metals (Na, K, Cs) and nitrates
- Process Equipment
  - 8 hr Feed Accumulation tank (3000 gallons)
  - 3 storage tanks (cement, fly ash, slag), with pneumatic conveyers
  - Mixing in 10-15 minutes, Pour in 3.6 m^3 Boxes (4' X 4' x 8')
  - 15 Containers/day
  - Assumed 28 days curing in storage before disposal

4

Process Flexibility

- Ease of Handling Variation of Waste Feed
  - Formulations can be optimized with additional development
  - Variations adjusted to Sodium concentration or waste loading
- Ease of Building Modular Process
  - Grout offers simple process
  - Control of curing process important to quality
  - Assumed permanent structure in estimate

5

Acceleration

	Original Baseline	Containerized Grout Flow Path #6
Tanks Processed by WTP	177	109
Tanks Processed by Alternative	-0-	68
ILAW Glass Via WTP	157,900 m^3 420,000 MT	69,100 m^3 183,800 MT
Alternate Waste	-0-	282,000 m^3 364,000 MT
Years to Process ILAW in WTP @ 30 MTG/day	38.4 yrs	19.5 yrs
Total ILAW Volume	157,900 m^3	362,100 m^3

6

Technical Maturity

- Pretreatment
  - Scale of Previous Deployment(s)
    - Cesium IX same for all options
  - Scale Up Required ~ None
- Immobilization
  - Scale of Previous Deployment(s)
    - Hanford grout treatment facility an order of magnitude larger
    - Used internationally for waste immobilization
  - Scale Up Required ~None

7

Regulatory Compliance

- Alternate Waste Form Product Performance, dependent upon:
  - Crystal structure
  - Connectivity of pore structure
  - Ion exchange properties of dry materials
  - Disposal system barriers
- Temperature
  - Processing ambient
  - Curing, may need cooling
- Off Gas Treatment
  - Dust control for dry materials (Non-Radioactive)
  - Confinement for processing (Radioactive)

8

Regulatory Compliance (cont'd)

- Ease of gaining a Permit
  - Precedence at Hanford and other sites
  - Challenges; nitrates and organics
- Ease of gaining WIR
  - Agreement reached in 1993
  - Probably requires update with NRC
- Is Technetium Removed?
  - Selective dissolution

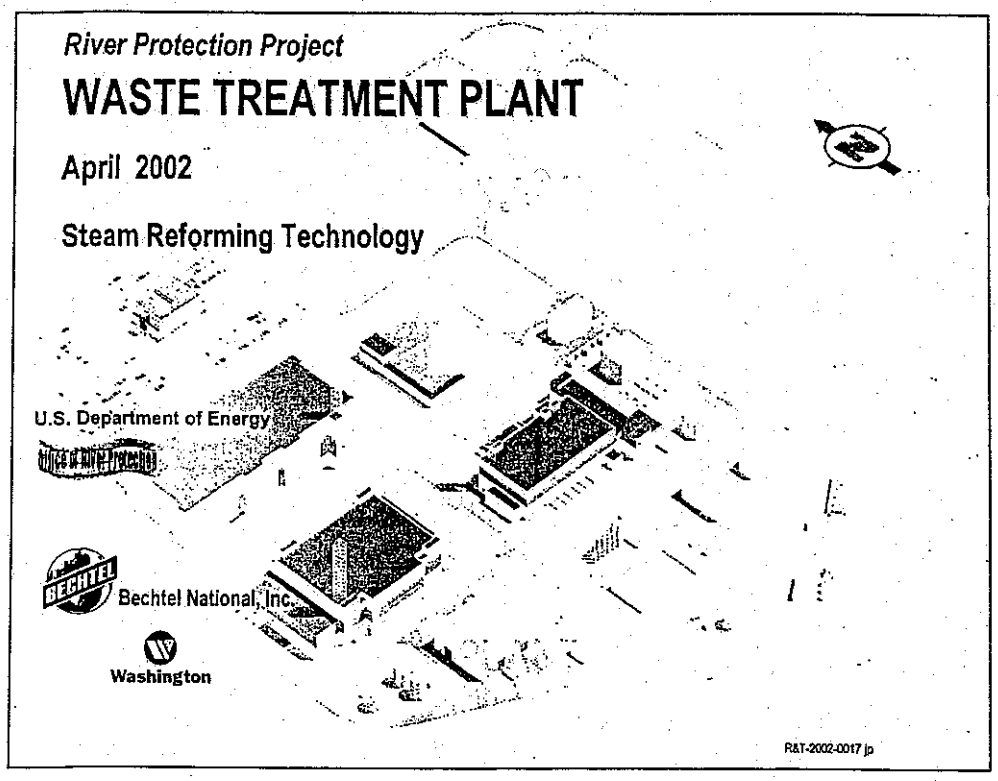
9

Investment Driver - Cost

Description		Cost $M
Development		20
Infrastructure & Facilities		42
Process Systems		41
Selective Dissolution		11
Solid/Liquid Separation		11
Cs Ion Exchange		14
Waste Specific Grout		**6**
Other Project Costs		13
Operations		19
Closure		6
	Sub Total	141
Contingency		42
Escalation		12
	Total	**$195 M**

10

Steam Reforming



Steam Reforming Technology

- **Alternative Processing Technology - Steam Reforming**
  - Technology based on fluid bed process
- **Basis for Consideration at WTP**
  - Eliminate nitrates
  - Destroy organics
  - Simple, robust design and operation
  - Higher throughput/unit area compared to vitrification
  - Advance the overall waste processing schedule
  - Simplify processing - eliminate recycle

R&T-2002-0017 jp

Steam Reforming Opportunity

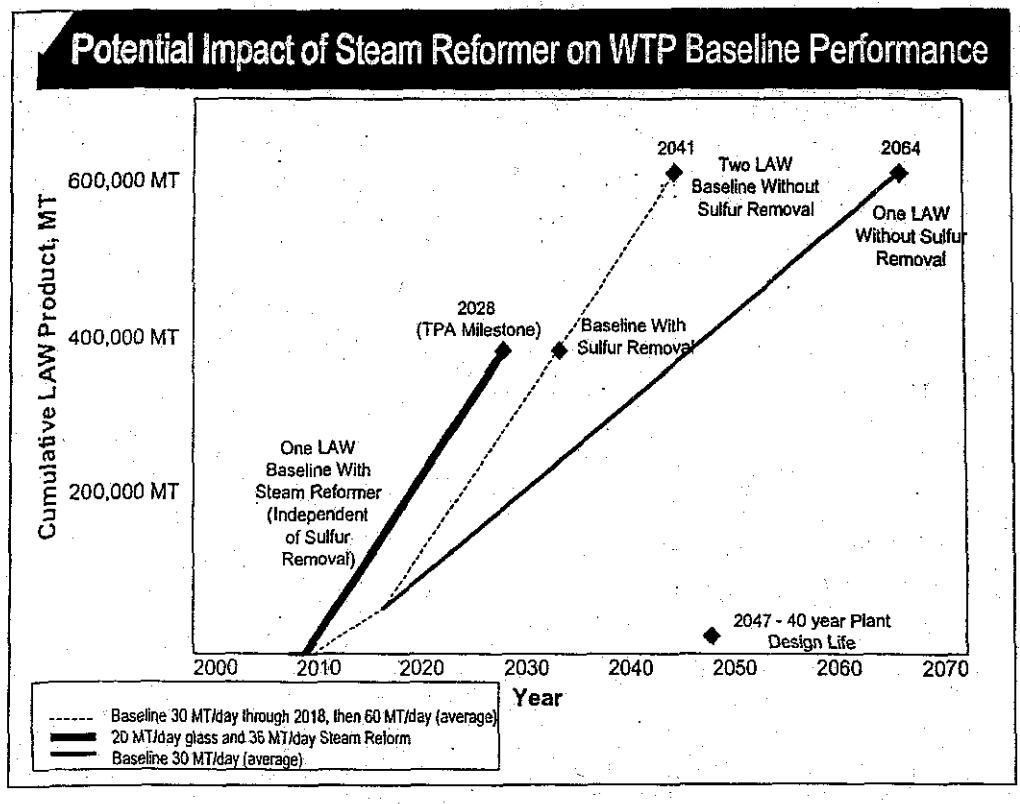
- Steam Reforming Technology
  - Reactions occur in fluidized bed reactor
  - Reduce nitrates to N2
  - Reduce/destroy organics
  - Operating pressure below atmosphere
  - Operating temperature around 700°C
- Steam Reformer Product
  - Solid, granular material
  - Initial tests promising
    - Cs, sulfur, captured in waste "mineral" waste form
- Status
  - Developed detailed R&T Plan to complete evaluation of technology 4/2f

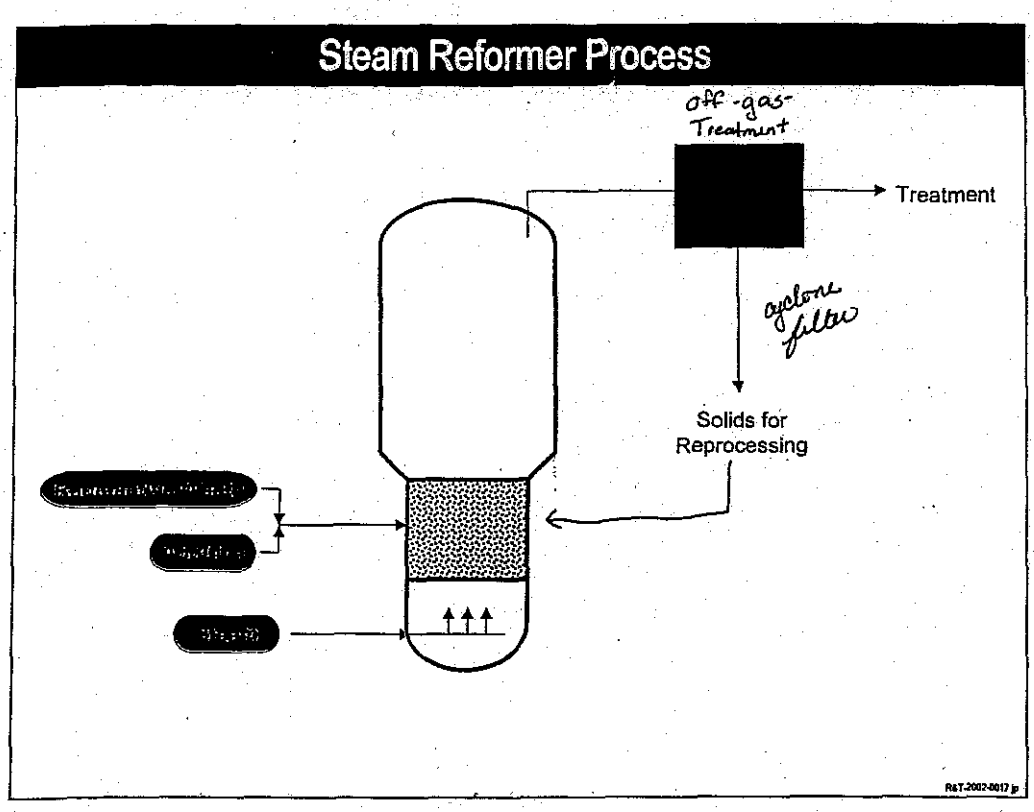
R&T-2002-0017 jp

What Is Steam Reforming?

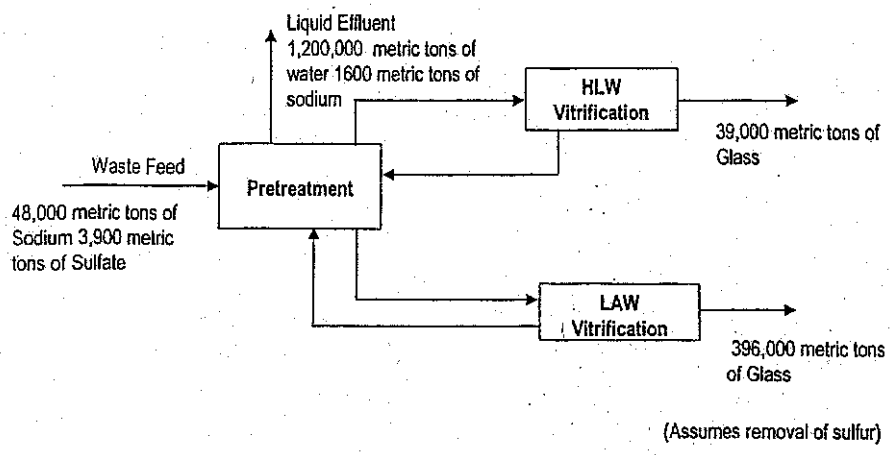
- Technology utilized in other industry for decades - first studied in 1868
- Used in large scale by the petrochemical industry
- What is it?
  - Organic + $H_20^{(steam)} \longrightarrow CO + H_2$ (organic destruction)
- Why consider for Hanford wastes?
  - Low-level waste comprised of spent chemicals - sodium hydroxide, sodium nitrate
  - $CO + NO_x \xrightarrow[\text{Catalyst}]{\Delta} N_2 + CO_2$ (nitrate destruction)

R&T-2002-0017 jp

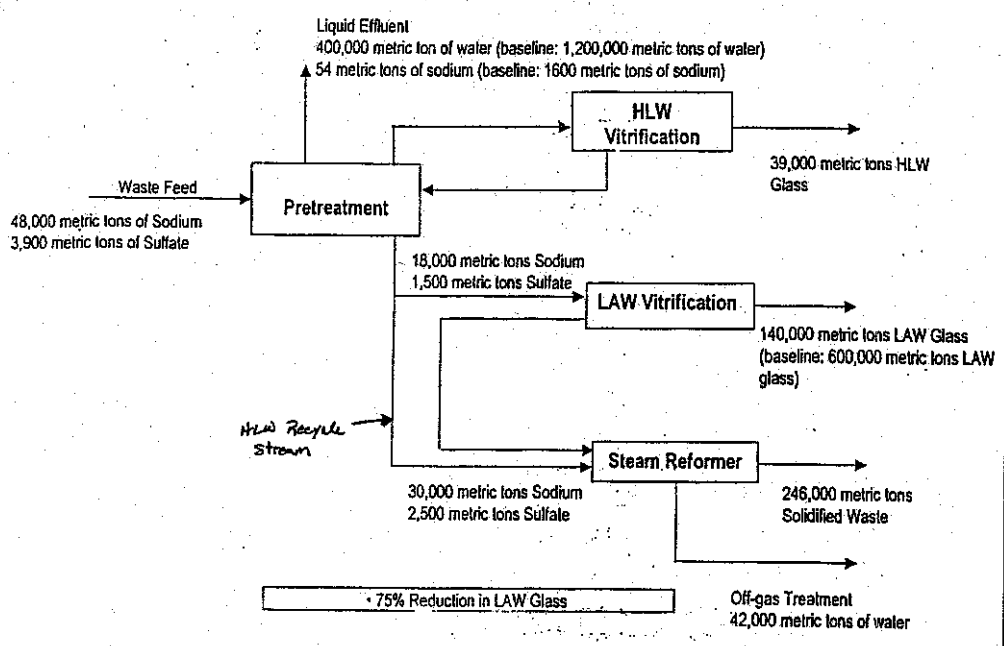

Potential Impact of Steam Reformer on WTP Baseline Performance
Cumulative LAW Product, MT
600,000 MT
400,000 MT
200,000 MT
2041
Two LAW Baseline Without Sulfur Removal
2064
One LAW Without Sulfur Removal
2028 (TPA Milestone)
Baseline With Sulfur Removal
One LAW Baseline With Steam Reformer (Independent of Sulfur Removal)
2047 - 40 year Plant Design Life
2000
2010
2020
2030
2040
2050
2060
2070
Year
Baseline 30 MT/day through 2018, then 60 MT/day (average)
20 MT/day glass and 36 MT/day Steam Reform
Baseline 30 MT/day (average)


Steam Reformer Process
off-gas Treatment
Treatment
cyclone filter
Solids for Reprocessing

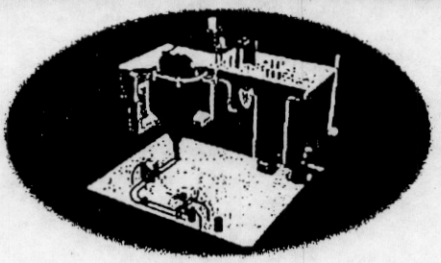
Baseline WTP Material Balance



Steam Reformer Implementation Option (LAW Solidification and Off-gas Treatment Solidification)



Potential Benefits of Steam Reforming



- Enables completion of mission by 2028
- Safely destroys nitrates in the wastes
- Destroys organic waste
- Eliminates waste recycle between facilities (single pass operation)
- Produces a stable mineral waste form
- Opportunity for early tank closure

RLT-2002-0017 jp

River Protection Project

WASTE TREATMENT PLANT

May 9, 2002

Steam Reforming Briefing to Hanford Advisory Board

U.S. Department of Energy
Office of River Protection

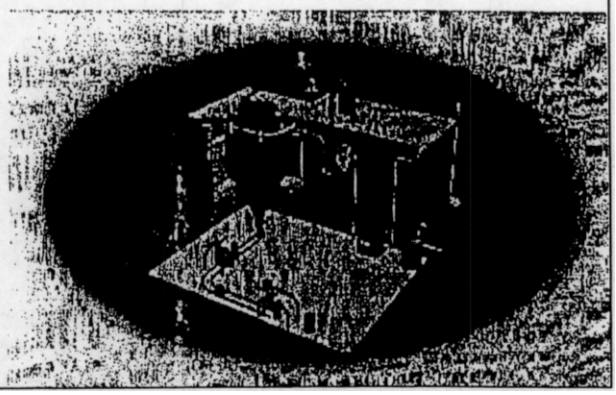
Bechtel National, Inc.

Washington

www.waste2glass.com

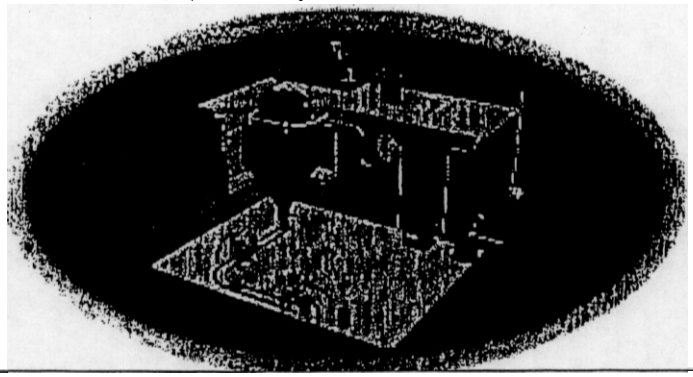
Steam Reforming Briefing to HAB

- Technical Aspects of Steam Reforming
- Using Steam Reforming in WTP
- Path Forward



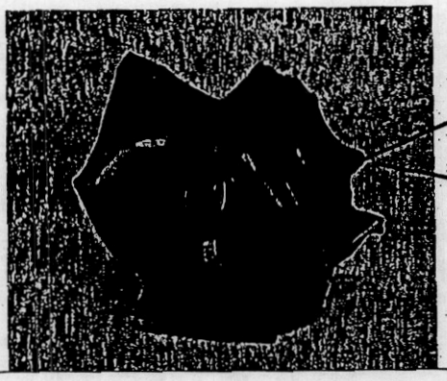
Why Consider Steam Reforming?

- A technology used in conjunction with vitirifcation that may:
  - Enable project to be completed sooner
  - Reduce life cycle operating costs
  - Simplify plant operations



WTP Baseline

- Our focus: Vitrification of Hanford's tank waste
- Construct the WTP using the baseline technology



High-Level Waste
39,000 MT glass

Low-Level Waste
600,000 MT glass

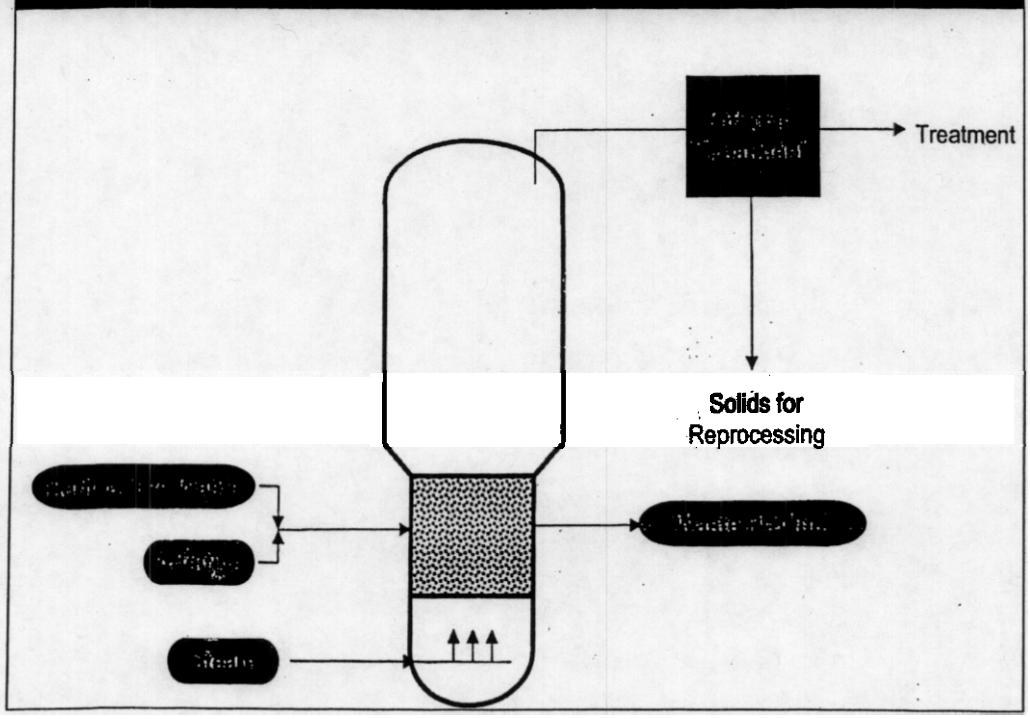
Why Consider Steam Reforming?

- A technology used in conjunction with vitirifcation that may:
  - Enable project to be completed sooner
  - Reduce life cycle operating costs
  - Simplify plant operations

What Is Steam Reforming?

- What is it?
  - Organic + $H_20^{(steam)}$ $CO + H_2$ (organic destruction)
- Why consider for Hanford wastes?
  - Low-level waste comprised of spent chemicals - sodium hydroxide, sodium nitrate
  - $CO + NO_x \xrightarrow[\text{Catalyst}]{\Delta} N_2 + CO_2$ (nitrate destruction)
  - Product is solid granular material - a stable "mineral" form
  - Cs, other radionuclides, and sulfur captured in this waste "mineral" form

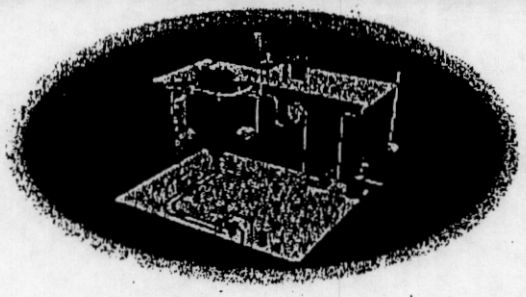
Steam Reformer Process



Experience with Steam Reforming

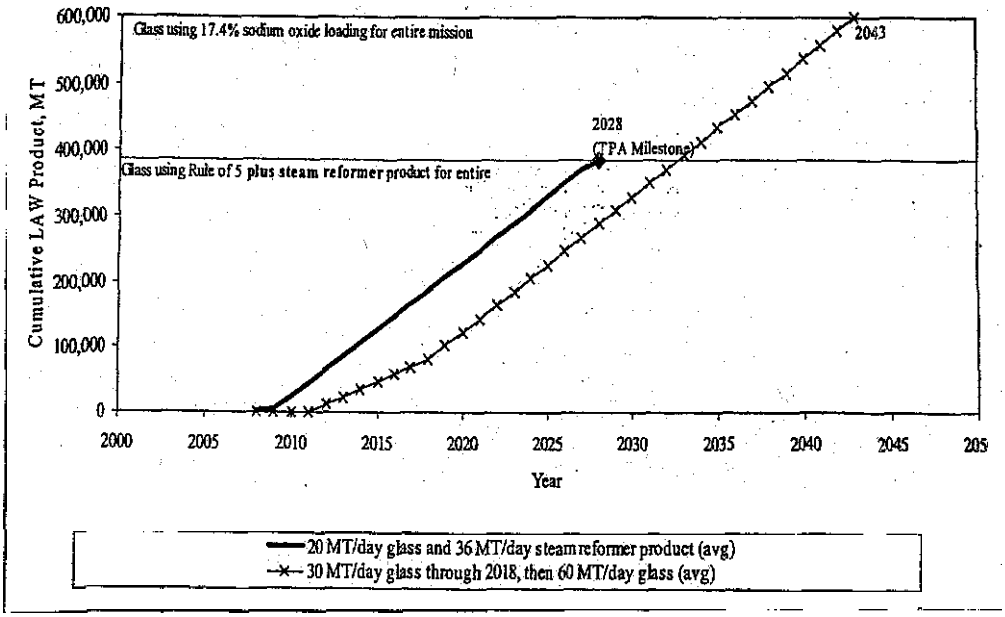
- Technology utilized in other industry for decades - first studied in 1868
- Used in large scale by the petrochemical industry
- Has been used commercially for low level waste by Duratek, Thermo Chem, and Studsvik.
- BNI has AN-107 tank simulant tested in 2001

Potential Benefits of Steam Reforming

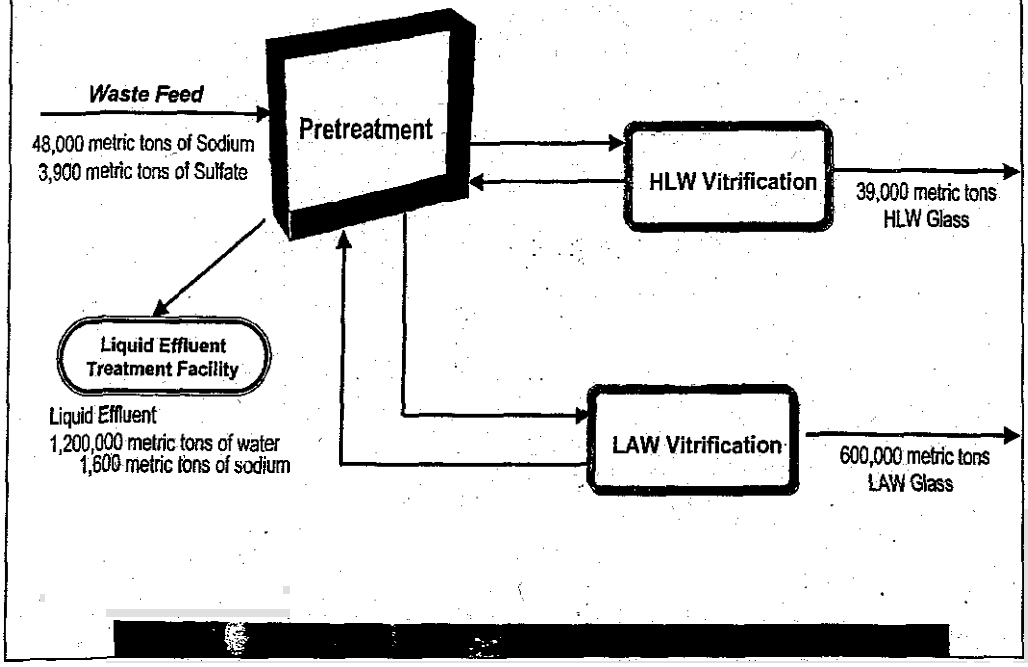


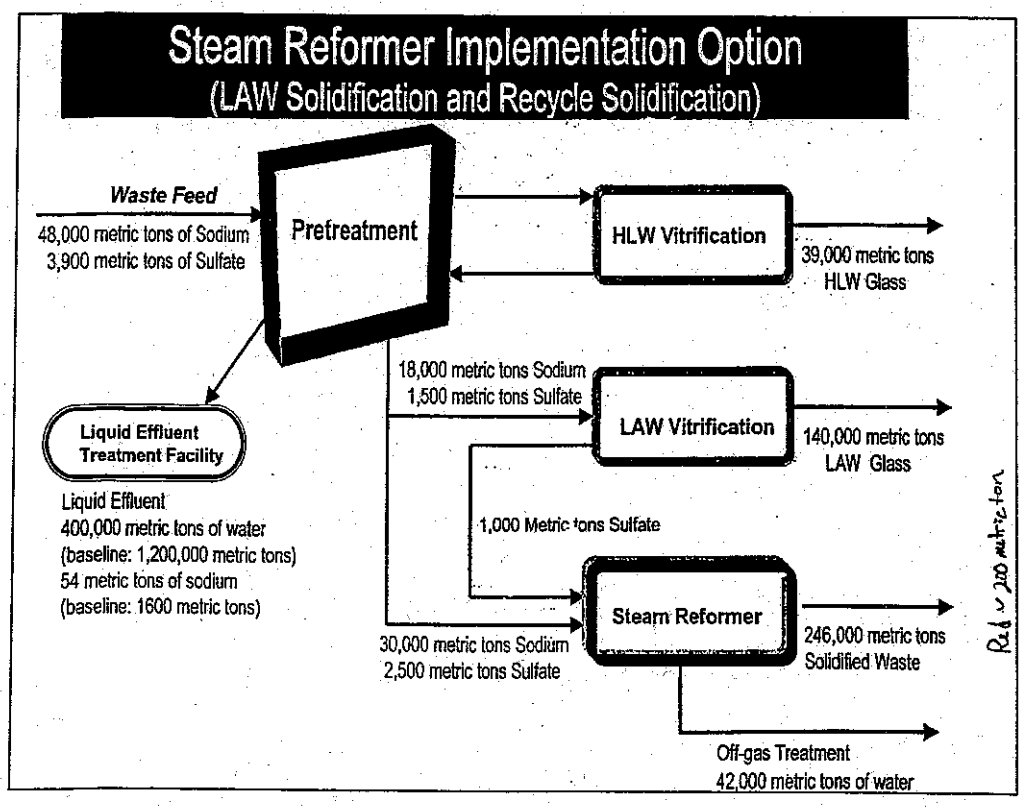
- Enables earlier completion of mission - opportunity for early tank closure
- Eliminates waste recycle between facilities (single pass operation)
- Can be implemented in the WTP flowsheet with essentially no impact to baseline - no HLW and Pre-treatment impact - and minimal impact to LAW
- Reduced waste volume compared to glass and reduced effluents
- Cost effective alternative to additional vitrification
- Destroys nitrates and organic waste effectively; produces comparable waste form

Impact of Steam Reformer on WTP Baseline Performance



Baseline WTP Material Balance





Steam Reforming

Next Step:
Perform durability test on waste product

Followed by:
Competitively bid testing phase to determine process that will:

- Validate performance of process
- Reduce mass of material disposed
- Determine waste form characteristics; must produce an acceptable waste form for disposal
- Give confidence to proceed with design phase

Steam Reforming

Schedule for Testing Phase

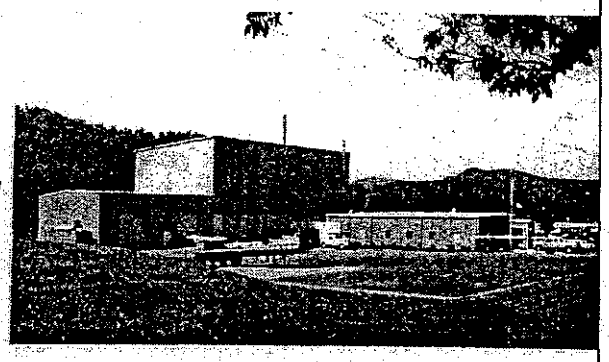
- Request bids to acquire steam reforming technology (5/02)
- Complete Lab scale testing (7/02)
- Award technology contract (7/02)
- Complete bench-scale tests using simulant (12/02)
- Complete bench-scale tests using radioactive waste(1/03)
- Proposed start of pilot plant and full-scale steam reformer design(4/03)

THORsm Steam Reformer Technology for Hanford Tank Waste Support

THOR

Outline

- Studsvik Experience
- Hanford Tank Waste Application
  - Flow Diagram
  - Operations and Safety
  - Waste Form
- Process Maturity

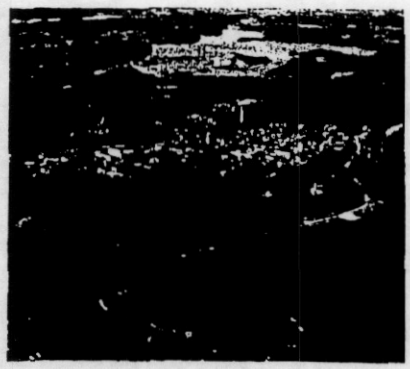


Studsvik

RESUME

THOR

- Studsvik, AB (Swedish Parent of Studsvik, Inc.)
  - DAW Incinerator since 1982
  - Decommissioning
    - Chemical Decon
    - Metal Melting
  - Research Reactor
  - Laboratory Facilities
  - Environmental Consulting
  - Resin Pyrolysis Processing



- Studsvik Processing Facility (Erwin TN, 1996)

Studsvik

RADWASTE TREATMENT EXPERIENCE

THOR

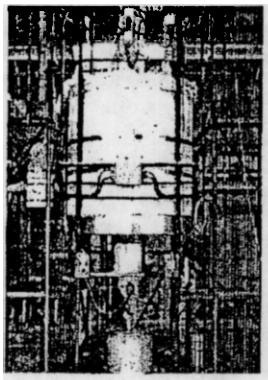
- Steam Reforming (gasification, salt conversion, denitration)
- Pyrolysis (gasification)
- Vitrification (glassification)
- Fluidized Bed Technology (gasification,drying)
- Incineration (DAW)
- Evaporators and Dryers (salts, inorganics)
- HICs, Specialized Waste Containers
- Remote Handling Devices
- Waste Solidification Systems (cement, polymer)

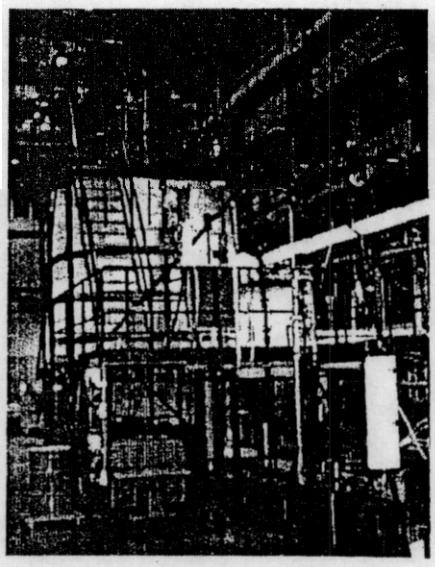
Studsvik

THORsm DEVELOPMENT

Pyrolysis Test Facilities

- LLRW Qualification
- Dry Resin Input
- 10 kg/hr



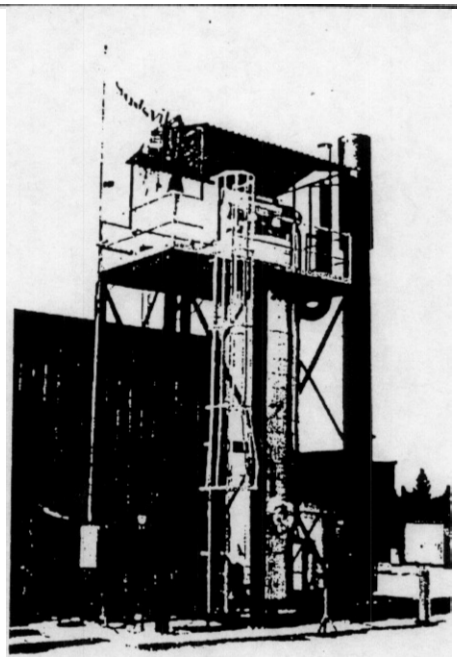


Studsvik

THORsm DEVELOPMENT

Pyrolysis Demo Facility

- Scale Up Demonstration
- Dry Resin Input
- 100 kg/hr



Studsvik

THORsm STEAM REFORMING

THOR

Studsvik Processing Facility - Overview

- Pyrolysis + Steam Reforming
- 45" Fluid Bed Steam Reformer
- Waste Feed:
  - 300 to 550 kg/h Slurry Feed
  - Up to 400 R/h LLRW Input Feed
  - >60,000 cu ft Ion Exchange Resin, Salts, Oils
- Commercial Operations: > 2.5 years
- Licensing: Non-Incineration
- Residue Radionuclide Retention: >99.9% (Including Cs)

Studsvik

THORsm STEAM REFORMING

THOR

Studsvik Processing Facility -Overview

- Turnkey Production Scale Plant
- Operating Commercially since July 1999
- Process Systems Proven in Radiological Service
- Remotely Operable, Heavily Shielded
- Contact Maintenance
- Single Step Thermal Denitration and Immobilization

Studsvik

THOR^{sm} STEAM REFORMING APPLICATIONS*

- Organic Destruction
  - $C_xH_y + H_2O \rightarrow CO / CO_2 + H_2O$
- Conversion of Alkali Metals to Stable Minerals
  - Na / K + Additive $\rightarrow$ $Na_2O\text{-}Al_2O_3\text{-}2SiO_2$
    $Na_2O\text{-}Al_2O_3$
    Na_2CO_3
- Conversion of Metals to Oxides/Carbonates
  - $Cr/CrO_3 \rightarrow Cr_2O_3$
- Gasification of Carbon
  - $C + H_2O \rightarrow CO + H_2$
- Reduction of Nitrates and Nitrites to Nitrogen Gas
  - $NO_3 / NO_2 + CO/H_2 \rightarrow N_2 + CO_2 + H_2O$

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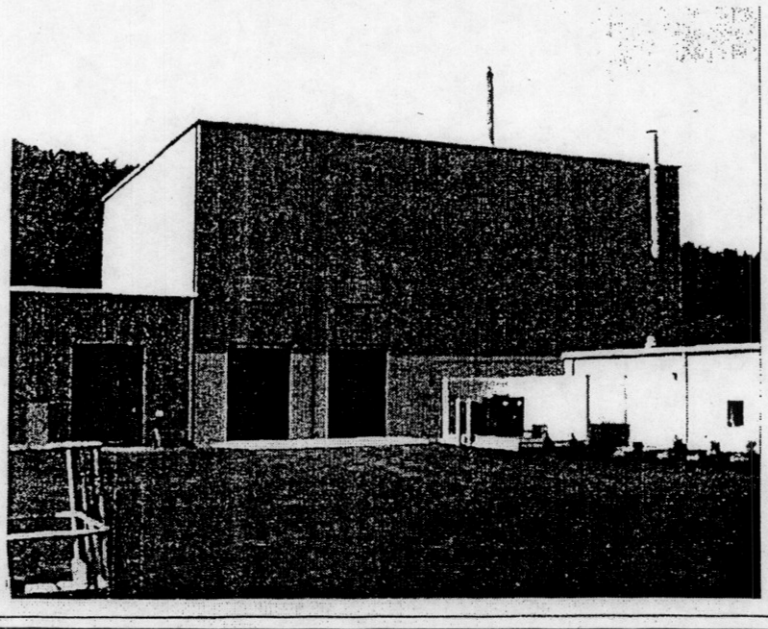
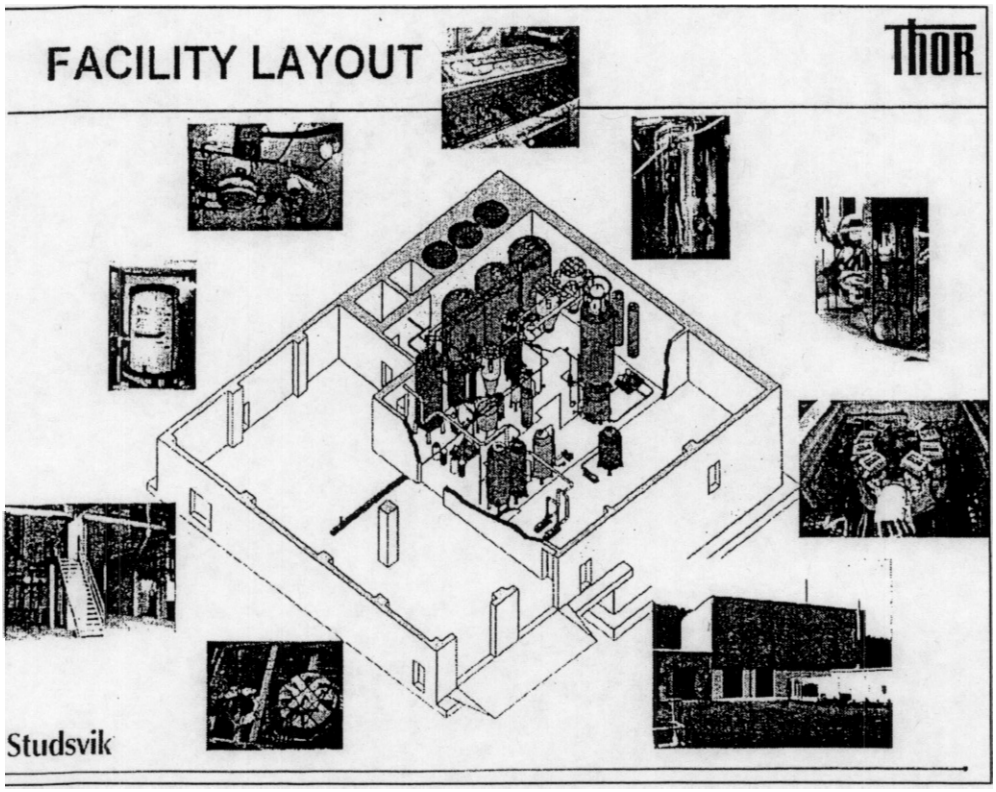
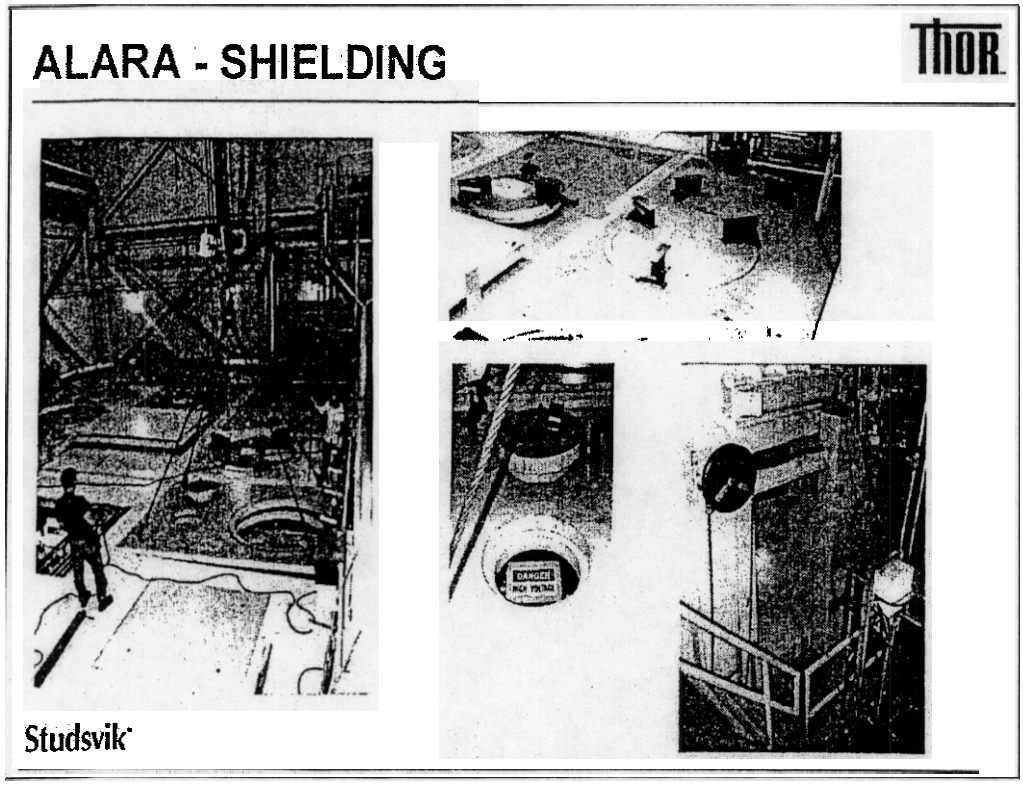
* Protected by Issued and Pending Patents

Studsvik Processing Facility



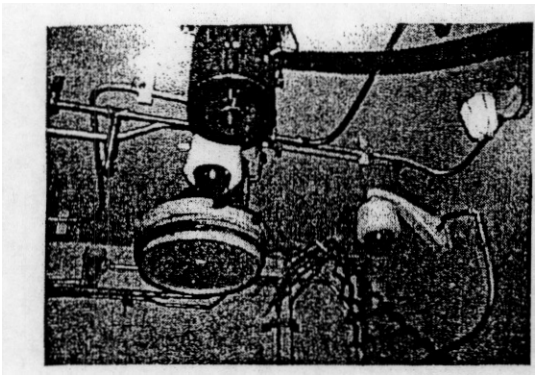
Studsvik

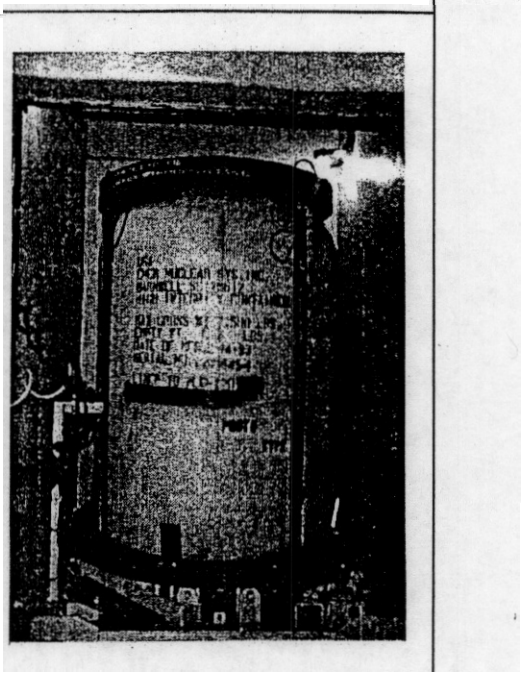

FACILITY LAYOUT
THOR
Studsvik


ALARA - SHIELDING
THOR
Studsvik

RESIDUE PACKAGING STATION

THOR





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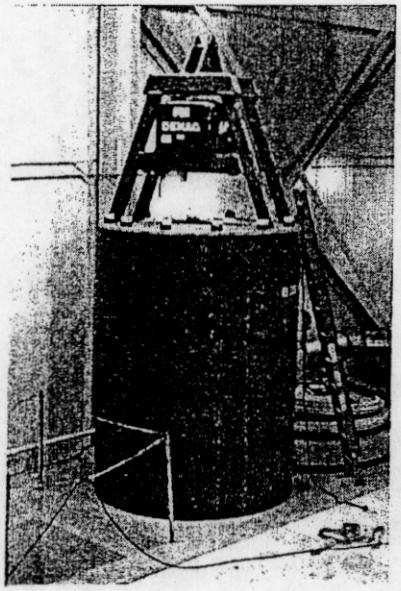
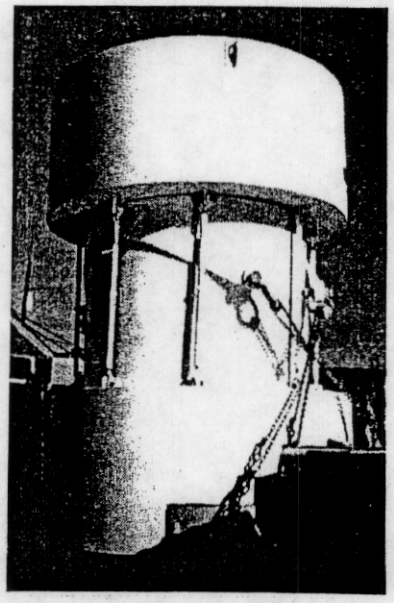
TRANSFER BELL - TRANSPORTATION CASK

THOR

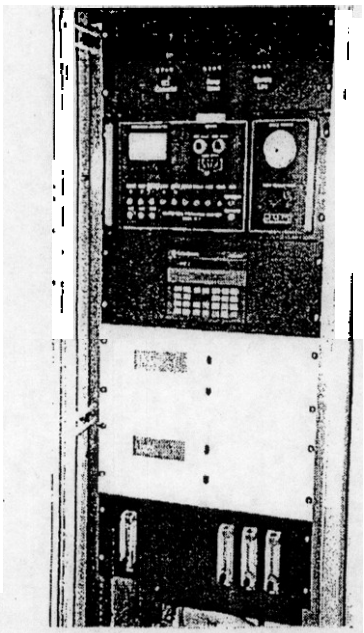


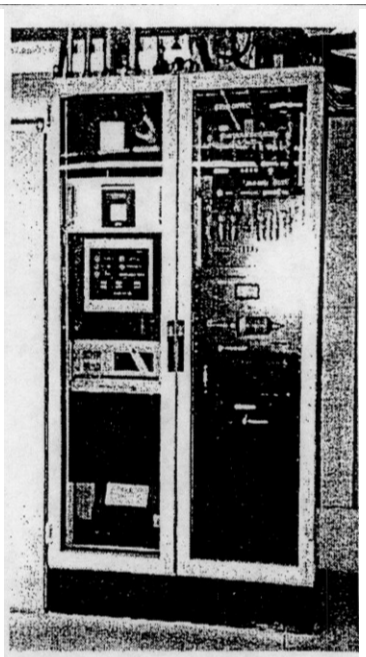


Studsvik™

CEMS AND STACK MONITOR

THOR





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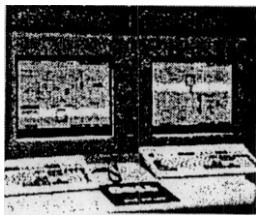
CONTROL ROOM – Remote Operations



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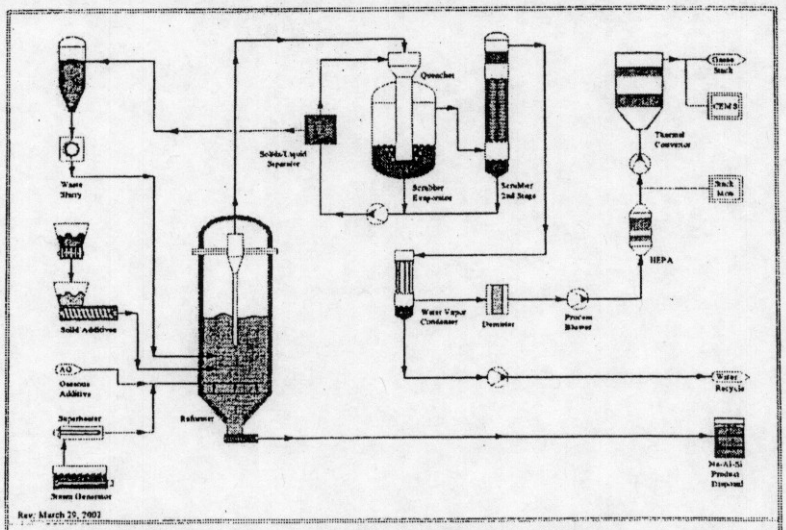
Thermal Denitration and Immobilization

THOR



Studsvik THOR℠ Steam Reformer System - Flow Diagram

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THORsm STEAM REFORMING – OPERATIONS AND SAFETY

THOR

- Fluidized Bed: Inert or Reactive, Multiple Zone
- Steam Reforming: Reducing or Oxidizing
- Single Vessel Thermal Treatment
- Waste Feed
  - Solid, Liquid, Slurry or Gaseous Feeds
  - Accepts high water, organic and sulfur content
  - High Throughputs
- Agglomerations
  - Additives prevent formation of monolithic solids
  - Additives convert alkali metals to stable granular minerals
- Remotely Operated
- Remotely Maintainable

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THOR^{sm} STEAM REFORMER – OPERATIONS AND SAFETY (Cont'd)

THOR

- Fast Shutdown - <1 minute
- Eliminates Flammable Mixtures in Off-Gas
- Explosion-Resistant Design – Pressure Vessels
- Retention of S, Cl and F in Solid Product
- Retention >99.9% of Cs and Tc (Re) in Solid Product
- No Secondary Process Wastes
- Zero-Liquid Discharge
- Stable Mineralized Nepheline Product
  - Water Insoluble Na_2O-Al_2O_3-$2SiO_2$
  - >19% Na_2O Loading, Inert, Low Leachability

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THOR^{sm} STEAM REFORMER – OPERATIONS AND SAFETY (Cont'd)

THOR

- Off-gas
  - Direct Conversion of NO_2 and NO_3 to Nitrogen in Reformer
  - No Ammonia for Off-Gas NOx Control
  - Low, Stable Flow
  - <500ppm NOx in Off-Gas
  - < 20 ppm Cl, S, F
- Consumables
  - Low Cost, Commercially Available
  - Non-Hazardous
- Cost Impact Compared to Vitrification
  - Low cost additives and disposal containers
  - Reduced Capital Cost
  - Reduced Maintenance Cost

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THOR^{sm} STEAM REFORMER – OPERATIONS AND SAFETY (Cont'd)

THOR

- Modular Process Equipment or Fixed Facility
  - Amenable to Transportable Modular Fabrication
  - Rugged, Compact Hardware
- Utility Services:
  - Electrical Power — 750 to 1,000 kw
  - Steam — 750 to 1,500 lb/hr
  - Nitrogen — 20 to 50 SCFM
  - Additives
    - Reductants, Solid — Proprietary
    - Catalyst, Solid — Proprietary Metal Oxide
    - Autothermal Gas
    - Clay

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THOR STEAM REFORMER SYSTEMS– PROCESS MATURITY

THOR

- Slurry Waste Feed - Radioactive Service
  - Studsvik Processing Facility: 0-3 gpm slurry
  - INTEC Calciner
- Steam Reformer - Radioactive Service
  - Studsvik Processing Facility: 300-500 kg/hr slurry, up to 400 R/h
- Quencher/Scrubber and Off-Gas Handling– Radioactive Service
  - SRS DWPF: submerged bed scrubber, full off-gas system
  - Studsvik Processing Facility: 3,000 SCFM, full off-gas system
  - Non-Radioactive Service: commercial systems, many installations
- Product Solids Handling – Radioactive Granules/Powder
  - Studsvik Processing Facility: double containment, blind fittings
  - INTEC Calciner: blind fittings
  - Non-Radioactive Service: commercial systems, many installations

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HANFORD S-112 TANK EVALUATION

THOR

- Waste Feed Input – Main Components
  - Salt Cake Solids:

• Na, K	530,000 kg
• NO_2 and NO_3	825,000 kg
• Hydroxide	309,000 kg
Total Dry, Solids Input	1,975,000 kg

- Waste Output - Product
  - Mineralized Solids (19.4% Na_2O):

• Na_2O-Al_2O_3-$2SiO_2$	3,280,000 kg
• Excess Additive: Clay	130,000 kg
• SO_4, Cl, F, PO_4, Cr, etc. in matrix	200,000 kg
Total Solid Product	3,610,000 kg

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HANFORD S-112 TANK EVALUATION (Cont'd)

THOR

- Volume Basis
  - Tank Contents – Dry Input Basis: 1,573 cu meter
  - Total Waste Product – Dry Output: 4,180 cu meter
- Weight Basis
  - Tank Contents – Dry Input Basis: 1,975 ton (metric)
  - Total Waste Product – Dry Output: 3,610 ton (metric)

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HANFORD S-112 TANK EVALUATION (Cont'd) THOR

Final Waste Form

- Nepheline Mineral Matrix: Na_2O-Al_2O_3-$2SiO_2$
- Substitute in Mineral Matrix: SO_4, PO_4, Cl, F, metal oxides
- Dry, Inert, Water Insoluble, Solid Granular Product
- Average Na_2O content: 19.4%
- Radionuclide Retention in Product: >99.9% (Including Cs, Tc)
- No Free Liquids
- No Explosive or Toxic Gas Potential
- Not Pyrophoric, Not Explosive
- High Resistance to Thermal, Radiation, Biodegradation, and Immersion Degradation
- No Known Issues for Product to Meet NRC Disposal Guidelines

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HANFORD S-112 TANK EVALUATION (Cont'd) THOR

- Secondary Process Wastes
  - Solids: **None**, no salts - scrubber solution recycled to feed
  - Liquids: **None**, Zero-Liquid Release Facility
- Off-Gas Emissions
  - CO_2 and Water Vapor
  - Gaseous Radionuclides (H^3,C^{14},I)
  - < 3,000 SCFM Off-Gas Flow

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THOR[sm] STEAM REFORMER – CONCLUSION

THOR

- Full-Scale, Steam Reforming Process
- Two Years from Start of Design to LLRW Operations
- Successful Commercial LLRW Operations
- Demonstrated Denitration and Immobilization Process
  - December, 2001 Privately Funded Demo
  - Confirmed Very Low Product Leachability
  - High Retention of Radionuclides
  - Safe, Reliable, Cost-Effective Operations
- Ready to Mobilize for Use at Hanford

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ATTACHMENT 5B

EVALUATORS POST-MEETING COMMENTS

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ATTACHMENT B5

EVALUATORS POST-MEETING COMMENTS

Comments from Bill Holtzsheiter

Overall Comment

The review evaluated nine technologies with added variations in a manner that gave the technologies a fair review on a relative basis; in that, the process effectively compared technologies. I felt strongly that the process did not adequately consider that fact that the bulk of the waste being evaluated had already had been processed for cesium and strontium removal and had, therefore, been pretreated. The waste incidental to reprocessing (WIR) scores reflect this anywhere that the radionuclides are allowed to go with the waste form versus being returned to the double-shell-tanks (DSTs) for processing in the Waste Treatment Plant (WPT). Technologies that did not include a denitration step did not fare well in waste form performance or land disposal restriction (LDR) compliance. Unfortunately, denitration technologies (vitrification, steam reforming, calcination, and active metal reduction) are either complex or immature.

Technology Path 1: Bulk Vitrification

General Comments: This technology was evaluated based on the reviewers' overall knowledge of vitrification and not just on the specific process presented. The reviewers did not feel that the glass form proposed was necessarily the best option and allowed that the glass formulation and process operating temperature (1,600 °C) could be changed to more favorable conditions as required to meet waste performance requirements and to minimize recycle of volatile components. There was a strong opinion by many of the reviewers that bulk vitrification is not easily skid-mounted in spite of the operating history of the GeoMelt process, the operation of the Transportable Vitrification System, and the availability of commercial vendors that have transportable skid-mounted units.

Compliance and Safety: The obvious uncontested strength of vitrification is the waste form and its ability to meet waste requirements and the expectation of the regulators. The weakness of the process is the higher operating temperatures and the complexity of the off-gas system. The lower than expected scores on the WIR are attributed to the lack of ^{99}Tc removal as a part of the process. This issue prevailed through all processes that did not return the key radionuclides to the DSTs. The other key issue was the perspective that vitrification must be housed in a facility. Operating experience with LAW in other venues does not support that position.

Project Utility: Vitrification scored well in this category due the robustness of the process and the large volume reduction associated with the process and the waste form.

Project Operability: Vitrification scored low in this area due to the high-temperature off-gas system and the opinion that vitrification is not compatible with skid-mounted design and operation. One reviewer did not agree with that position due to the demonstrated performance of the Transportable Vitrification System and GeoMelt on LAW.

Technical Risk: Vitrification scored well in this area due to the large number of vitrification plants successfully operating around the world on radioactive wastes.

Programmatic Risk: Vitrification scored lower than expected in this due to the fact that it is vitrification and DOE Office of Environmental Management (EM) programmatic direction is interpreted to mean reduce vitrification rather than reduce cost and schedule.

Technology Path 2: Active Metal Reduction

General Comments: This technology incorporates adaptation of operations used commercially in metal processing; however, in the combination and application for Hanford Site LAW, the process is still in the development stage and has several key chemical reactions that need further definition with respect to kinetics and distribution of product gases. There are hazardous gases produced, and the partitioning of radionuclides has not been demonstrated between the off-gas, secondary wastes, and the waste form. The chemistry of the waste form indicates excellent durability; however, no testing has been performed to show durability or retention of radionuclides.

Compliance and Safety: The waste form was presumed to perform well because it is an aluminosilicate and because a ^{99}Tc removal step was added to the process when the review team recognized that without technetium removal, non-glass waste forms would require verification. If the aluminosilicate performs well, the technetium removal step can be eliminated. The nature of the off-gas with multiple flammable and hazardous gases was considered a detriment from an operational safety perspective.

Project Utility: This process was expected to reduce the schedule significantly but to have only a minor affect on total waste volume.

Operability: The process was expected to have fairly significant issues with respect to operability. The nature of the off-gas system, the sensitivity of the kinetics of the reactions, the lack of anything but laboratory-scale data, and the number of unit operations that must be integrated led the review team to score this technology low.

Technical Risk: This process was based on literature evaluations of laboratory data. This was insufficient to consider this process anywhere near ready for demonstration or implementation in the time frame required for this project.

Programmatic Risk: Due to the nature of the off-gas, the level of understanding of the process and the issues to be resolved to allow deployment were significant. In addition, the cost was fairly high for the impact to waste volume.

Technology Path 3: Steam Reforming

General Comments: Steam reforming is a technology that has much in common with calcination with respect to additives to address sodium, off-gas treatment, and final product. The significant advantage of steam reforming is that it appears to be an excellent and robust technology for denitration, yielding an off-gas that is mostly nitrogen and oxygen. The technology has been used at a production scale for low-level reactor waste stabilization with a reasonable activity

level. The available information for evaluation of this process was presented separately and not on the same basis for the cost evaluations.

Compliance and Safety: Based on data presented by Studsvik on very limited samples and testing relevant to Hanford Site LAW, the waste form was considered to be durable for the constituents of concern, and it was assumed that if necessary, the waste form could be grouted for disposal. Regulatory and permitting issues were considered to be more difficult due to the high-temperature off-gas system, and some felt that the facility must be housed in a building and was not amenable to skid-mounting.

Project Utility: Steam reforming was rated robust in this area since there is such a lot of operating experience with calcination and specifically steam reforming.

Operability: Because of the high-temperature process and off-gas, operability was considered more difficult than non-thermal processes. The issues with skid mounting and getting started up on the DOE Site were considered fairly significant and may add to the deployment time.

Technical Risk: Technical risk was considered low since the process is operating and relevant pilot-scale testing has been completed. The panel recognized that there may be some developmental issues with the waste form; however, the product can easily be grouted and most likely will be acceptable directly from the steam reformer.

Programmatic Risk: The issues with deployment were considered significant for the state of Washington since steam reforming is a thermal process even though it has been very successfully run in other states on heterogeneous radioactive feeds.

Technology Paths 4A and 4B: Clean Salt Ceramic Grout Without and with Cesium Removal

General Comments: This process basically returned all the "do bads" except sodium nitrate back to the DSTs. Since there is not a cost-effective disposal path for sodium nitrate, this process results in simply moving the waste around without notable reduction in volume or processing time in the WTP. One reviewer felt that this process was not worth pursuing unless an inexpensive disposal path were found for the "clean" sodium nitrate.

Compliance and Safety: Since this process does not address the radionuclides, the regulatory and permitting issues were not considered significant. However, the disposal of sodium nitrate is very problematic.

Project Utility: This was considered to improve the schedule for WTP by diverting the sodium nitrate; however, a large volume of sodium nitrate would still have to be disposed of as RCRA-listed waste unless the sodium nitrate were delisted (assumption of this evaluation was that the wastes were not delisted).

Operability: The unit operations in this process are used in commercial industry; however, the reviewers observed that there is a significant number of unit operations, that there is temperature sensitivity in the crystallization step, and the the process is complex enough that skid-mounting was not considered viable.

Technical Risk: Technical risk was high on this process both from the complexity of the process and from the fact that only laboratory development has been completed in this country in similar applications.

Programmatic Risk: This technology was considered difficult to deploy due to maturity, complexity, and with current sodium nitrate disposal options, not very beneficial to the project.

Technology Paths 5A and 5B: Clean Salt with Sulfate Removal Without and with Cesium Removal

General Comments: This process is complex with a lot of unit operations that have sensitive control requirements. The addition of sulfate removal helps with the waste loading for this waste stream in the WTP; however, the impact is less without application to the DSTs. The sodium nitrate disposal issue remains just as significant as that observed for technology paths 4A and 4B.

Compliance and Safety: Since this process does not address the radionuclides, the regulatory and permitting issues were not considered significant. However, the disposal of sodium nitrate is very problematic.

Project Utility: This was considered to improve the schedule and waste volume for WTP by diverting the sodium nitrate and reducing the sulfate; however, a large volume of sodium nitate would still have to be disposed of as RCRA-listed waste unless the sodium nitrate were delisted (assumption of this evaluation was that the wastes were not delisted).

Operability: The unit operations in this process are used in commercial industry; however, the reviewers observed that there is a significant number of unit operations, there is temperature sensitivity in the crystallization step, and that the process is complex enough that skid mounting was not considered viable.

Technical Risk: Technical risk was high on this process both from the complexity of the process and from the fact that only laboratory development has been completed in this country in similar applications.

Programmatic Risk: This technology was considered difficult to deploy due to maturity, complexity, and with current sodium nitrate disposal options, not very beneficial to the project.

Technology Path 6: Containerized Grout

General Comments: Containerized grout, although an excellent waste form for LAW like that in the subject tanks, will have a very difficult time at the Hanford Site. With ^{99}Tc removal, containerized grout should be suitable for LAW. However, grouts and phosphate-bonded ceramics do not chemically immobilize nitrate. The points of compliance are very restrictive for Hanford Site disposal facilities (e.g., the points of compliance are 100 m down-gradient from the facilities rather than at site boundaries or points of risk to drinking water) making grout a difficult waste form to be accepted by the state of Washington without denitration. With the level of cesium and strontium already removed, and ^{99}Tc removal, engineered barriers, and delisting should be consider to make this waste form viable. The cost and simplicity of this process should not be ignored.

Compliance and Safety: Operating and permitting issues were considered very favorable since the process is low temperature and simple. Waste form issues were another story. Although grout will have been treated twice for cesium removal, filtered for the removal of transuranics and insolubles, and treated once for ^{99}Tc removal (will achieve very low levels in the final form), the waste form faired badly from comparison with glass and its inability to retain nitrate.

Project Utility: This is a simple process and is robust from a project and operational perspective. There is a volume increase as wastes are diverted from the WTP. This should be carefully evaluated when the disposal costs are factored into the analysis.

Operability: No operational issues were identified. It is a robust process.

Technical Risk: No technical risk was identified. This is a robust, proven process nationally and internationally.

Programmatic Risk: The significant issue is the mind-set of the state regulatory agencies.

Technology Path 7: Sulfate Removal

General Comments: Sulfate removal is a proven, fairly simple process that only removes sulfate and returns the radionuclides back to the DSTs. There is a volume increase due the acidification of the entire SST volume of removed salts that are again neutralized with NaOH. Before pursuing this process, other paths to addressing the sulfate solubility issue in low-activity glass should be pursued. For example, in the Tanks Focus Area Melter Technology review, it was noted that phosphate glasses have a significantly higher solubility limit for sulfate and with some study and optimization may fully address the issue. In balance, phosphate glasses in operation in Russia have had corrosivity issues with ceramic melters that will have to be addressed. The issue was not pursued for HLW glasses since there was no significant impact; however, for LAW glasses where contact maintenance is planned, it would seem worth pursuing.

Compliance and Safety: The acidification step is the only part of this process that gets much notice. It was considered straightforward for regulatory and permitting issues. The waste form is simply the immobilization of sulfate with trace radionuclides and nitrate.

Project Utility: No issues were identified here except that there is a volume increase in total LAW.

Operability: This process has been run in B Plant at the Hanford Site and is operationally robust in the opinion of the reviewers.

Technical Risk: No technical risks were noted.

Programmatic Risk: The overall benefit is minimized due to limited impact. If the process did not increase total waste so much and could be applied to the DSTs where the most significant sulfate issue exists, it might be more attractive to deploy. However, there are more cost-effective fixes with the glass formulation and sulfur solubility in the glass.

Comments from Jimmy Bell

The discussions during the Review of the Mission Acceleration Initiative Demonstration meeting at Richland seemed to include a disproportionate amount of time devoted to questions and concerns about technetium. The primary reasons for such concerns are the possible environmental consequences of technetium release into the environment and primarily concerns about effects on the ground water. The regulatory approach seemed to be to seek a zero release of technetium from low-level nuclear waste since the potential biohazards of technetium in the environment are largely unknown. As a scientist, I must ask how can this soft (low-energy) beta degradation of technetium constitute a significant biohazard? What do we know about technetium that would allow us to evaluate its environmental effects?

We do know that ^{99m}Tc is widely used in medical analysis and that this short-lived isotope degrades to ^{99}Tc. Also, we know that the resulting ^{99}Tc seeks out the bones in a human body. Little is known about the possible teratogenic effects of low-energy or soft beta decay on the bones. Even less is known about the body's rentention levels for the technetium isotope.

In addition, scientists currently do not have a good understanding of the chemical changes of the technetium-VII oxidation state when it is subjected to temperatures greater than 1,000 °C, as in the vitrification of nuclear waste. Although there has been regulatory concern about technetium release throughout the life-history of the underground storage tanks, no government agency has stepped forward to support the simple experiments that would provide a factual basis for understanding the high-temperature chemical changes of the technetium-VII oxidation state and for evaluating possible biohazards of technetium release. With the wide range of resources available in our national laboratories, I can only wonder why the research that has the potential to save billions of dollars in the tank waste remediation program has not been done. It seems to be more beneficial to the regulatory bureaus to wonder and discuss rather than to encourage a research program that would provide a factual basis for regulation of technetium.

My recommendation is that DOE should immediately implement a technetium research program to evaluate the following parameters:

1. The volatility of technetium at temperatures greater than 1,000 °C from a matrix that initially includes the technetium-VII oxidation species

2. Human-body retention rates for the technetium-VII species

3. Potential biohazards of human ingestion of technetium-VII species in drinking water.

Such a research investment should cost less than a million dollars and could save DOE billions of dollars in the tank waste remediation effort.

Comments from Ken Lang

The sulfate removal process is not really a competitor with the other alternatives. It is more akin to the cesium and technetium removal processes and applies to most of the flow sheets as well as to WTP. It should be judged separately from the others.

Some reviewers pointed out that skid-mounting means different things to different people. Most of the technology alternatives considered can be constructed skid-mounted offsite, which could potentially save construction cost. Once assembled onsite, most of the alternatives considered will have to go into a facility if only for environmental climate control. None of these alternatives could run effectively from a process control standpoint (most of these alternatives need good temperature control) or from an operational availability standpoint due to the extreme winter–summer temperatures, rain, snow, etc. These factors would require the 'skids' to be contained in a facility of some type. Also, because of the shielding and remote handling requirements for most of the processes, none of the alternatives is really 'transportable' from one tank farm to another. So the advantages of skid-mounting are mostly related to construction costs.

Increasing LAW throughput using any of the alternatives considered or increasing throughput by expanding the currently planned LAW vitrification facility will shorten the duration of the program, thus saving money for each year the program is completed early. The real discriminators are the cost of the new facility (which in order to have a low uncertainty needs to be at ~30% design) and the cost and time to obtain all of the regulatory approvals for operation and disposal.

Comments from the Washington State Department of Ecology

We thank you for inviting us to participate in the May 21-23 Mission Acceleration Initiative (MAI) workshop for the evaluation of different processes for accelerating treatment of Hanford's tank wastes, and for allowing us to present these comments.

The MAI started out by targeting 68 saltcake tanks that could benefit by a skid-mounted waste treatment process. During the workshop these 68 saltcake tanks were identified as lower risk. Ecology would like to point out that saltcake tanks tend to list high on risk to groundwater due to ^{99}Tc content. Ecology would also like to point out that nothing in this supplemental treatment process should interfere with the present Waste Treatment Plant (WTP) as planned, designed, and permitted.

As the MAI workshop progressed, the evaluators discovered that most of the tank treatment processes under consideration would have to be housed in a permanent facility. Also, most of the processes would require another facility that housed cesium and technetium ion exchange columns (and associated ultrafiltration and potentially resin regeneration equipment). Its function would be similar to the Pretreatment Facility currently being designed for the WTP. This additional facility would increase cost and would have regulatory requirements.

Using the vitrified waste form as a guide, qualification of a new waste form could take several years. This time would have to be factored into technology selection and utilization. For expediency, this development would most likely occur in a laboratory. It would be necessary for all technologies testing to include Hanford tank waste.

Final deployment in the field for treating the targeted tanks would likely require several years for permitting, designing, and constructing the facility. An important and practical benefit of "mission acceleration," by treating wastes in the vicinity of the 68 tanks, is that the critical limitation of double-shell tank (DST) space is eased. This benefit is lost if the supplemental process is considered to be an adjunct to the WTP and does not reduce DST burden.

It appears that a more detailed analysis of the proposed new path forward in conjunction with current baseline needs to be done first. Location and configuration of the facility, and its utility in relieving the shortage in DST space, are criteria that need to be defined, weighted and understood before meaningful process ranking for deployment, or even pilot testing can be done.

Ecology has not had an opportunity to verify the information and flow sheets presented at the workshop to evaluate supplemental technologies; therefore, we can give only limited guidance. As regulators we would consider accommodating new technology if it would indeed accelerate the cleanup mission. We reiterate and confirm that on no account will we allow any slowdown of the current baseline of vitrification.

In the workshop, Ecology's role was not to "develop approaches" but to participate in discussions and provide comments that will facilitate a smooth regulatory process for the technologies being considered. We gave our impressions on technologies either when requested or when the approach presented appeared to have technical or regulatory problems. We are definitely not proponents of any particular technology, especially since the data presented had not been independently verified and validated. Furthermore, critical steps and critical data for

the flow sheet development, and total waste form volume projections, need to be confirmed by the developers of each process

If the regulatory qualification process for Hanford's vitrification program is used as a guide, we envision a qualification period of several years for acceptance of this new waste form. The available data on the technologies under consideration should be independently verified and validated before any funding decisions are made.

Ecology's involvement in the C3T effort should not be misconstrued, by any reader, to be an evaluator of the merits of any particular technology being explored and certainly not extended to 'recommendation for funding.' We would like to see all promising technologies be given a level playing field. As a result of the process evaluation results, the evaluation points (for the clean salt processes) of 57 for 4B and 56 for 5B cannot be statistically distinguished from the Steam Reforming process score of 60. Thus they also appear to be promising technologies.

However, evaluating the Steam Reformer presentation was difficult since it did not comply with the format required for the other technologies. The presentation made by the steam reformer vendor at the workshop, and the materials provided by Bechtel National Inc. since March 2002, did not include any substantial data on the waste form, only qualitative statements. Other comments on this process are:

1. With the lack of data it is impossible to verify the claims of the robustness of the waste form and the suitability of the process. Most of their commercial experience has been with ion exchange resins, which are vastly different from Hanford's tank waste. Agglomeration and feed nozzle pluggage will need further testing and evaluation.
2. We question Steam Reforming for treating Hanford's tank waste, this technology appears to be in its infancy. Industrial experience in treating spent ion exchange resins in a steam reformer will likely be of limited use and worldwide calcination experience (most at over 1,000 °C) might not be useful in treating Hanford's alkaline wastes in the steam reformer, which operates at much lower temperatures. This technology will have to be proven successful in the planned tests.

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APPENDIX C

CLEANUP CONSTRAINTS AND CHALLENGES MISSION ACCELERATION INITIATIVE SUBGROUP REPORT

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APPENDIX C

CLEANUP CONSTRAINTS AND CHALLENGES MISSION ACCELERATION INITIATIVE SUBGROUP REPORT

1. Statement of Scope (Team Charter)

Pursuant to the Mission Acceleration Initiative (MAI) team charter, our objectives have been to explore (1) potential options to enhance Waste Treatment Plant (WTP) design and operations so as to get the most out of the parties' investment and (2) potential options to apply supplemental tank waste treatment technologies to some portion of tank waste following retrieval.

The team has focused on technologies to supplement the WTP's low-activity waste (LAW) treatment capabilities via the Cleanup Challenge and Constraints Team (C3T) process using Hanford Site, regulatory agency, and independent, external expertise. The team also recognized that high-level waste (HLW) treatment capability within the WTP would need augmentation (e.g., a second melter).

At the meeting on the C3T "Gang of 5" on June 27 and 28, 2002, the MAI team was given clear direction to move forward with the developmental testing of treatment/enhancement technologies necessary to complete tank waste treatment by 2028, and to continue to meet to monitor and shepherd the treatment acceleration projects forward.

2. Agreements Reached by the Team

a. The WTP, per current contract requirements, will not have the capability to complete tank waste treatment by 2028. The Office of River Protection (ORP) has advised the Washington State Department of Ecology that the high volume of LAW feed poses the most difficult challenge. Completing LAW treatment by 2028 would require making optimal use of the WTP to maximize its throughput through its design life and also providing supplemental LAW treatment approaches where it is appropriate and possible to do so.

b. In determining which (potential) supplemental LAW technologies appear to have sufficient merit to warrant further investigation, the team agreed that long-term waste form performance would be a critical determining factor due to the contaminants of concern (chemical and radiological). Similarly, the treatment processes deployed must result in wastes being compliant with Washington State Dangerous Waste Requirements for treatment and disposal. The team recognizes that any waste form will have to undergo an intense waste form qualification process including testing to show compliance with the land disposal restrictions. This waste form performance will likely be an issue of concern to public and tribes.

c. Over two dozen technology candidates were screened. Of those, four technical approaches — sulfate removal, containerized grout, bulk vitrification, and steam reforming — appear to warrant further consideration in the near term as potential LAW

supplemental treatment technologies. All appear to offer a potential to reduce the time to complete LAW processing by as much as 15 to 20 years. Analysis of each technology assumed radionuclide separations prior to LAW feed treatment to keep radiation doses as low as reasonably achievable (ALARA) and to meet waste disposal considerations. The team recognized that a determination against the requirements from U.S. Department of Energy (DOE) O 435.1, *Radioactive Waste Management*, regarding waste incidental to reprocessing (WIR) would be an issue requiring a high degree of scrutiny and coordination by the agencies – and likely would be an issue of concern to the public and the tribes.

The following is a summary of the treatment technologies warranting further development (in order of highest to lowest scoring).

(1) Sulfate removal by acid-side strontium precipitation is recommended for consideration by ORP as a WTP enhancement to increase waste loading in glass. This relatively simple technology can enhance the waste loading in borosilicate glass produced in the WTP thus reducing the time to treat the waste.

(2) Containerized grout can be tailored to immobilize numerous waste constituents and is relatively easy to deploy. Containerized grout results in substantially increased waste volumes (on the order of three to four times, relative to glass, for the fraction of waste that is grouted) and carries significant waste form performance issues with it. It also faces local controversy due to a previously failed program with the grout vaults.

(3) Bulk vitrification in roll-off bin size containers may produce an aluminosilicate glass waste form allowing high waste loadings, good waste form performance, and diminished final waste volumes. Bulk vitrification would occur within a structure that provides containment, emission control, and protection from the weather.

(4) Steam reforming may produce a sodium aluminosilicate mineral-like waste form with high waste loadings and potentially good waste form performance but increased overall waste volumes due to a low specific gravity. Steam reforming would be deployed as an adjunct to the WTP to supplement LAW glass.

d. All potential technologies will face regulatory and policy challenges including the following:

Bulk vitrification and steam reforming operate at elevated temperatures, so they will likely have maximum achievable control technology (MACT) standards invoked through the *Resource Conservation and Recovery Act of 1976* (RCRA), Subpart X, and will face the same rigor of permitting as is required for the WTP.

Treatment technologies using grout would need to be tailored to overcome waste form performance issues regarding the retention of mobile long-lived radionuclides and some hazardous constituents such as nitrates and nitrites.

A number of the technologies are likely to generate an increased volume compared with a vitrified waste form and could therefore require a larger overall amount of land for disposal.

In addition, the team recognized that for any option there would be secondary waste stream issues and impacts to supporting facilities.

e. All four technologies require further bench or cold testing prior to committing to pilot-scale hot testing.

f. The team also found that active metal denitration appears to be a promising technology capable of producing a competent waste form (sodium aluminosilicate). It operates exothermically using the free energy in scrap aluminum. It has only been tested at bench-scale however, and needs further development to work out potential safety issues (e.g., gas generation) prior to pilot- or full-scale testing with hot materials. As such, further research and investigation is better pursued at present using alternative sources of funding such as the DOE Office of Science and Technology (EM-50).

Conclusion: While there are no silver bullet supplemental technology candidates (i.e., all have some issues), the technologies (sulfate removal, containerized grout, bulk vitrification, and steam reforming recommended for fiscal year (FY) 2003 bench-scale or cold testing) hold the potential to substantially accelerate risk reduction and shorten the time to mission completion.

3. Path Forward Schedule and Recommendation

a. Recommend that ORP fund sulfate removal, containerized grout, bulk vitrification, and steam reforming on a limited scale in FY 2003 to obtain data needed to determine merit and likelihood of successful deployment; if warranted, one or more of these technologies would result in pilot testing in FY 2005 and hot field deployment between FY 2006 and 2008

b. Continue a working group for tank waste treatment enhancements and supplemental technologies to the tank waste treatment plant.

4. Key Decision and Policy Issues Requiring Resolution

Recommend approval by agency executive management.

5. Potential Cost Savings from Implementation of the Opportunity

In examining the supplemental technologies, reduction in the length of time needed to complete tank waste treatment was used as a surrogate measure for life-cycle cost.

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APPENDIX D

CANDIDATE SALTCAKE WASTE FOR SELECTIVE DISSOLUTION

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APPENDIX D

CANDIDATE SALTCAKE WASTE FOR SELECTIVE DISSOLUTION

The Tank Waste Information Network System (TWINS) was queried on April 10, 2002, to download the Best Basis Inventory estimates for aluminum, nitrate, potassium, sodium, sulfate, ^{241}Am, ^{137}Cs, ^{237}Np, ^{239}Pu, ^{240}Pu, ^{90}Sr, and ^{99}Tc for the single-shell and double-shell tanks. Estimates of the liquid, saltcake, and sludge waste volumes contained in each of the single-shell and double-shell tanks were obtained from HNF-EP-0182, *Waste Tank Summary Report for Month Ending December 31, 2001*. The information was entered into a Microsoft Excel spreadsheet.

The "Gimple rule" was used to calculate in the Microsoft Excel spreadsheet the estimated mass of low-activity waste (LAW) glass that would be produced from treatment of the waste in each of the single-shell and double-shell tanks. The Gimple rule calculates the sodium oxide loading in immobilized LAW (ILAW) glass based on the sodium and sulfate masses in the pretreated LAW as stated in Equation 1. Equation 2 is then used to calculate the amount of ILAW glass.

$$\text{Wt\% } Na_2O = 0.22369 / [(1+(SO_4 / 96*80*20.321) / (Na / 23*31))] \qquad \text{Equation (1)}$$

$$\text{ILAW Glass (MT)} = Na * (62 / 46) / \text{wt\% } Na_2O \qquad \text{Equation (2)}$$

The amount of ILAW glass that the Waste Treatment Plant (WTP) is capable of producing from 2007 through 2028 was calculated in the Microsoft Excel spreadsheet assuming the baseline LAW vitrification facility contains three melters. The three LAW melter systems are assumed to be capable of producing an average 30 metric tons (MT) ILAW glass per day. The WTP is estimated to produce 2.3×10^5 MT of ILAW glass from 2007 through 2028.

Based on the estimated ILAW glass production, the waste that would not be processed in the WTP was identified by inspection of the Microsoft Excel spreadsheet, assuming that the WTP preferentially treats wastes in double-shell tanks, followed by single-shell tanks containing less than 50,000 gal of saltcake waste, and finally single-shell tanks containing 50,000 gal or more of saltcake waste. The Microsoft Excel spreadsheet was then sorted assuming this waste processing sequence. Out of 149 single-shell tanks, 68 tanks contained 50,000 gal or more of saltcake waste. Of these 68 single-shell tanks tanks, 60 tanks were identified that would not be processed in the WTP by 2028 given the current WTP production schedule. These 60 tanks would require alternative waste treatment in order to process all tank waste by 2028.

To process the 60 single-shell tanks identified for alternative treatment, the tanks are assumed to undergo selective dissolution to remove cesium. The process is applied to saltcake waste consisting of solids and associated interstitial liquid. Water is used as the solvent to selectively dissolve, and remove, species from the saltcake. The target specie of interest is cesium; however, other waste constituents also are dissolved in the process.

When the selective dissolution assumptions are applied to the saltcake waste that would not be processed in the WTP by 2028, 30 percent of the sodium and 10 percent of the sulfate contained in this saltcake are transferred to the WTP along with 60 percent of the ^{137}Cs inventory. The additional sodium and sulfate transferred to the DSTs from selective dissolution would result in additional ILAW glass produced by the WTP, further reducing the number of single-shell tanks processed by the WTP under the current schedule. By iteration it was determined that 68 single-shell tanks containing 50,000 gal or more of saltcake waste would not be processed in the WTP by 2028. The saltcake waste contained in these 68 single-shell tanks, listed in Table D-1, would require alternative waste treatment to allow the remainder of the wastes contained in the single-shell and double-shell tanks to be processed from 2007 through 2028 in the WTP. The inventory of select radionuclides and analytes present in these 68 single-shell tanks is provided in Table D-2.

Table D-1. Single-Shell Tanks Containing at Least 50,000 Gallons of Saltcake Waste.

Tank	Tank	Tank
A-101	S-101	T-101
AX-101	S-102*	T-109
AX-103	S-103	TX-102
B-101	S-105	TX-103
B-103	S-106	TX-105
B-104	S-107	TX-106
B-105	S-108	TX-108
B-106	S-109	TX-110
B-107	S-110	TX-111
B-109	S-111	TX-112
BX-110	S-112*	TX-113
BX-111	SX-101	TX-114
BY-101	SX-102	TX-115
BY-102	SX-103	TX-116
BY-103	SX-104	TX-117
BY-104	SX-105	TX-118
BY-105	SX-106	TY-102
BY-106	SX-109	U-102
BY-107	SX-114	U-103
BY-108		U-105
BY-109		U-106
BY-110		U-107
BY-111		U-108
BY-112		U-109
		U-111

*The waste contained in these tanks is scheduled for retrieval to a double-shell tank prior to deployment of the Mission Acceleration Initiative technology alternative process. The Mission Acceleration Initiative technology alternative could be used to treat these wastes following retrieval to a double-shell tank.

Table D-2. Composition of Waste in Selected Single-Shell Tanks. (4 sheets)

Tank	Total Volume kgal	Supernate kgal	Sludge kgal	Saltcake kgal	Volume (liters) Normalized to 5M Na	Al Kg	Na Kg	K Kg	NO_3 kg	Tc-99 Ci	Cs-137 Ci	Sr^{90} Ci	Np-237 Ci	Pu-240 Ci	Pu-239 Ci	Am-241 Ci	SO4 Kg
A-101	877	494	3	380	9.30E+06	1.64E+05	1.07E+06	2.23E+04	7.92E+05	8.95E+02	1.18E+06	1.74E+05	3.16E+00	2.76E+01	1.57E+02	4.20E+02	6.28E+04
AX-101	662	364	3	295	7.03E+06	1.13E+05	8.09E+05	1.65E+04	6.60E+05	6.46E+02	8.74E+05	1.61E+05	2.29E+00	3.62E+01	1.96E+02	2.27E+02	5.49E+04
AX-103	112	0	8	104	9.57E+05	1.52E+04	1.10E+05	2.07E+03	6.47E+04	1.61E+02	1.12E+05	4.84E+05	1.90E-01	1.89E+01	9.53E+01	1.01E+03	1.09E+04
B-101	113	0	0	113	9.65E+05	2.46E+04	1.11E+05	5.58E+02	1.18E+05	7.45E+00	1.03E+04	9.58E+05	2.84E-02	1.04E+02	3.58E+02	7.86E+02	3.56E+04
B-103	59	0	0	59	5.03E+05	1.07E+04	5.79E+04	3.04E+02	3.46E+04	7.13E-01	5.44E+03	1.36E+03	4.39E-03	4.47E+00	5.67E+01	1.27E+00	2.22E+04
B-104	371	1	309	61	1.95E+06	3.48E+03	2.24E+05	1.40E+03	5.49E+05	2.04E+01	8.13E+04	4.24E+04	7.95E-03	6.86E+00	9.23E+01	6.33E-01	4.11E+04
B-105	158	0	28	130	2.83E+06	6.42E+04	3.26E+05	1.61E+03	1.78E+05	4.30E+00	3.09E+04	6.57E+03	1.72E-02	3.52E+00	4.43E+01	7.20E+00	1.28E+05
B-106	117	1	0	116	6.15E+05	3.79E+03	7.07E+04	1.63E+02	1.15E+05	6.02E+00	1.04E+04	3.30E+04	2.69E-03	1.91E+00	2.45E+01	5.39E-01	1.06E+04
B-107	165	1	93	71	1.30E+06	1.61E+04	1.49E+05	6.33E+02	1.57E+05	1.67E+01	2.29E+04	1.22E+05	1.06E-02	2.45E+01	1.67E+02	1.06E+02	7.70E+04
B-109	127	0	63	64	1.37E+06	4.21E+04	1.57E+05	6.04E+02	8.78E+04	1.18E+00	1.53E+04	3.84E+05	7.50E-03	4.96E+00	3.00E+01	1.46E+00	4.98E+04
BX-110	207	3	133	71	2.38E+06	2.77E+04	2.74E+05	2.00E+03	4.40E+05	1.14E+02	7.32E+04	1.63E+04	3.33E-01	5.42E+00	5.79E+01	2.57E+01	1.48E+04
BX-111	162	1	25	136	2.15E+06	1.66E+04	2.47E+05	1.53E+03	4.01E+05	1.16E+02	7.68E+04	1.59E+04	3.76E-01	1.41E+00	1.50E+01	6.70E+00	4.85E+03
BY-101	387	0	109	278	5.24E+06	5.42E+04	6.03E+05	5.64E+03	8.64E+05	2.80E+02	2.92E+05	2.65E+05	9.45E-01	4.08E+00	4.50E+01	5.18E+01	7.04E+03
BY-102	277	0	0	277	3.73E+06	4.99E+04	4.29E+05	4.20E+03	1.82E+05	1.90E+02	1.22E+05	2.55E+04	6.40E-01	1.40E+01	8.16E+01	3.58E+01	7.02E+04
BY-103	400	0	9	391	4.94E+06	7.95E+04	5.68E+05	5.56E+03	5.59E+05	2.93E+02	2.04E+05	1.05E+05	9.85E-01	1.87E+01	1.06E+02	7.78E+01	4.16E+04
BY-104	326	0	150	176	4.08E+06	6.55E+04	4.69E+05	7.84E+03	5.04E+05	2.63E+02	2.07E+05	3.61E+05	8.85E-01	2.04E+01	1.31E+02	7.04E+01	4.33E+04
BY-105	489	0	48	441	6.00E+06	7.28E+04	6.90E+05	3.38E+03	1.36E+06	8.17E+01	1.81E+05	1.59E+05	3.07E-01	5.62E+01	3.53E+02	1.74E+02	2.19E+04
BY-106	538	-6	84	460	5.34E+06	6.93E+04	6.14E+05	9.59E+03	9.25E+05	3.64E+02	3.93E+05	1.47E+05	1.22E+00	4.09E+00	3.31E+01	3.26E+01	3.07E+04

Table D-2. Composition of Waste in Selected Single-Shell Tanks. (4 sheets)

Tank	Total Volume kgal	Supernate kgal	Sludge kgal	Saltcake kgal	Volume (liters) Normalized to 5M Na	Al Kg	Na Kg	K Kg	NO_3 kg	Tc-99 Ci	Cs-137 Ci	Sr^{90} Ci	Np-237 Ci	Pu-240 Ci	Pu-239 Ci	Am-241 Ci	SO4 Kg
BY-107	266	0	40	226	3.68E+06	6.07E+04	4.23E+05	7.52E+03	3.22E+05	1.73E+02	2.10E+05	8.24E+04	5.81E-01	3.52E+00	2.45E+01	1.44E+01	2.60E+04
BY-108	228	0	154	74	2.03E+06	8.49E+04	2.33E+05	1.74E+03	2.29E+05	1.30E+02	5.16E+04	1.42E+05	4.38E-01	5.47E+00	4.16E+01	2.54E+01	2.62E+04
BY-109	290	0	57	233	2.83E+06	7.22E+04	3.25E+05	3.89E+03	1.29E+05	1.55E+02	1.03E+05	2.39E+05	5.23E-01	1.14E+01	6.62E+01	3.13E+01	1.03E+05
BY-110	398	0	103	295	4.06E+06	4.67E+04	4.67E+05	6.13E+03	2.43E+05	2.11E+02	1.99E+05	1.73E+05	7.10E-01	6.56E+00	5.07E+01	7.14E+01	4.47E+04
BY-111	459	0	0	459	3.98E+06	4.75E+04	4.58E+05	3.90E+03	2.73E+05	1.95E+02	1.31E+05	2.66E+04	6.56E-01	2.03E+01	1.18E+02	5.19E+01	6.71E+04
BY-112	291	0	0	291	5.17E+06	3.91E+04	5.94E+05	4.59E+03	1.44E+05	2.06E+02	1.39E+05	2.81E+04	6.94E-01	1.45E+01	8.80E+01	3.59E+01	5.23E+04
S-101	427	12	211	204	3.40E+06	1.87E+05	3.91E+05	2.89E+03	4.02E+05	2.06E+02	3.47E+05	6.06E+05	8.19E-01	8.00E+01	5.48E+02	1.22E+02	1.57E+04
S-102	492	0	105	387	3.17E+06	3.56E+04	3.64E+05	2.31E+03	5.07E+05	2.17E+02	2.55E+05	9.29E+04	1.30E+00	1.90E+01	1.15E+02	1.23E+02	8.92E+03
S-103	237	1	9	227	2.30E+06	3.43E+04	2.64E+05	2.14E+03	3.30E+05	2.24E+02	2.17E+05	4.10E+04	8.24E-01	2.88E+01	1.82E+02	1.22E+02	1.43E+04
S-105	456	0	2	454	4.38E+06	4.82E+04	5.04E+05	2.66E+03	6.30E+05	2.60E+02	3.00E+05	4.17E+04	9.62E-01	6.59E+01	3.98E+02	1.94E+02	3.54E+04
S-106	455	0	0	455	5.23E+06	5.15E+04	6.01E+05	2.06E+03	9.84E+05	2.88E+02	2.90E+05	3.91E+04	1.07E+00	7.80E+00	5.29E+01	1.97E+01	2.09E+04
S-107	376	14	293	69	2.01E+06	1.19E+05	2.31E+05	1.44E+03	1.51E+05	3.16E+01	1.87E+05	3.43E+05	1.12E-01	3.14E+02	1.75E+03	6.91E+01	3.30E+03
S-108	432	0	5	427	6.06E+06	6.45E+04	6.97E+05	3.37E+03	9.15E+05	3.20E+02	3.92E+05	6.40E+04	1.19E+00	9.94E+01	6.01E+02	2.73E+02	4.68E+04
S-109	533	0	13	520	6.70E+06	2.06E+04	7.71E+05	1.19E+03	1.91E+06	3.13E+02	4.76E+04	6.05E+04	1.16E+00	1.17E+01	8.11E+01	1.01E+01	2.50E+04
S-110	390	0	131	259	4.19E+06	1.24E+05	4.82E+05	1.47E+03	9.04E+05	2.38E+02	1.78E+05	2.48E+05	8.94E-01	7.28E+01	4.98E+02	9.40E+01	2.32E+04
S-111	467	106	117	244	3.94E+06	1.50E+05	4.53E+05	2.32E+03	5.53E+05	3.00E+02	3.52E+05	4.84E+05	1.12E+00	5.08E+00	3.39E+01	1.37E+01	3.17E+04
S-112	622	79	6	537	8.55E+06	3.85E+04	9.83E+05	1.91E+03	1.39E+06	2.47E+02	2.26E+05	1.07E+05	1.56E+00	9.36E+00	6.08E+01	7.24E+01	1.33E+05
SX-101	416	0	0	416	4.42E+06	1.56E+05	5.08E+05	2.24E+03	7.10E+05	1.85E+02	3.11E+05	6.52E+05	7.38E-01	9.67E+01	6.57E+02	1.81E+02	4.83E+03

Table D-2. Composition of Waste in Selected Single-Shell Tanks. (4 sheets)

Tank	Total Volume kgal	Supernate kgal	Sludge kgal	Saltcake kgal	Volume (liters) Normalized to 5M Na	Al Kg	Na Kg	K Kg	NO_3 kg	Tc-99 Ci	Cs-137 Ci	Sr^{90} Ci	Np-237 Ci	Pu-240 Ci	Pu-239 Ci	Am-241 Ci	SO4 Kg
SX-102	513	133	0	380	5.03E+06	8.49E+04	5.78E+05	5.72E+03	6.62E+05	3.56E+02	5.29E+05	2.43E+05	1.32E+00	4.65E+01	2.95E+02	1.90E+02	2.99E+04
SX-103	507	0	109	398	5.58E+06	9.05E+04	6.42E+05	4.68E+03	1.03E+06	3.16E+02	4.33E+05	3.90E+05	1.19E+00	2.45E+01	1.48E+02	6.79E+02	4.17E+04
SX-104	446	0	136	310	4.17E+06	1.77E+05	4.79E+05	2.64E+03	6.08E+05	1.84E+02	2.93E+05	5.34E+05	7.18E-01	1.50E+02	1.00E+03	1.71E+02	2.38E+04
SX-105	484	0	65	419	3.30E+06	8.16E+04	3.80E+05	3.24E+03	4.26E+05	1.90E+02	2.40E+05	1.76E+05	7.11E-01	7.62E+01	4.43E+02	5.10E+02	1.89E+04
SX-106	397	0	0	397	3.86E+06	4.93E+04	4.44E+05	3.27E+03	5.52E+05	3.60E+02	3.44E+05	1.05E+04	1.32E+00	4.24E+01	2.50E+02	3.07E+02	1.08E+04
SX-109	249	0	60	189	2.24E+06	1.48E+05	2.58E+05	1.16E+03	3.90E+05	5.75E+01	1.36E+05	3.95E+05	2.58E-01	6.08E+01	4.10E+02	1.60E+02	2.38E+03
SX-114	165	0	44	121	1.37E+06	8.82E+04	1.57E+05	7.92E+02	2.13E+05	4.03E+01	1.05E+05	2.40E+05	1.81E-01	3.98E+01	2.71E+02	8.06E+01	1.87E+03
T-101	102	1	37	64	7.46E+05	3.58E+04	8.58E+04	5.89E+02	1.20E+05	4.59E+01	4.62E+04	1.05E+04	1.63E-01	1.25E+01	7.99E+01	3.17E+01	9.28E+03
T-109	58	0	0	58	4.99E+05	3.54E+02	5.74E+04	9.68E+01	1.44E+04	5.91E-01	1.31E+03	1.08E+03	3.64E-03	2.66E-01	3.26E+00	1.33E-01	1.31E+03
TX-102	217	0	0	217	2.36E+06	2.49E+04	2.71E+05	1.57E+03	4.31E+05	1.53E+02	1.22E+05	2.95E+04	5.45E-01	3.79E+01	2.36E+02	1.17E+02	3.25E+04
TX-103	157	0	0	157	1.59E+06	1.63E+04	1.83E+05	1.03E+03	2.93E+05	1.00E+02	7.77E+04	1.96E+04	3.57E-01	2.52E+01	1.55E+02	7.83E+01	2.19E+04
TX-105	609	0	0	609	6.43E+06	6.40E+04	7.40E+05	4.10E+03	1.23E+06	3.94E+02	2.94E+05	8.04E+04	1.40E+00	1.12E+02	7.01E+02	3.31E+02	8.88E+04
TX-106	341	0	0	341	3.82E+06	4.34E+04	4.39E+05	2.51E+03	7.08E+05	2.43E+02	1.89E+05	6.24E+04	8.63E-01	6.50E+01	4.04E+02	1.91E+02	5.25E+04
TX-108	134	0	6	128	1.41E+06	1.40E+04	1.62E+05	8.92E+02	2.66E+05	8.58E+01	6.53E+04	2.18E+04	3.05E-01	2.35E+01	1.47E+02	7.03E+01	1.96E+04
TX-110	462	0	37	425	5.04E+06	5.11E+04	5.80E+05	3.12E+03	9.73E+05	3.00E+02	2.17E+05	6.23E+04	1.05E+00	8.64E+01	5.38E+02	2.61E+02	7.03E+04
TX-111	370	0	43	327	3.86E+06	3.95E+04	4.44E+05	2.37E+03	7.45E+05	2.26E+02	1.63E+05	4.73E+04	7.86E-01	6.60E+01	4.14E+02	2.00E+02	5.40E+04
TX-112	649	0	0	649	7.12E+06	6.88E+04	8.19E+05	4.39E+03	1.36E+06	4.22E+02	3.09E+05	8.67E+04	1.50E+00	1.19E+02	7.31E+02	3.56E+02	9.75E+04
TX-113	653	0	0	653	7.98E+06	1.70E+04	9.18E+05	1.80E+03	1.68E+06	4.78E+02	3.37E+04	6.39E+03	1.66E+00	6.04E+00	5.83E+01	3.17E+01	2.23E+05

Table D-2. Composition of Waste in Selected Single-Shell Tanks. (4 sheets)

Tank	Total Volume kgal	Supernate kgal	Sludge kgal	Saltcake kgal	Volume (liters) Normalized to 5M Na	Al Kg	Na Kg	K Kg	NO_3 kg	Tc-99 Ci	Cs-137 Ci	Sr^{90} Ci	Np-237 Ci	Pu-240 Ci	Pu-239 Ci	Am-241 Ci	SO4 Kg
TX-114	535	0	4	531	5.92E+06	5.34E+04	6.81E+05	3.45E+03	1.11E+06	3.24E+02	2.34E+05	6.81E+04	1.15E+00	9.44E+01	5.86E+02	2.80E+02	7.93E+04
TX-115	568	0	0	568	6.19E+06	6.16E+04	7.12E+05	3.90E+03	1.19E+06	3.78E+02	2.79E+05	8.45E+04	1.34E+00	1.05E+02	6.45E+02	3.17E+02	8.60E+04
TX-116	631	0	68	563	6.16E+06	6.61E+04	7.08E+05	2.69E+03	1.43E+06	2.08E+02	1.04E+05	9.78E+03	7.48E-01	5.26E+01	3.60E+02	1.50E+02	8.85E+04
TX-117	626	0	29	597	5.04E+06	3.29E+04	5.80E+05	2.23E+03	8.35E+05	1.91E+02	1.38E+05	4.05E+04	6.84E-01	5.91E+01	3.82E+02	1.67E+02	5.84E+04
TX-118	286	0	21	265	2.62E+06	1.54E+04	3.01E+05	9.53E+02	1.06E+05	1.51E+02	6.96E+04	1.80E+05	5.35E-01	1.52E+03	9.36E+03	1.20E+04	1.12E+04
TY-102	64	0	0	64	7.60E+05	1.59E+03	8.74E+04	3.41E+02	1.91E+05	9.40E+00	1.13E+04	2.73E+03	1.02E-01	1.64E-01	1.29E+00	4.01E+00	8.04E+03
U-102	289	0	43	246	2.77E+06	6.52E+04	3.19E+05	2.76E+03	4.81E+05	1.86E+02	2.65E+05	2.07E+05	6.75E-01	5.45E+01	3.65E+02	1.13E+02	2.13E+04
U-103	418	1	13	404	4.10E+06	4.86E+04	4.72E+05	2.83E+03	5.04E+05	2.56E+02	3.09E+05	5.17E+04	9.47E-01	2.33E+01	1.38E+02	1.68E+02	2.99E+04
U-105	353	0	32	321	3.58E+06	6.25E+04	4.12E+05	4.01E+03	6.41E+05	3.60E+02	3.27E+05	1.97E+04	1.31E+00	9.10E+01	5.37E+02	8.81E+02	3.67E+04
U-106	172	2	0	170	1.54E+06	1.11E+04	1.77E+05	1.19E+03	2.03E+05	1.14E+02	1.56E+05	6.34E+04	4.23E-01	6.20E+01	3.63E+02	4.87E+02	8.94E+03
U-107	397	33	15	349	4.06E+06	4.86E+04	4.67E+05	3.57E+03	7.63E+05	5.35E+02	2.46E+05	5.48E+03	1.96E+00	9.12E+01	6.31E+02	1.05E+02	6.46E+03
U-108	466	22	29	415	5.30E+06	6.46E+04	6.09E+05	5.14E+03	6.86E+05	4.64E+02	4.40E+05	1.96E+04	1.70E+00	1.08E+02	6.52E+02	1.76E+01	3.37E+04
U-109	387	0	35	352	2.97E+06	5.13E+04	3.41E+05	2.17E+03	4.70E+05	2.26E+02	2.13E+05	1.35E+04	8.31E-01	6.05E+00	3.92E+01	2.09E+01	2.25E+04
U-111	329	0	26	303	3.12E+06	4.95E+04	3.59E+05	3.01E+03	4.30E+05	3.23E+02	3.10E+05	5.63E+04	1.18E+00	3.54E+01	2.29E+02	1.83E+02	1.96E+04
Total for above tanks	2.48E+04	1.26E+03	3.16E+03	2.04E+04	2.57E+08	4.00E+06	2.96E+07	2.22E+05	3.95E+07	1.50E+04	1.45E+07	1.02E+07	5.47E+01	4.53E+03	2.80E+04	2.32E+04	2.72E+06

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TWINS, Tank Waste Information Network System best basis inventory as of April 10, 2002 (http://twins.pnl.gov: 8001/twins.html).

HNF-EP-0182, 2002, *Waste Tank Summary Report for Month Ending December 31, 2001*, Rev. 165, Fluor Hanford, Inc., Richland, Washington.

APPENDIX E

FLOW SHEET OPTIONS ALSO CONSIDERED

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APPENDIX E

FLOW SHEET OPTIONS ALSO CONSIDERED

E1.0 INTRODUCTION

The flow sheets described in this appendix were presented in the April 2-3 workshop and were included in the subsequent flow sheet analysis work to develop material balances and other information. All of these flow sheets were included in the evaluation done by the May 21-23 Cleanup Constraints and Challenges Team (C3T) Mission Acceleration Initiative (MAI) Subgroup. For various reasons summarized in Chapter 7.0 and described in detail in Appendices A, B, and C of this report, the C3T MAI Subgroup did not recommend that these flow sheets be pursued as part of the MAI in fiscal year 2003. The discussion provided in this appendix is from RPP-11131, *Mission Acceleration Initiative Demonstration Information Package*, which was developed in preparation of the May 21-23 workshop.

E1.1 ACTIVE METAL REDUCTION

The active metal reduction process uses a stirred tank or a fluidized bed reactor to decompose nitrates and nitrates present in the saltcake waste. The sodium aluminate–aluminum hydroxide product from the active metal reduction reactor is mixed with phosphoric acid or silica to produce a sodium alumino-silicate or alumino-phosphate ceramic waste form.

Based on a preliminary evaluation of the estimated waste inventory in 68 single-shell tanks (SSTs), this path reduces the Waste Treatment Plant (WTP) total mission immobilized low-activity waste (ILAW) glass volume to 46 percent of the baseline. The volume of the alternate waste form produced is equivalent to 101 percent of the WTP total mission ILAW glass baseline. The total volume of ILAW glass produced by the WTP plus the supplemental waste form (i.e., alumino-silicate or alumino-phosphate ceramic) is equivalent to about 147 percent of the baseline volume of ILAW glass produced in the WTP. Table E-1 summarizes projected low-level waste production. Sulfate to be treated by WTP as low-activity waste (LAW) feed is reduced to 10 percent of the baseline. The reduction in waste volume and associated sulfate inventory is an asset to the River Protection Project (RPP).

E1.1.1 Process Description

Figure E-1 is reproduced from the process flow diagram in RPP-11131 and shows only the processing steps and streams after the pretreatment process steps (material balance table and processing notes are not shown in the figure). The saltcake waste inventory from the 68 SSTs is retrieved and processed through the selective dissolution and solid–liquid separation steps. Both the cesium-rich and separated solids are sent to the double-shell tank (DST) system for processing through the WTP. The liquid stream from the solid–liquid separation step is further treated to separate cesium and technetium. The resulting low-cesium and low-technetium solution is sent to the active metal reduction reactor.

The active metal reduction reactor was assumed to be a fluidized bed reactor operating at 120 °C or less. Waste feed flows continuously through a bed of aluminum pellets that are in suspension because of flow, gas generation from the dissolution of the pellets, and the boiling of the feed. The aluminum metal reactant, in a pellet form, is continuously added as it is consumed in the reaction. Aluminum metal reacts with sodium nitrate, sodium nitrite, and sodium hydroxide to produce sodium aluminate and aluminum hydroxide along with hydrogen and ammonia off-gas.

Out of the active metal reduction reactor, the sodium aluminate and aluminum hydroxide slurry is sent to a stirred back-mix reactor (phosphate ceramic reactor). Sodium aluminate reacts with added phosphoric acid to form insoluble sodium alumino-phosphate. The slurry from the stirred reactor is sent to a solid–liquid separator. Liquid from this processing step is expected to be low in dissolved solids (from the removal of sodium and destruction of nitrates) and is immobilized in a phosphate-based cement. The liquid is sent through a filtrate evaporator and blended with phosphate ceramic formers to form a chemically bonded ceramic. Based on the assumptions used in this evaluation, the waste loading of the chemical bonded ceramic is 40 wt% waste sodium oxide.

The wet sodium alumino-phosphate and aluminum hydroxide product separated by solid–liquid separation includes precipitated calcium and strontium. These solid materials are poured into a large (4 ft by 4 ft by 8 ft) disposal container to cure into a solid mass. Curing time is expected to be comparable to that of concrete (7 to 28 days). Based on the assumptions used in this evaluation, the waste loading in the final product is 17 wt% waste sodium oxide.

E1.1.2 Findings Relevant to Cleanup Constraints and Challenges Team Preliminary Criteria

Table E-2 summarizes relevant information identified for the active metal reduction processing steps as they relate to the preliminary C3T criteria. Because selective dissolution and solid–liquid separation were not specifically evaluated for this information package, no findings for these processing steps are discussed in the table. General considerations relative to technical, authorization basis, environmental compliance, and programmatic risk are discussed below.

The active metal reduction process has been demonstrated on a laboratory scale and the process chemistry has not been entirely confirmed. This path is a potentially complete LAW treatment option with no streams returning to DSTs. Pilot-plant work remains to establish a technical basis for this process that will support an operable system. Further research is required to confirm chemical reactions on actual waste, the liquid effluent stream and off-gas compositions, and the performance of the phosphate-bonded ceramic waste form produced in this path. It will be necessary to test a scaled-up system in order to provide process and material handling information.

Table E-1. Impact of Each Option on Waste Treatment Plant Low-Activity Waste Processing Duration and Immobilized Low-Activity Waste Total Volume.

Option		Treatment of 68 SSTs					Treatment of other 81 SSTs + 28 DSTs	ORP mission impact		
Path	Option name	WTP ILAW from selective dissolution (m^3)[a]	WTP ILAW unique to path (m^3)[b]	Total path WTP ILAW volume (m^3)	Percent of baseline WTP ILAW	Volume supplemental solid LLW (m^3)	WTP ILAW (m^3)	Total ILAW + alternative solid LLW (m^3)	Percent of baseline WTP ILAW	Years to process ILAW in WTP[c]
NA	Baseline[a]	0	136,000	136,000	100.0%	0	68,700	205,000	100.0%	49.5
1	Bulk vitrification	26,200	0	26,200	19.2%	53,300	68,700	148,000	72.3%	23.0
2	Active metal reduction	26,200	0	26,200	19.2%	207,000	68,700	302,000	147.3%	23.0
3	Steam reforming[d]	26,200	0	26,200	19.2%	154,000	68,700	248,900	121.4%	23.0
4A	Clean salt, no Cs IX	26,200	83,300	110,000	80.3%	47,600	68,700	226,000	110.2%	43.2
4B	Clean salt, with Cs IX	26,200	83,300	110,000	80.3%	47,600	68,700	226,000	110.2%	43.2
5A	Clean salt and SO_4 removal, no Cs IX	26,200	13,300	39,500	29.0%	58,600	68,700	167,000	81.3%	26.2
5B	Clean salt and SO_4 removal, with Cs IX	26,200	13,300	39,500	29.0%	58,600	68,700	167,000	81.3%	26.2
6	Containerized grout	26,200	0	26,200	19.2%	264,000	68,700	359,000	175.2%	23.0
7	Sulfate removal	26,200	55,700	81,900	60.1%	32,800	68,700	183,000	89.4%	36.4

Note: A table in this format was used in the May 21-23, 2002, workshop (see Appendix A). This table contains corrected waste volumes and durations.

[a] Baseline is volume of WTP glass produced from processing all LAW in WTP. Does not include sodium added from process operations conducted in WTP.

[b] *WTP ILAW calculated volume is based on the Gimple Rule and density of 2.65 g/c^3.*

[c] WTP ILAW net glass production rate is 30 metric tons of glass per day.

[d] Estimate of steam reforming product is based on the presentation, "THOR Steam Reformer Technology for Hanford Tank Waste Support," made to the Cleanup Constraints and Challenges Team Mission Acceleration Initiative Subgroup by Brad Mason, Studsvik, AB, on May 22, 2002.

Cs IX = cesium ion exchange.
DST = double-shell tank.
LAW = low-activity waste.
ILAW = immobilized low-activity waste.
LLW = low-level waste.
NA = not applicable.
ORP = U.S. Department of Energy, Office of River Protection.
SST = single-shell tank.
WTP = Waste Treatment Plant.

Figure E-1. Excerpt from Process Flow Diagram for Active Metal Reduction Flow Sheet.

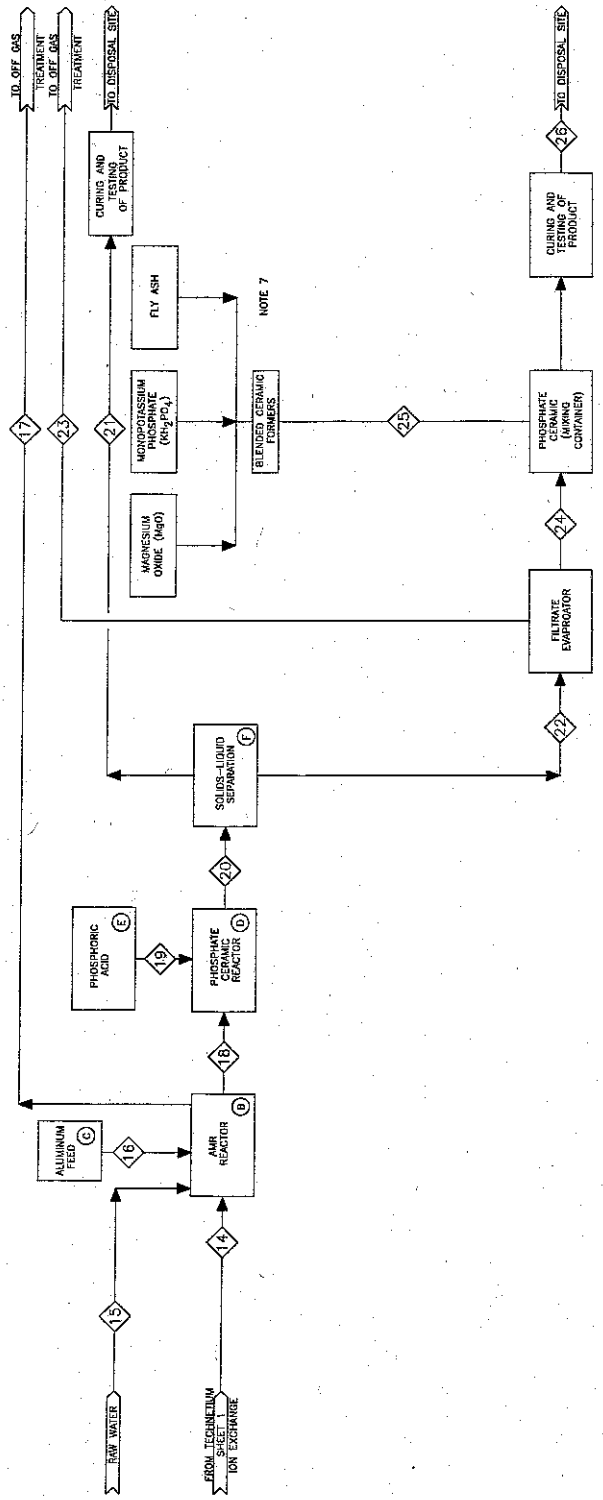


Table E-2. Active Metal Reduction Flow Sheet Findings and Risk Assessment. (2 sheets)

Preliminary C3T criteria	Defining attributes	Active metal reduction flow sheet findings
Project utility	Applies to the 68 SSTs that each contain greater than 50,000 gal of saltcake	Flow sheet only evaluated for tank 241-S-112 inventory Organics may impact immobilization step
	Impact on ILAW (vitrified) quantity produced by WTP	Potentially a complete LAW treatment option; reduces total mission ILAW quantity produced by WTP to 51% baseline
	Quantity of alternate ILAW waste form sent to Hanford Site burial grounds	144% WTP total mission ILAW baseline (assuming 10% sodium waste loading)
	Total volume of ILAW to be disposed of at Hanford Site relative to the WTP baseline	Increased (194% of baseline)
Environmental compliance	What is the alternate waste form and its performance?	Phosphate ceramic product Performance data not identified
	Ease of gaining regulatory permit	System operating data not identified
	Are there secondary waste stream issues associated with transfer to interface facility?	Liquid effluent stream produced
Authorization basis	Maximum temperature of pretreatment or immobilization process	Nitrate reduction performed at 120 °C
	Issues with energetics?	Exothermic reactions
	Flammable gas generation concerns?	Ammonia and hydrogen gas emitted
	Shielding concerns?	Cesium ion exchange step will require shielding
	Acidic reaction steps?	Phosphoric acid used to create final waste form
Technical risk	Pretreatment technology maturity	Investigated for Hanford Site use past 6 years Used for alkaline waste at ORNL
	Immobilization technology maturity	Nitrate reduction demonstrated at bench-scale Pilot-scale design for nitrate reduction step Phosphate ceramic step not tested
	Ease in achieving a process modular, skid-mountable (i.e., mobile) unit	Specific design data not identified
	Process ability to handle variation in waste feed composition	Unknown impact for treatment steps
Technical risk (cont.)	Disposition of treated off-gas	Ammonia and hydrogen gas generated.
Programmatic risk	Ease in achieving a WIR designation	Separation occurs in selective dissolution and solid–liquid separation steps

Table E-2. Active Metal Reduction Flow Sheet Findings and Risk Assessment. (2 sheets)

Preliminary C3T criteria	Defining attributes	Active metal reduction flow sheet findings
	Technetium separated?	Yes
	Cost	$258M
	Technical issues that may lengthen MAI schedule	Bench-scale testing has been performed at ORNL
Operability	Are there any special operability concerns?	First-of-a-kind equipment
	Are there issues for the path from completion of immobilization to final disposal?	Curing time is not known for phosphate ceramic

C3T = Cleanup Constraints and Challenges Team.
ILAW = immobilized low-activity waste.
LAW = low-activity waste.
MAI = Mission Acceleration Initiative.
ORNL = Oak Ridge National Laboratory.
SST = single-shell tank.
WIR = waste incidental to processing.
WTP = Waste Treatment Plant.

E1.1.3 Technical Analysis

E1.1.3.1 Exothermic Reactions and Potentially Flammable Gases

Although reliable cooling systems and treatment of hydrogen and ammonia are established technologies in nuclear facilities, preparing the supporting safety basis documentation for the exothermic aluminum reduction reaction and the potentially flammable off-gas mixtures may be difficult. Additionally, the reactions to produce the phosphate-bonded ceramic via this path are exothermic leading to a maximum temperature of 80 °C. Uncertainties in the process technical basis add to the uncertainty in establishing a safety basis.

E1.1.3.2 Phosphate-Based Waste Form Performance

The active metal reduction (de-nitration) process will be adaptable for the production of various waste forms (e.g., phosphate, zeolite or sodium aluminate–aluminum hydroxide). Laboratory test results suggest that the baseline phosphate-based waste form performance will be acceptable; however, further formulation and testing will be required to demonstrate that the waste form will meet disposal requirements. Secondary waste effluent and control of off-gas emissions will need to be addressed relative to applicable waste acceptance criteria and permitting requirements, respectively. Completing the *Resource Conservation and Recovery Act* (RCRA) permit and operation readiness activities by July 31, 2006, under the current project schedule and the lack of technical maturity present a considerable risk.

E1.2 CLEAN SALT WITHOUT CESIUM ION EXCHANGE

E1.2.1 Process Description

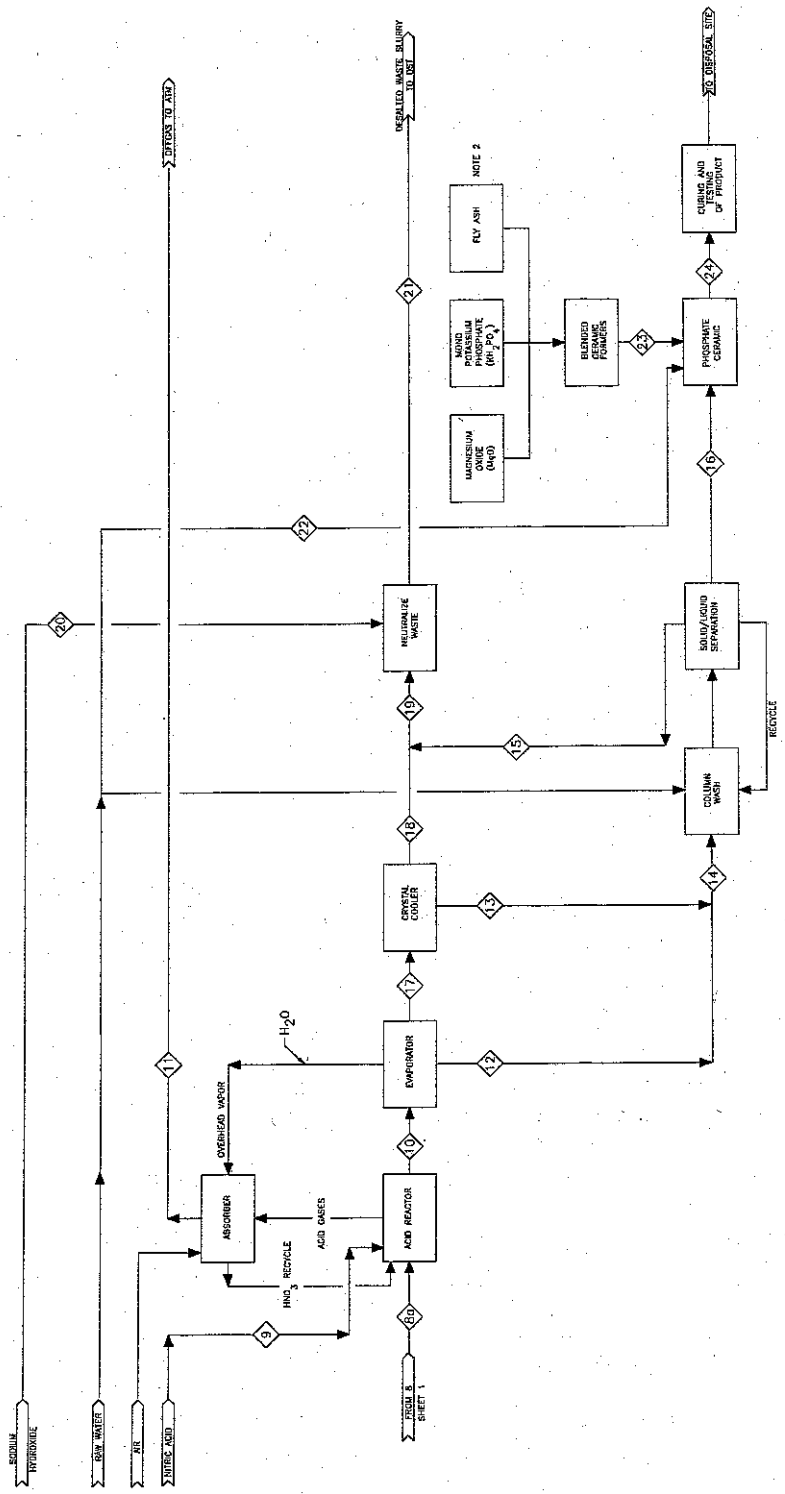
The saltcake waste is retrieved and processed through the selective dissolution and solid–liquid separation steps. Both the cesium-rich and separated solids are sent to the DST system for processing through the WTP. The liquid stream from the solid–liquid separation step is the feed for the flow sheet-specific treatment steps. Figure E-2 is taken from the detailed process flow diagram in RPP-11131 and shows only the processing steps and streams (material balance table and processing notes are not shown) that occur after the selective dissolution and solid–liquid separation steps that are common to all of the pathways. Cesium and technetium ion exchange columns are not used for this flow sheet option because the radionuclides are inherently separated from the clean salt as part of the process.

The liquid waste stream from the solid–liquid separation step is sent to an acid reactor where it is acidified with nitric acid to pH 2.0. Acidification neutralizes sodium hydroxide and sodium carbonate, dissolves aluminum hydroxide, and converts all the nitrite to nitrate and nitrogen oxide. The primary form of sodium leaving the acid reactor is sodium nitrate. Crystallization of sodium nitrate is performed in two steps. First, the acidified liquid stream is evaporated at approximately 110 °C at atmospheric pressure until about 50 wt% of the sodium nitrate is crystallized out. Second, the liquid stream is cooled to crystallize another 20 wt% of the sodium nitrate.

The liquid stream, which has a reduced sodium nitrate content, is neutralized by slowly adding the liquid to a sodium hydroxide bath. Once neutralized, the waste stream is sent to the DST system for treatment by the WTP. Because cesium and technetium ion exchange are not performed in this path, the sodium nitrate crystals are processed through a single wash column to remove cesium, technetium, and other soluble radionuclide species. The washed crystals are separated from the filtrate in a solid–liquid separation step that sends the filtrate to the neutralization step and the washed crystals to the immobilization step. A single stage of fractional crystallization is assumed to be adequate to produce sufficient radionuclide decontamination to meet applicable requirements.

Waste sodium nitrate needs to be immobilized because as a waste form it does not comply with the land disposal restrictions due to toxicity and flammability. The sodium nitrate is proposed to be immobilized into a phosphate-bonded ceramic. Waste is sent to a mixer along with water and ceramic formers. The ceramic formers are magnesium oxide, mono-potassium phosphate, and

Figure E-2. Excerpt from Process Flow Diagram for Clean Salt Flow Sheet without Cesium Ion Exchange.



fly ash. Fly ash provides strength to the final product. The ceramic is formed by the reaction of magnesium oxide, mono-potassium phosphate, and water. Once mixed, the ceramic waste form is poured into disposal containers and cured. Set time is estimated to be 2 hours. Once the waste product is set, the cure time is estimated to be 15 days. Table E-1 provides the estimated volumes of phosphate ceramic and ILAW glass produced at the WTP from processing the saltcake waste contained in the 68 SSTs through the clean salt process with the balance of the tank waste processed at the WTP.

E1.2.2 Findings Relevant to Cleanup Constraints and Challenges Team Preliminary Criteria

Table E-3 summarizes relevant information identified for the clean salt processing steps. Because selective dissolution and solid–liquid separation were not specifically evaluated for this information package, no findings for these processing steps are discussed in the table. General considerations relative to technical, authorization basis, environmental compliance, and programmatic risk are discussed below. The clean salt pretreatment process has been demonstrated with a bench-scale laboratory demonstration and computer modeling. Similar unit operations have been developed and were deployed in Russia at an industrial scale to treat high-level waste. The phosphate-bonded ceramic process is immature for reasons similar to those described for active metal denitration. It will be necessary to test a scaled-up system that will provide process and material handling information.

E1.2.3 Technical Analysis

There are several potential safety issues relative to this path. Clean salt is an acidic process and is performed above ambient temperatures (100 °C for the evaporator). The phosphate-bonded ceramic process is exothermic (temperatures up to 80 °C reported). Because this path does not have a cesium ion exchange module, additional shielding for process equipment would be required. Authorization bases have been established for similar conditions; however, the immaturity of the overall process presents some risks.

Laboratory test results suggest that the waste form performance will be acceptable; however, further formulation and testing will be required to demonstrate that the waste form will meet disposal requirements. Secondary waste effluent and control of off-gas emissions will need to be addressed relative to applicable waste acceptance criteria and permitting requirements, respectively. Completing the RCRA permit and operation readiness activities by July 31, 2006, under the current project schedule and the lack of technical maturity present a considerable risk.

Based on a preliminary evaluation of the estimated waste inventory in 68 SSTs, this path slightly reduces the WTP total mission ILAW volume to 87 percent of the baseline. The volume of the alternate waste form produced is equivalent to 23 percent of the WTP total mission ILAW baseline.

Table E-3. Clean Salt without Cesium Ion Exchange Findings. (2 sheets)

Preliminary C3T criteria	Defining attributes	Clean salt without Cs IX findings
Project utility	Applies to the 68 SSTs that each contain greater than 50,000 gal of saltcake	Path only evaluated for tank 241-S-112 inventory Clean salt tested on tank 241-AW-101 waste
	Impact on ILAW (vitrified) quantity produced by WTP	Removes sodium from LAW stream Nearly all of current baseline because all of the sulfate goes to WTP Reduces total mission ILAW quantity produced by WTP to 88% baseline
	Quantity of alternate ILAW waste form sent to Hanford burial grounds	28% of WTP ILAW baseline
	Total volume of ILAW to be disposed of at the Hanford Site relative to the WTP baseline	Increased (116% of baseline = 20% above baseline)
Environmental compliance	What is the alternate waste form and its performance?	Phosphate-bonded ceramic product Performance data not identified
	Ease of gaining regulatory permit	New processes; data for assessment not identified
	Are there secondary waste stream issues associated with transfer to interface facility?	Liquid waste stream will be neutralized and sent to DST system
Authorization basis	Maximum temperature of pretreatment or immobilization process	Above ambient temperature processes (100 °C for evaporator and 90 °C for phosphate-based reactions)
	Issues with energetics?	Neutralization step requires care Phosphate step is exothermic
	Flammable gas generation concerns?	Data for assessment not identified
	Shielding concerns?	Shielding may be needed throughout clean salt process because no cesium ion exchange used
	Acidic reaction steps?	Clean salt process is acidic
Technical risk	Pretreatment technology maturity	Laboratory- and bench-scale testing performed on Hanford Site waste
	Immobilization technology maturity	Application data not identified
	Ease in achieving a process modular, skid-mountable (i.e., mobile) unit	Conceptual design identified for clean salt processing steps Design for immobilization step not identified; may be similar to grout
Technical risk (cont.)	Process ability to handle variation in waste feed composition	Data for assessment not identified
	Disposition of treated off-gas	Acidic off-gas generated from clean salt process No off-gas identified for immobilization step

Table E-3. Clean Salt without Cesium Ion Exchange Findings. (2 sheets)

Preliminary C3T criteria	Defining attributes	Clean salt without Cs IX findings
Programmatic risk	Ease in achieving a WIR designation	Separation occurs prior to path-specific steps
	Is technetium removal possible?	Technetium assumed to transfer to DST
	Cost	$244M
	Technical issues that may lengthen MAI schedule	Processing steps have not been demonstrated at desired scale
Operability	Are there any special operability concerns?	Field system would be first-of-a-kind Clean salt is acidic process
	Are there issues for the path from completion of immobilization to final disposal?	Data for assessment not identified Curing of phosphate ceramic is needed

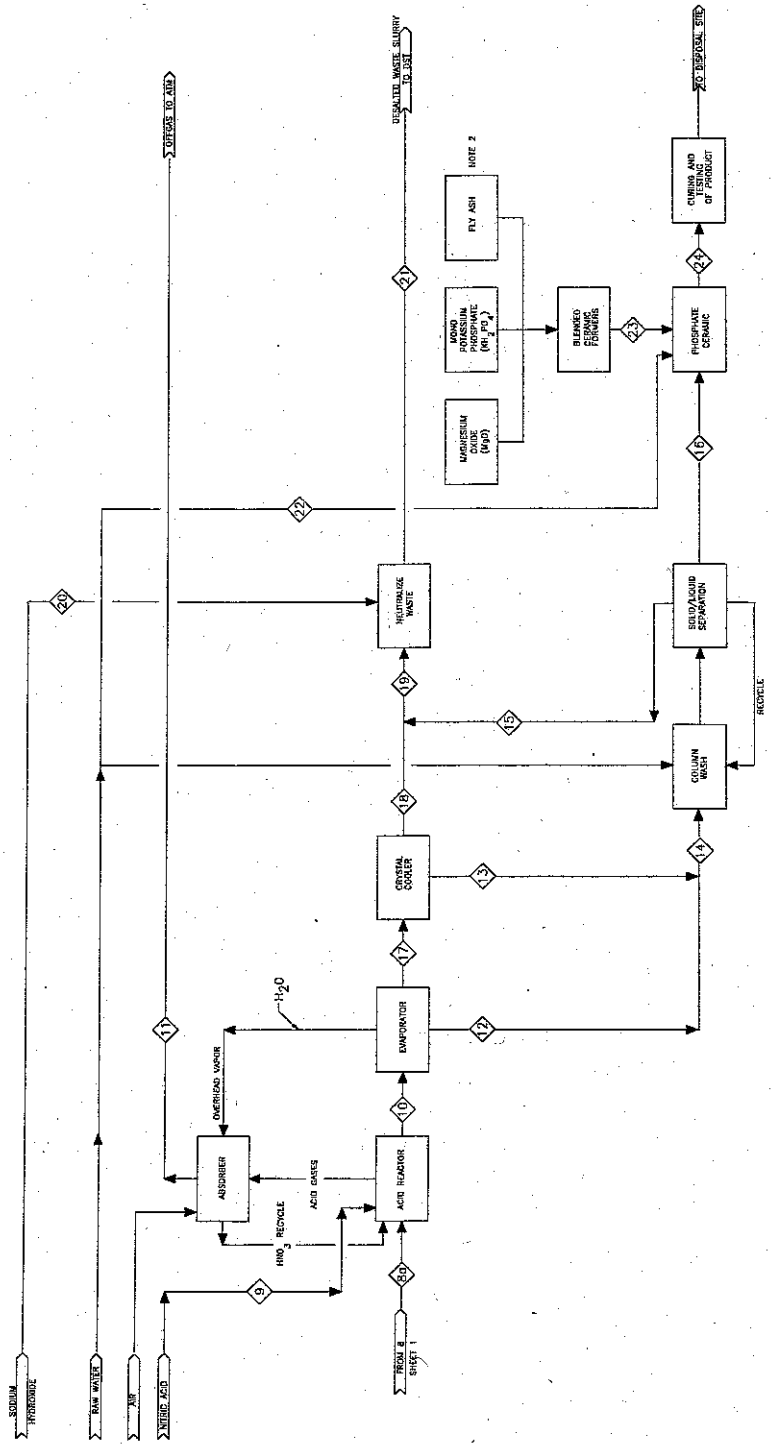
C3T = Cleanup Constraints and Challenges Team.
Cs IX = cesium ion exchange.
DST = double-shell tank.
ILAW = immobilized low-activity waste.
LAW = low-activity waste.
MAI = Mission Acceleration Initiative.
SST = single-shell tank.
WIR = waste incidental to reprocessing.
WTP = Waste Treatment Plant.

E1.3 CLEAN SALT WITH CESIUM ION EXCHANGE

E1.3.1 Process Description

The saltcake waste is retrieved and processed through the selective dissolution and solid–liquid separation steps. Both the cesium-rich and separated solids are sent to the DST system for processing through the WTP. The liquid stream from the solid–liquid separation step is the feed for the clean salt with cesium ion exchange-specific treatment steps. Figure E-3 is taken from the process flow diagram in RPP-11131 and shows only the processing steps and streams (material balance table and processing notes are not shown) that occur after the selective dissolution and solid–liquid separation steps that are common to all of the pathways. For the clean salt with cesium ion exchange flow sheet, a cesium ion exchange column is the first processing step. Technetium is inherently separated from the clean salt and a separate technetium ion exchange column is not needed.

Figure E-3. Excerpt from Process Flow Diagram for the Clean Salt with Cesium Ion Exchange Flow Sheet.



The liquid waste stream from the solid–liquid separation step is sent through a cesium ion exchange column, with the resulting low-cesium solution sent to an acid reactor where it is acidified with nitric acid to pH 2.0. This neutralizes sodium hydroxide and sodium carbonate, dissolves aluminum hydroxide, and converts all the nitrite to nitrate and nitrogen oxide. The primary form of sodium leaving the acid reactor is sodium nitrate. Crystallization of sodium nitrate is performed in two steps. First, the acidified liquid stream is evaporated at approximately 110 °C at atmospheric pressure until about 50 wt% of the sodium nitrate is crystallized out. Second, the liquid stream is cooled to crystallize another 20 wt% of the sodium nitrate.

The liquid stream, which has a reduced sodium nitrate content, is neutralized by slowly adding the liquid to a sodium hydroxide bath. Once neutralized, the waste stream is sent to the DST system for treatment by the WTP. Sodium nitrate crystals are separated from the filtrate in a solid–liquid separation step that sends the filtrate to the neutralization step and the crystals to the immobilization step. A wash column is not used in this path because a cesium ion exchange step is part of the path. A single stage of fractional crystallization is assumed to be adequate to produce sufficient radionuclide decontamination to meet applicable requirements.

Waste sodium nitrate is immobilized into a phosphate-bonded ceramic. Waste is sent to a mixer along with water and ceramic formers. The ceramic formers are magnesium oxide, mono-potassium phosphate, and fly ash. Fly ash provides strength to the final product. The ceramic is formed by the reaction of magnesium oxide, mono-potassium phosphate, and water. Once mixed, the ceramic waste form is poured into disposal containers and cured. Set time is estimated to be 2 hours. Once the waste product is set, the cure time is estimated to be 15 days.

Table E-1 provides the estimated volume of phosphate ceramic and ILAW glass produced at the WTP from processing the saltcake waste contained in the 68 SSTs through the clean salt process with the balance of the tank waste processed at the WTP.

E1.3.2 Findings Relevant to Cleanup Constraints and Challenges Team Preliminary Criteria

Table E-4 summarizes relevant information identified for the clean salt with cesium ion exchange flow sheet processing steps. Because selective dissolution and solid–liquid separation were not specifically evaluated for this information package, no findings for these processing steps are discussed in the table. General considerations relative to technical, authorization basis, environmental compliance, and programmatic risk are discussed below.

The clean salt with cesium ion exchange flow sheet has the same assessment as the clean salt without cesium ion exchange flow sheet described in the Section E.2. The path described here includes cesium ion exchange that would reduce shielding requirements.

Table E-4. Clean Salt with Cesium Ion Exchange Flow Sheet Findings. (2 sheets)

Preliminary C3T Criteria	Defining attributes	Clean salt with Cs IX flow sheet findings
Project utility	Applies to the 68 SSTs that each contain greater than 50,000 gal of saltcake	Path only evaluated for tank 241-S-112 inventory Clean salt tested on tank 241-AW-101 waste
	Impact on ILAW (vitrified) quantity produced by WTP	Removes sodium from LAW stream Nearly all of current baseline because all of the sulfate goes to WTP Reduces total mission ILAW quantity produced by WTP to 88% baseline
	Quantity of alternate ILAW waste form sent to Hanford Site burial grounds	28% of WTP ILAW baseline
	Total volume of ILAW to be disposed of at Hanford Site relative to the WTP baseline	Increased (116% of baseline = 20% above baseline)
Environmental compliance	What is the alternate waste form and its performance?	Phosphate-bonded ceramic product Performance data not identified
	Ease of gaining regulatory permit	Data exist for cesium ion exchange Data for assessment of other steps not identified
	Are there secondary waste stream issues associated with transfer to interface facility?	Liquid waste stream will be neutralized and sent to DST system
Authorization basis	Maximum temperature of pretreatment or immobilization process	Above ambient temperature processes (100 °C for evaporator and 90 °C for phosphate-based reactions)
	Issues with energetics?	Neutralization step requires care Phosphate step is exothermic
	Flammable gas generation concerns?	Data for assessment not identified
	Shielding concerns?	Less shielding may be needed because cesium ion exchange used
	Acidic reaction steps?	Clean salt process is acidic
Technical risk	Pretreatment technology maturity	Cesium ion exchange investigated for Hanford Site use Cesium ion exchange used for alkaline waste at ORNL Laboratory testing for clean salt performed on Hanford Site waste
	Immobilization technology maturity	Application data not identified
Technical risk (cont.)	Ease in achieving a process modular, skid-mountable (i.e., mobile) unit	Conceptual design identified for clean salt processing steps Design for immobilization step not identified; may be similar to grout

Table E-4. Clean Salt with Cesium Ion Exchange Flow Sheet Findings. (2 sheets)

Preliminary C3T Criteria	Defining attributes	Clean salt with Cs IX flow sheet findings
	Process ability to handle variation in waste feed composition	Cesium ion exchange is sensitive to feed variation Data for assessment of other path steps not identified
	Disposition of treated off-gas	Acidic off-gas generated from clean salt process No off-gas identified for immobilization step
Programmatic risk	Ease in achieving a WIR designation	Separation occurs prior to path-specific steps
	Is technetium removal possible?	Technetium assumed to transfer to DST
	Cost	$244M
	Technical issues that may lengthen MAI schedule	Processing steps have not been demonstrated at desired scale
Operability	Are there any special operability concerns?	Field system would be first-of-a-kind Clean salt is acidic process
	Are there issues for the path from completion of immobilization to final disposal?	Data for assessment not identified Curing of phosphate ceramic is needed

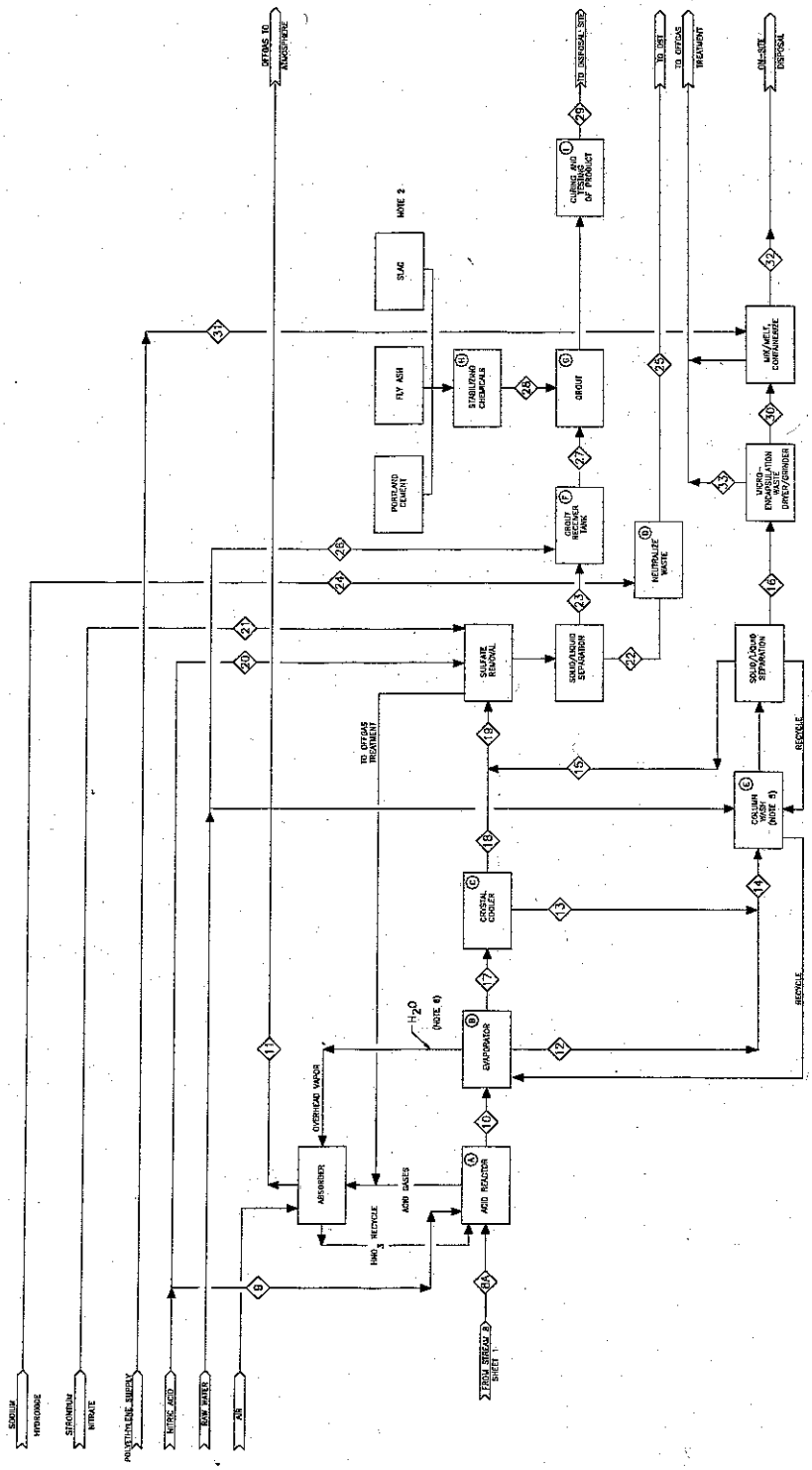
C3T = Cleanup Constraints and Challenges Team.
Cs IX = cesium ion exchange.
DST = double-shell tank.
ILAW = immobilized low-activity waste.
LAW = low-activity waste.
MAI = Mission Acceleration Initiative.
ORNL = Oak Ridge National Laboratory.
SST = single-shell tank.
WIR = waste incidental to reprocessing.
WTP = Waste Treatment Plant.

E1.4 CLEAN SALT AND SULFATE REMOVAL WITHOUT CESIUM ION EXCHANGE

E1.4.1 Process Description

In the clean salt and sulfate removal without cesium ion exchange flow sheet, the saltcake waste is retrieved and processed through the selective dissolution and solid–liquid separation steps. Both the cesium-rich and separated solids are sent to the DST system for processing through the WTP. The liquid stream from the solid–liquid separation step is the feed for the clean salt and sulfate removal without cesium ion exchange-specific treatment steps. Figure E-4 is taken from the process flow sheet in RPP-11131 and shows only the processing steps and streams (material balance table and processing notes are not shown) that occur after the selective dissolution and

Figure E-4. Excerpt from Process Flow Diagram for Clean Salt and Sulfate Removal with no Cesium Ion Exchange.



solid–liquid separation steps that are common to all of the pathways. For this flow sheet, cesium and technetium ion exchange columns are not utilized because these radionuclides are inherently separated from the clean salt.

The liquid waste stream from the solid–liquid separation step is sent to an acid reactor where it is acidified with nitric acid to pH 2.0. This neutralizes sodium hydroxide and sodium carbonate, dissolves aluminum hydroxide, and converts all the nitrite to nitrate and nitrogen oxide. The primary form of sodium leaving the acid reactor is sodium nitrate. Crystallization of sodium nitrate is performed in two steps. First, the acidified liquid stream is evaporated at approximately 110 °C at atmospheric pressure until about 50 wt% of the sodium nitrate is crystallized out. Second, the liquid stream is cooled to crystallize another 20 wt% of the sodium nitrate. Because cesium and technetium ion exchange columns are not used in this path, the sodium nitrate crystals are processed through a single wash column to remove cesium and other soluble radionuclide species. The washed crystals are separated from the filtrate in a solid–liquid separation step that sends the filtrate to the sulfate removal step and the washed crystals to the micro-encapsulation immobilization step.

The sulfate removal step is a batch-type process that involves selectively precipitating the sulfate using strontium nitrate. To remove the sulfate as a strontium precipitate, the waste feed is adjusted to pH 1.0 using nitric acid, followed by the addition of excess strontium nitrate. The acidified solution is allowed to digest approximately 1 hour to allow the strontium sulfate to precipitate. Precipitated solids are removed from the liquid stream and sent to a grout step. As was done for the two clean salt flow sheets without sulfate removal described in Sections E.2 and E.3, the liquid stream is neutralized by slowly adding the liquid to a sodium hydroxide bath. Once neutralized, the waste stream is sent to the DST system for treatment by the WTP.

The grout immobilization step involves mixing the sulfate precipitate waste stream with grout-forming additives. The three grout-forming additives (Portland cement, fly ash, and slag) are stored in individual containers, each equipped with a solids conveyer and dust control system. Pneumatic solids transfer equipment or other compatible transfer mechanisms may be used to transfer these additives to the solids blending equipment. The three additives are proportionally premixed and then added to the liquid effluent in grout mixing equipment. Grout formers are added to the waste stream at a ratio of about 0.6:1 by weight.

The material exiting the mixer is much like the commercial concrete that is used in the construction industry. It is poured into the final disposal containers and allowed to harden. The initial setting of the grout should be completed in 24 hours; once set, individual containers are moved to the curing area. There is information that the properties of the final waste form may be sufficient after 7 days to meet waste acceptance criteria. However, a conservative 28-day period was used to estimate the size of the curing area needed. In addition, the longer period ensures that the chemical heat of reaction will have time to diffuse from the large (4 ft by 4 ft by 8 ft) waste form. This will obviate issues of heat and temperature at the permanent disposal site.

Waste sodium nitrate is immobilized by micro-encapsulation using a polyethylene polymer. The waste sodium nitrate stream is dried to about 1 wt% water content and is then ground to ensure compatible particle sizes. Polyethylene is added to make a 70 wt% waste blend, and the mixture is melted at 120 °C to 180 °C and extruded into containers for disposal.

Table E-1 provides the estimated volume of low-level waste generated by the clean salt process and the ILAW glass produced at the WTP

E1.4.2 Findings Relevant to Cleanup Constraints and Challenges Team Preliminary Criteria

Table E-5 summarizes relevant information identified for the clean salt and sulfate removal without cesium ion exchange flow sheet processing steps as they relate to the preliminary C3T criteria. Because selective dissolution and solid–liquid separation were not specifically evaluated for this information package, no findings for these processing steps are discussed in the table. General considerations relative to technical, authorization basis, environmental compliance, and programmatic risk are discussed below. This path uses four technology options. Each option has been tested at a minimum at laboratory scale. The clean salt process has been demonstrated on bench scale (refer to clean salt without cesium ion exchange described in Section E.2). Sulfate precipitation has been used in a full-scale process on Hanford Site waste at B Plant. The micro-encapsulation process has been tested on a laboratory scale with a limited range of wastes. Results are promising; however, because of its technical immaturity, this subsystem presents risk to the overall system. The grout immobilization subsystem has an extensive history with laboratory- to full-scale radioactive demonstration (refer to containerized grout flow sheet described in Section 5.2). The overall path system has not been tested or demonstrated at any level. Process control, material handling, and equipment operability issues need to be addressed through a testing program.

Table E-5. Clean Salt and Sulfate Removal Without Cesium Ion Exchange Findings and Risk Assessment. (3 sheets)

Preliminary C3T criteria	Defining attributes	Clean salt and sulfate removal without Cs IX findings
Project utility	Applies to the 68 SSTs that each contain greater than 50,000 gal of saltcake	Path only evaluated for tank 241-S-112 inventory Clean salt tested on tank 241-AW-101 waste
	Impact on ILAW (vitrified) quantity produced by WTP	Removes sodium and sulfate from LAW stream Reduces total mission ILAW quantity produced by WTP to 56% of baseline
	Quantity of alternate ILAW waste form sent to Hanford Site burial grounds	35% WTP ILAW total mission baseline
	Total volume of ILAW to be disposed of at Hanford Site relative to the WTP baseline	Minimal ILAW volume reduction (92% of baseline) (decreased approximately 10% from baseline)
Environmental compliance	What is the alternate waste form and its performance?	Micro-encapsulation for sodium nitrate Grout for precipitated sulfate
	Ease of gaining regulatory permit	System operating data exists for grout
	Are there secondary waste stream issues associated with transfer to interface facility?	Liquid waste stream will be neutralized and sent to DST system

Table E-5. Clean Salt and Sulfate Removal Without Cesium Ion Exchange Findings and Risk Assessment. (3 sheets)

Preliminary C3T criteria	Defining attributes	Clean salt and sulfate removal without Cs IX findings
Authorization basis	Maximum temperature of pretreatment or immobilization process	Pretreatment and grout steps are at ambient temperature Sulfate extension operated at 110 °C Micro-encapsulation is operated at 180 °C
	Issues with energetics?	Micro-encapsulation waste form involves hydrocarbon and oxidizer mixtures
	Flammable gas generation concerns?	Data for assessment not identified
	Shielding concerns?	Shielding may be needed throughout process because no cesium ion exchange column used
	Acidic reaction steps?	Clean salt process is acidic
Technical risk	Pretreatment technology maturity	Lab testing for clean salt performed on Hanford Site waste Sulfate precipitation performed at B Plant in the 1970's
	Immobilization technology maturity	Formulated grout used at Savannah River Micro-encapsulation tests completed with simulants
Technical risk (cont.)	Ease in achieving a process modular, skid-mountable (i.e., mobile) unit	Conceptual design identified for clean salt steps Design for immobilization steps identified
	Process ability to handle variation in waste feed composition	Variations require micro-encapsulation and grout formulation
	Disposition of treated off-gas	Acidic off-gas generated from clean salt process
Programmatic risk	Ease in achieving a WIR designation	Separation occurs before path-specific steps
	Is technetium removal possible?	Technetium separated and transferred to DST
	Cost	$319M
	Technical issues that may lengthen MAI schedule	Processing steps have not been demonstrated at desired scale
Operability	Are there any special operability concerns?	Field system would be first-of-a-kind
	Are there issues for the path from completion of immobilization to final disposal?	Data for assessment not identified Curing of grout is needed

Table E-5. Clean Salt and Sulfate Removal Without Cesium Ion Exchange Findings and Risk Assessment. (3 sheets)

Preliminary C3T criteria	Defining attributes	Clean salt and sulfate removal without Cs IX findings

C3T = Cleanup Constraints and Challenges Team.
Cs IX = cesium ion exchange.
DST = double-shell tank.
ILAW = immobilized low-activity waste.
LAW = low-activity waste.
MAI = Mission Acceleration Initiative.
SST = single-shell tank.
WIR = waste incidental to reprocessing.
WTP = Waste Treatment Plant.

E1.4.3 Technical Analysis

There are several potential safety issues relative to this path. Sulfate and sodium nitrate removal is an acidic process and is performed above ambient temperatures (110 °C for the evaporator). Micro-encapsulation is operated at 180 °C. Because this path does not have a cesium ion exchange module, additional shielding for process equipment would be required. No substantial safety issues have been identified for the micro-encapsulation or grout subsystems. The authorization bases have been established for similar conditions for some of the subsystems; however, the immaturity of the overall process presents some risk

Laboratory test results suggest that the waste form performance will be acceptable; however, further formulation and testing will be required to demonstrate that the waste form will meet disposal requirements. Secondary waste effluent and control of off-gas emissions will need to be addressed relative to applicable waste acceptance criteria and permitting requirements, respectively. Completing the RCRA permit and operation readiness activities by July 31, 2006, under the current project schedule and the lack of technical maturity present a considerable risk.

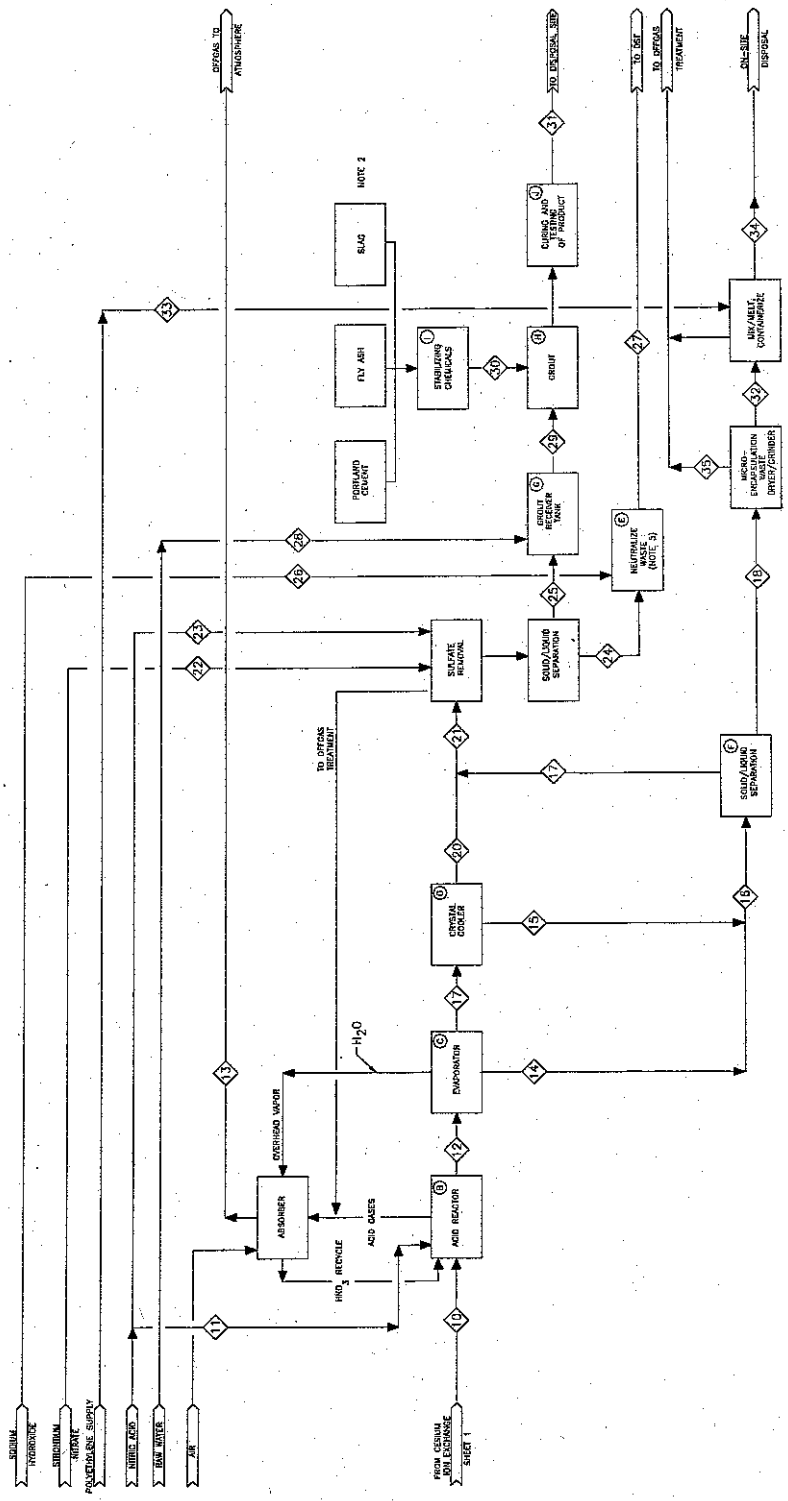
Based on a preliminary evaluation of the estimated waste inventory in 68 SSTs this path reduces the WTP total mission ILAW volume to 56 percent of the baseline. The volume of alternate waste form produced is equivalent to 35 percent of the total mission ILAW WTP baseline. Sulfate to be treated by WTP as LAW feed is reduced to 10 percent of the baseline. The projected saltcake disposal ^{99}Tc inventory is not expected to be impacted by this path. Although reduction in the sulfate inventory processed by WTP may be favorable, very little LAW product volume reduction is realized. Previous stakeholders' concerns relative to the grout waste form type also contribute to the programmatic risk.

E1.5 CLEAN SALT AND SULFATE REMOVAL WITH CESIUM ION EXCHANGE

E1.5.1 Process Description

The saltcake waste is retrieved and processed through the selective dissolution and solid–liquid separation steps. Both the cesium-rich and separated solids are sent to the DST system for processing through the WTP. The liquid stream from the solid–liquid separation step is the feed for the specific treatment steps. Figure E-5 is taken from the process flow diagram in RPP-11131 and shows only the processing steps and streams (material balance table and processing notes are not shown) that occur after the selective dissolution and solid–liquid separation steps that are common to all of the pathways. For the clean salt and sulfate removal with cesium ion exchange flow sheet, a cesium ion exchange column is the first processing step. Technetium is inherently separated from the clean salt and a separate technetium ion exchange column is not needed.

Figure E-5. Excerpt from Process Flow Diagram for the Clean Salt and Sulfate Removal with Cesium Ion Exchange.



The liquid waste stream from the solid–liquid separation step is sent through the cesium ion exchange column, with the resulting low-cesium solution sent to an acid reactor where it is acidified with nitric acid to pH 2.0. This neutralizes sodium hydroxide and sodium carbonate, dissolves aluminum hydroxide, and converts all the nitrite to nitrate and nitrogen oxide. The primary form of sodium leaving the acid reactor is sodium nitrate. Crystallization of sodium nitrate is performed in two steps. First, the acidified liquid stream is evaporated at approximately 110 °C at atmospheric pressure until about 50 wt% of the sodium nitrate is crystallized out. Second, the liquid stream is cooled to crystallize another 20 wt% of the sodium nitrate. Because a cesium ion exchange column is used in this path, the sodium nitrate crystals are not washed. The crystals are separated from the filtrate in a solid–liquid separation step that sends the filtrate to the sulfate removal step and the sodium nitrate crystal stream to the micro-encapsulation step.

The sulfate removal step is a batch-type process that involves selectively precipitating the sulfate using strontium nitrate. To remove the sulfate as a strontium precipitate, the waste feed is adjusted to pH 1.0 using nitric acid heated to 60 °C, followed by the addition of excess strontium nitrate. The acidified solution is allowed to digest approximately 1 hour to allow the strontium sulfate to precipitate. Precipitated solids are removed from the liquid stream and sent to a grout step. As was done for the clean salt flow sheets with and without cesium removal described in Sections E.2 and E.3, the liquid stream is neutralized by slowly adding the liquid to a sodium hydroxide bath. Once neutralized, the waste stream is sent to the DST system for treatment by the WTP.

The grout immobilization step involves mixing the sulfate precipitate waste stream with grout-forming additives. The three grout-forming additives (Portland cement, fly ash, and slag) are stored in individual containers, each equipped with a solids conveyer and dust control system. Pneumatic solids transfer equipment or other compatible transfer mechanisms may be used to transfer these additives to the solids blending equipment. The three additives are proportionally premixed and then added to the liquid effluent in grout mixing equipment. Grout formers are added to the waste stream at a ratio of about 0.6:1 by weight.

The material exiting the mixer is much like the commercial concrete that is used in the construction industry. It is poured into the final disposal containers and allowed to harden. The initial setting of the grout should be completed in 24 hours; once set, individual containers are moved to the curing area. There is information that the properties of the final waste form may be sufficient after 7 days to meet waste acceptance criteria. However, a conservative 28-day period was used to estimate the size of the curing area needed. In addition, the longer period ensures that the chemical heat of reaction will have time to diffuse from the large (4 ft by 4 ft by 8 ft) waste form. This will obviate issues of heat and temperature at the permanent disposal site.

Waste sodium nitrate is immobilized by micro-encapsulation using a polyethylene polymer. The waste sodium nitrate stream is dried to about 1 wt% water content and is then ground to ensure compatible particle sizes. Polyethylene is added to make a 70 wt% waste blend, and the mixture is melted and extruded into containers for disposal.

Table E-1 provides the estimated volume of low-level waste produced by the clean salt process and the ILAW glass produced at the WTP.

E1.5.2 Findings Relevant to Cleanup Constraints and Challenges Team Preliminary Criteria

Table E-6 summarizes relevant information identified for the clean salt and sulfate removal with cesium ion exchange flow sheet processing steps as they relate to the C3T preliminary criteria. Because selective dissolution and solid–liquid separation were not specifically evaluated for this information package, no findings for these processing steps are discussed in the table. General considerations relative to technical, authorization basis, environmental compliance, and programmatic risk are discussed below.

Clean salt and sulfate removal with cesium ion exchange flow sheet has the same assessment as the clean salt and sulfate removal without cesium ion exchange flow sheet described in Section E.4. This path has cesium ion exchange that would reduce shielding requirements.

Table E-6. Clean Salt and Sulfate Removal With Cesium Ion Exchange Findings and Risk Assessment. (2 sheets)

Preliminary C3T criteria	Defining attributes	Clean salt and sulfate removal with Cs IX findings
Project utility	Applies to the 68 SSTs that each contain greater than 50,000 gal of saltcake	Path only evaluated for tank 241-S-112 inventory Clean salt tested on tank 241-AW-101 waste
	Impact on ILAW (vitrified) quantity produced by WTP	Removes sodium and sulfate from LAW stream Reduces total mission ILAW quantity produced by WTP by 56% of baseline
	Quantity of alternate ILAW waste form sent to Hanford Site burial grounds	35% WTP ILAW total mission baseline
	Total volume of ILAW to be disposed of at Hanford Site relative to the WTP baseline	Minimal ILAW volume reduction (92% of baseline; decreased approximately 10% from baseline)
Environmental compliance	What is the alternate waste form and its performance?	Micro-encapsulation for sodium nitrate Grout for precipitated sulfate
	Ease of gaining regulatory permit	Data exists for cesium ion exchange System operating data exists for grout
	Are there secondary waste stream issues associated with transfer to interface facility?	Liquid waste stream will be neutralized and sent to DST system
Authorization basis	Maximum temperature of pretreatment or immobilization process	Pretreatment and grout steps are at ambient temperature Sulfate extension operated at 110 °C Micro-encapsulation is operated at 180 °C
	Issues with energetics?	Micro-encapsulation waste form involves hydrocarbon and oxidizer mixture
	Flammable gas generation concerns?	Data for assessment not identified
	Shielding concerns?	Cesium ion exchange step will require shielding

Table E-6. Clean Salt and Sulfate Removal With Cesium Ion Exchange Findings and Risk Assessment. (2 sheets)

Preliminary C3T criteria	Defining attributes	Clean salt and sulfate removal with Cs IX findings
	Acidic reaction steps?	Clean salt process is acidic
'echnical risk	Pretreatment technology maturity	Cesium ion exchange investigated for Hanford Site use Cesium ion exchange used for alkaline waste at ORNL Laboratory testing for clean salt performed on Hanford Site waste Sulfate precipitation performed at B Plant in 1970's
	Immobilization technology maturity	Formulated grout used at Savannah River Micro-encapsulation tests completed with simulants
	Ease in achieving a process modular, skid-mountable (i.e., mobile) unit	Modular designs for cesium ion exchange unit exist Conceptual design identified for clean salt steps Design for immobilization steps identified
	Process ability to handle variation in waste feed composition	Cesium ion exchange is sensitive to feed variation Variations require new micro-encapsulation and grout formulation
	Disposition of treated off-gas	Acidic off-gas generated from clean salt process
rogrammatic risk	Ease in achieving a WIR designation	Separation occurs before path-specific steps
	Is technetium removal possible?	Technetium separated and transferred to DST
	Cost	$370M
	Technical issues that may lengthen MAI schedule	Processing steps have not been demonstrated at desired scale
perability	Are there any special operability concerns?	Field system would be first-of-a-kind
	Are there issues for the path from completion of immobilization to final disposal?	Data for assessment not identified Curing of grout is needed

C3T = Cleanup Constraints and Challenges Team.
Cs Ix = cesium ion exchange.
DST = double-shell tank.
ILAW = immobilized low-activity waste.
LAW = low-activity waste.
MAI = Mission Acceleration Initiative.
ORNL = Oak Ridge National Laboratory.
SST = single-shell tank.
WIR = waste incidental to reprocessing.
WTP = Waste Treatment Plant.

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APPENDIX F

IDENTIFICATION OF TRANSURANIC AND LOW-LEVEL TANK WASTES

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APPENDIX F

IDENTIFICATION OF TRANSURANIC AND LOW-LEVEL TANK WASTES

F1.0 INTRODUCTION

This Appendix identifies that some of the wastes stored in the Hanford Site underground storage tanks may be classified as either transuranic waste or low-level waste. Alternatives for treatment of these tank wastes are discussed in Chapter 8.

F1.1 IDENTIFICATION OF TRANSURANIC TANK WASTES

There are 149 single-shell tanks (SSTs) and 28 double-shell tanks (DSTs) located at the Hanford Site. These tanks received supernatants and precipitated sludges originating from the reprocessing of spent nuclear fuels and waste management activities. The waste contained in the SSTs and DSTs, along with the active and inactive miscellaneous underground storage tanks, are managed to provide protection to the worker, environment and the public.

Numerous spent nuclear fuel reprocessing and waste management activities were conducted at the Hanford Site starting in 1944. The 221-T Plant, first used for reprocessing of spent nuclear fuel in December 1944, operated until 1956 using the bismuth phosphate process. The 221-B Plant reprocessed spent nuclear fuel from April 1945 to 1952 also using the bismuth phosphate process. Both the 221-T and 221-B Plants used a precipitation process that was batch operated. Later, REDOX (202-S) and PUREX (202-A) plants replaced B and T Plants using the continuous solvent extraction processes for separating uranium and plutonium from dissolved nuclear fuels. Refer to DOE/RL-97-02, *National Register of Historic Places Multiple Property Document Form - Historic, Archaeological and Traditional Cultural Properties of the Hanford Site, Washington, February 1997* for additional details on these processes.

The transfer records for wastes stored within the SSTs and DSTs were summarized in 1980 and later published in 1990 as WHC-MR-0132, *A History of the 200 Area Tank Farms*. This document was reviewed to determine which of the single-shell and double-shell underground storage tanks potentially contain transuranic (TRU) wastes. For this evaluation, the definition of TRU waste is taken from The Waste Isolation Pilot Plant (WIPP) Land Withdrawal Act, as amended.

TRU waste is radioactive waste containing more than 100 ηCi of alpha-emitting TRU isotopes per gram of waste, with half-lives greater than 20 years, except for the following:

- High-level radioactive waste
- Waste that the Secretary of Energy has determined, with the concurrence of the Administrator of the Environmental Protection Agency, does not need the degree of isolation required by the disposal regulations of Title 40, *Code of Federal Regulations*,

Part 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes"

Or

- Waste that the U.S. Nuclear Regulatory Commission (NRC) has approved for disposal on a case-by-case basis in accordance with Title 10, *Code of Federal Regulations*, Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste."

High-level waste is defined by The Nuclear Waste Policy Act of 1982, as amended as the "highly radioactive waste material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and other highly radioactive material that the U.S. Nuclear Regulatory Commission, consistent with existing law, determines by rule requires permanent isolation." These definitions were applied to the wastes presently stored in single-shell and double-shell underground storage tanks to determine whether some of these wastes would be classified as TRU wastes and not high-level waste (HLW).

As part of the Mission Acceleration Initiative, a formal evaluation of the waste contained in the Hanford Site tanks should be conducted to designate which tanks contain TRU waste suitable for treatment and disposal in the WIPP.

F1.1.1 Transuranic Waste Stored in Single-Shell Tanks

Of the 149 SSTs, only 9 tanks contain wastes that may potentially be classified as TRU waste. The rationale for classification of these wastes as potentially TRU waste is based on these wastes originating during the reprocessing of spent nuclear fuels, confirmed through waste transfer records and sample analyses for some of these wastes, and on the TRU concentration exceeding 100 ηCi/g.

The sludges stored in tanks 241-T-201, 241-T-202, 241-T-203, 241-T-204, 241-B-201, 241-B-202, 241-B-203, and 241-B-204 all contain second-cycle decontamination waste and lanthanum fluoride process wastes. Second-cycle decontamination wastes originated from further fission product decontamination of plutonium solutions conducted at T and B Plants, whereas lanthanum fluoride process wastes originated from plutonium purification activities conducted at the 224-T and 224-B buildings.

WHC-SD-WM-ES-331, *Identification of Potential Transuranic Waste Tanks at the Hanford Site*, indicates that the wastes in tanks 241-T-201, 241-T-202, 241-T-203, and 241-T-204 are potentially TRU wastes but that the wastes in tanks 241-B-201, 241-B-202, 241-B-203, and 241-B-204 are not TRU wastes. The previous analysis states that inspection of WHC-MR-0132 indicates that tanks 241-B-201, 241-B-202, 241-B-203, and 241-B-204 received high-level metal waste during the first year of operation (WHC-SD-WM-ES-331). Closer inspection of WHC-MR-0132 indicates that tanks 241-B-201, 241-B-202, 241-B-203, and 241-B-204 initially received waste from the 224 Building followed by flushes from the B Plant metal waste operation. Metal waste was almost completely soluble radioactive liquid waste that contained approximately 90 percent of the fission products and all of the uranium from reprocessing of

spent nuclear fuel in B Plant. WHC-MR-0132 does not indicate any increase in the solids volume after addition of these flush solutions to tanks 241-B-201, 241-B-202, 241-B-203, and 241-B-204. Furthermore, the liquid waste in these tanks was cascaded to a crib, which would have resulted in the removal of the metal waste from these tanks. Sample analysis results for these tanks do not indicate the presence of high concentrations of ^{137}Cs, as would be expected if these tanks contained metal waste. Therefore, the sludges in tanks 241-B-201, 241-B-202, 241-B-203, and 241-B-204 are potentially TRU waste.

Tank 241-T-111 received second-cycle decontamination waste from T Plant and lanthanum fluoride process wastes from 224-T Building. According to WHC-MR-0132, these tanks were actively used from 1945 through 1976 and did not receive any other type of waste. The TRU concentration of the waste stored in the Tank 241-T-111 is estimated to be approximately 180 ηCi/g. This is consistent with a previous analysis of the waste in this tank in which the waste was determined to be potentially TRU waste (WHC-SD-WM-ES-331).

F1.1.2 Transuranic Waste Stored in Double-Shell Tanks

Of the 28 DSTs, only 3 tanks (241-AW-103, 241-AW-105, and 241-SY-102) contain waste that may potentially be classified as TRU waste. The rationale for classification of these wastes as potentially TRU waste is based on the origin of these wastes during the reprocessing of spent nuclear fuels, confirmed through waste transfer records and waste sample analyses.

The sludges stored in tanks 241-AW-103 (~273,000 gal) and 241-AW-105 (~255,000 gal) originated from dissolution of the Zircaloy cladding on spent nuclear fuel elements in the PUREX Plant. The cladding waste was mixed with sodium hydroxide and sodium nitrite solutions to inhibit corrosion of carbon steel and transferred to these two DSTs. The waste in these tanks is potentially TRU waste. This is consistent with a previous analysis of the waste in this tank in which the waste was determined to be potentially TRU waste (WHC-SD-WM-ES-331).

The sludge stored in tank 241-SY-102 (71,000 gal) originated from the plutonium purification process conducted at Z Plant and 222-S Analytical Laboratory wastes. Again, these wastes were mixed with sodium hydroxide and sodium nitrite solutions to inhibit corrosion of carbon steel and transferred to this DST. Tank 241-SY-102 also is used for interim storage of salt-well liquors that are pumped from the SSTs within the 200 West Area of the Hanford Site. Tank 241-SY-102 also will be used for interim storage of wastes retrieved from SSTs 241-U-107, 241-S-102, and 241-S-112. The supernatant fraction and suspended solids that are interim stored in tank 241-SY-102 are transferred to DSTs within the 200 East Area through the cross-site transfer line, leaving behind the settled sludge. The sludge in tank 241-SY-102 is potentially TRU waste. This is consistent with a previous analysis of the waste in this tank in which the waste was determined to be potentially TRU waste (WHC-SD-WM-ES-331).

F1.2 IDENTIFICATION OF LOW-LEVEL TANK WASTE

As part of evaluating whether the SSTs and DSTs contain waste that could be classified as TRU waste, it was identified that the approximately 369,000 gal of waste contained in tank 241-T-110 is potentially low-level waste. The waste stored in some of the other SSTs may also be potentially low-level waste. A thorough review of records for waste transferred into the SSTs is recommended to determine whether low-level waste is present exclusively in some of the SSTs such as tank 241-T-110.

The baseline approach for treatment of the waste stored in tank 241-T-110 is retrieval and processing as HLW in the Waste Treatment Plant (WTP). Treatment and disposal of the waste contained in tank 241-T-110 as low-level waste could reduce the duration of HLW processing in the WTP, thus supporting acceleration of the River Protection Project (RPP) mission completion. Specific alternative treatment approaches for the potentially low-level waste contained in tank 241-T-110 (or other tanks) have not been reviewed as part of this evaluation. An engineering study should be conducted to evaluate and identify alternative treatment approaches.

F1.2.1 Preliminary Classification of Tank 241-T-110 Waste as Low-Level Waste

Low-level radioactive waste is defined as radioactive waste that is not high-level radioactive waste, spent nuclear fuel, TRU waste, byproduct material (as defined in section 11e (2) of the *Atomic Energy Act of 1954*, as amended), or naturally occurring radioactive material. In order to determine whether the waste stored in tank 241-T-110 can potentially be classified as low-level waste, this waste must first be shown not to be high-level radioactive waste, spent nuclear fuel, TRU waste, byproduct material, or naturally occurring radioactive material.

According to WHC-MR-0132, tank 241-T-110 received second-cycle decontamination waste from 221-T Plant and lanthanum fluoride process wastes from plutonium separations conducted in the 224-T Building. Tank 241-T-110 actively received waste from 1945 through 1976 and did not receive any other type of waste. The second-cycle decontamination waste and lanthanum fluoride process waste were predominantly sludges. The supernatant fraction was removed from tank 241-T-110 as part of the interim stabilization activities for the SSTs, leaving approximately 368,000 gal of sludge and 1,000 gal of supernatant. Based on this information, the waste stored in tank 241-T-110 is clearly not spent nuclear fuel, byproduct material, or naturally occurring radioactive material.

High-level is defined as the highly radioactive waste material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and other highly radioactive material that is determined, consistent with existing law, to require permanent isolation. The definition of high-level waste from Title 10, *Code of Federal Regulations*, Part 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories," Section 60.2 is "the liquid wastes resulting from the operation of the first-cycle solvent extraction system, or equivalent, and the concentrated wastes from subsequent extraction cycles, or equivalent." Since the waste stored in tank 241-T-110 is second-cycle

decontamination waste and lanthanum fluoride process wastes from plutonium separations and not first-cycle solvent extraction waste (or the equivalent), the waste stored in tank 241-T-110 does not meet the definition of HLW.

The TRU concentration of the waste stored in tank 241-T-110 is approximately 53 ηCi/g with a 95 percent upper confidence value of 62 ηCi/g based on 30 primary and duplicate gross alpha analyses of core segment samples documented in RPP-10983, *Tank Classifications Based on BBI and Gross Alpha.* TRU waste is defined as radioactive waste containing more than 100 ηCi of alpha-emitting TRU isotopes per gram of waste, with half-lives greater than 20 years, except for the following:

- High-level radioactive waste
- Waste that the Secretary of Energy has determined, with the concurrence of the Administrator of the Environmental Protection Agency, does not to need the degree of isolation required by 40 CFR 191 disposal regulations

Or

- Waste that the NRC has approved for disposal on a case-by-case basis in accordance with 10 CFR 61.

The 95 percent upper confidence value for the gross alpha analyses of the waste in tank 241-T-110 is 62 ηCi/g, indicating that this waste is not TRU waste. Based on the above analysis, the waste in tank 241-T-110 can potentially be classified as low-level waste.

F1.3 REFERENCES

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