Sta # 10

OCT 24 1994

ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT 604341

2. To: (Receiving Organization) IPM Project		3. From: (Originating Organization) IPM Project Eng		4. Related EDT No.: 105597	
5. Proj./Prog./Dept./Div.: IPM/TWRS		6. Cog. Engr.: G. F. Howden		7. Purchase Order No.: N/A	
8. Originator Remarks: Document is the first of three, leading to the identification of needed facilities and infrastructure to support TWRS pretreatment and immobilization process testing/development.				9. Equip./Component No.: N/A	
				10. System/Bldg./Facility: N/A	
11. Receiver Remarks:				12. Major Assm. Dwg. No.: N/A	
				13. Permit/Permit Application No.: N/A	
				14. Required Response Date: 9/30/94	

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Approval Designator	Reason for Trans- mittal	Originator Dispo- sition	Receiver Dispo- sition
1	WHC-SD-WM-TA-156	ALL	0	TWRS Tank Waste Pretreatment & Vitrification Treatment Process Development Testing Requirements Assessment	q	1&2		

16. KEY					
Approval Designator (F)		Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)		1. Approval	4. Review	1. Approved	4. Reviewed no/comment
		2. Release	5. Post-Review	2. Approved w/comment	5. Reviewed w/comment
		3. Information	6. Dist. (Receipt Acknow. Required)	3. Disapproved w/comment	6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)											
(G)	(H)	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G)	(H)
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18. Signature of EDT Originator <i>G. F. Howden</i> 9/29/94		19. Authorized Representative Date for Receiving Organization <i>R. R. Gadd</i> 10-7-94		20. Cognizant Manager Date <i>B. K. Horsager</i> 10-7-94		21. DOE APPROVAL (if required) Ctrl. No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments	
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Document Number: WHC-SD-WM-TA-156

Document Title: Tank Waste Remediation System Tank Waste
Pretreatment and Vitrification Process Development
Testing Requirements Assessment

Release Date: 10/20/94

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This document was reviewed following the
procedures described in WHC-CM-3-4 and is:

APPROVED FOR PUBLIC RELEASE

* * * * *

WHC Information Release Administration Specialist:

Christine Willingham
C. WILLINGHAM

10/20/94

SUPPORTING DOCUMENT		1. Total Pages 209
2. Title Tank Waste Remediation System Tank Waste Pretreatment and Vitrification Process Development Testing Requirements Assessment	3. Number WHC-SD-WM-TA-156	4. Rev No. 0
5. Key Words Test, test requirements, test facilities, infrastructure, test capability, hot test, actual waste, tank waste, pretreatment, vitrification, immobilization, IPM Project, Initial Pretreatment Module, process development, process testing	6. Author Name: G. F. Howden <i>G. F. Howden</i> 10/24/94 Signature Organization/Charge Code 7F421/D8001	
7. Abstract This study assesses the technologies being proposed for pretreatment and vitrification of Hanford Site tank wastes and identifies issues that must be resolved by testing with nonradioactive simulants and actual tank wastes. The issues are characterized to identify the levels of testing (lab, hot lab, bench, etc.).		
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9. Impact Level Q		

APPROVED FOR
PUBLIC RELEASE
10-20-94

**TANK WASTE REMEDIATION SYSTEM
TANK WASTE PRETREATMENT AND VITRIFICATION
PROCESS DEVELOPMENT TESTING
REQUIREMENTS ASSESSMENT**

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October 1994

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ACKNOWLEDGEMENTS

The time and experience of a large number of individuals in Westinghouse Hanford Company, Pacific Northwest Laboratories, and Raytheon/British Nuclear Fuel, Ltd., have contributed to the preparation of the information presented in this report. The contributions of D. E. Place, W. J. Powell, M. Bullock, and R. E. Flora in planning and conducting the workshops, checking information, and drafting and reviewing this report are especially recognized and appreciated.

SUMMARY

A multi-faceted study was initiated in November 1993 to provide assurance that needed testing capabilities, facilities, and support infrastructure (sampling systems, casks, transportation systems, permits, etc.) would be available when needed for process and equipment development to support pretreatment and vitrification facility design and construction schedules. This first major report provides a snapshot of the known testing needs for pretreatment, low-level waste (LLW) and high-level waste (HLW) vitrification, and documents the results of a series of preliminary studies and workshops to define the issues needing resolution by cold or hot testing.

Identified in this report are more than 140 Hanford Site tank waste pretreatment and LLW/HLW vitrification technology issues that can only be resolved by testing. The report also broadly characterizes the level of testing needed to resolve each issue. A second report will provide a strategy(ies) for ensuring timely test capability. Later reports will assess the capabilities of existing facilities to support needed testing and will recommend siting of the tests together with needed facility and infrastructure upgrades or additions.

The major conclusions and recommendations reached in this report are as follows.

- Tank corrosion and the dynamics of in-tank washing (solids suspension, solubility, mass transfer and reaction rates) are significant issues needing resolution to confirm in-tank processing as a baseline part of the pretreatment process.

- Waste pretreatment testing for production plant design support requires primarily small-scale laboratory and bench-scale testing together with some in-tank testing.
- An assessment is needed to determine the quantity of pretreated waste required for feed to support LLW and/or HLW vitrification testing needs.
- The LLW vitrification program will require large, cold, pilot-scale test facilities (as defined in Table 3-2). The minimum recommended LLW hot testing includes crucible testing and small bench-scale tests. Small cold and hot LLW vitrification pilot plants are considered highly desirable. (Bench-scale tests are less complete and extensive than small pilot-scale tests.)
- The HLW vitrification program will require small and large, cold pilot plants and a small, hot pilot plant in order to complete process development and qualify the vitrified product.
- The capability to retrieve and handle larger samples of actual tank waste to support pretreatment testing and vitrification program development is required.

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**TANK WASTE REMEDIATION SYSTEM
TANK WASTE PRETREATMENT AND TREATMENT
PROCESS DEVELOPMENT TESTING REQUIREMENTS ASSESSMENT**

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of the testing requirements assessment is to identify the needs and requirements for additional testing capability, testing facilities, and supporting infrastructure to support the Tank Waste Remediation System (TWRS) mission as stated in a recent memo (Alumkal 1994).

The overall assessment effort will produce three reports that will examine: (1) the technical issues requiring testing for resolution; (2) possible testing strategies; and (3) needed enhancements and additions to present testing capabilities, facilities, and infrastructure for performing test work in support of the TWRS mission. This report will address the technical issues that require resolution by testing with nonradioactive waste simulants or actual tank waste. Other reports will address testing strategies and provide recommendations on siting the actual test work.

1.2 JUSTIFICATION FOR TESTING

Testing that is done to reduce the risk of failure is measured in terms of (1) technical failure to meet system performance expectations, (2) cost failure in terms of exceeding the expected system acquisition cost, or (3) schedular failure in that the expected system acquisition time has been exceeded. Because failure of a system acquisition typically involves at least two of these areas and often all three, a well-conceived and implemented technology and/or system test program can greatly improve the probability of success, particularly of a technically complex acquisition.

This report will address testing with actual Hanford Site tank wastes and testing with compounds that simulate many or all of the characteristics of concern in the waste, but without the radiation hazard. This report also will address testing at varying levels of complexity, the most basic being very small scale in an analytical chemistry laboratory, but ranging with increasing complexity, cost, and time to a full-scale production capability demonstration. Typically (and in the Hanford Site's case), the full-scale production capability demonstration with its larger cost and schedule is not required to provide needed information for risk reduction. Often the needed information can be obtained with more complex laboratory tests, sometimes referred to as bench-scale tests. Larger pilot-scale tests can be performed that are generally a fraction of the production system size, but are more closely scaled in configuration to the production system. Testing with actual waste and testing with a pilot-scale system (as compared to a smaller, simpler bench-scale test) generally represent the "upper limit" of testing capability except when testing within an actual waste tank.

Testing with actual waste must be employed when the waste stream to be processed cannot be: (1) reliably characterized, or (2) accurately simulated with cold chemicals with respect to the processes being considered. In general, supernates (the liquid fraction of waste in a tank) can be more easily and reliably characterized and simulated than sludges, and inorganic chemicals are easier to characterize than organic compounds. Some examples of where the emphasis must be placed on testing with actual radioactive wastes include the following:

- Soluble organics in the feed to organic destruction processes because the original organic materials have been broken down by radiolysis and hydrolysis. Not all the degradation products have been identified or fully characterized.
- Sludges for high-level waste (HLW) pretreatment or HLW vitrification processes caused by problems in dissolving the sludge and duplicating mineralization processes that occur in the underground tanks over extended time periods.
- Technetium (Tc) or transuranics (TRU), for which there are limited nonradioactive chemical equivalents (although sometimes a different chemical may be an adequate simulant for some testing purposes).

Even when adequate nonradioactive simulants are available, it is still prudent to conduct at least limited hot testing to validate the cold test results.

Pilot plants are often sized at a fraction of the expected plant size, in the range of one-tenth to one one-thousandth (but sometimes larger). Typically (compared to "bench scale") the pilot plant will use more exactly configured, but scaled down, equipment and will include more elaborate, if not exact, process control and instrumentation. Pilot-plant scale tests are used for the following purposes:

- To provide technical data that are unavailable from other sources but are needed for process flowsheet development, process design, process specification, safety, environmental compliance, plant/equipment design (including operability, reliability or maintainability aspects of the equipment). In particular, the physical aspects of some equipment cannot be predicted accurately and must be scaled up from a working unit.
- To investigate suspected problems or to verify the absence of unanticipated complications. This can be extremely important in the case of new chemical processes.
- To conduct research and optimization of new processes.
- To provide a product for further product testing.
- To train operators, supervisors, and engineers.
- To provide project sponsor and/or stakeholder confidence that the project will perform in accordance with requirements and meet or exceed expectations.

The final decisions on the need for testing with actual wastes can be more precisely based on factors such as those listed above than on the decision to test at bench versus pilot scale. The final decision on pilot-plant scale versus bench-scale testing may often be based on the perception of risk by a project's sponsors, managers, and stakeholders and less on technical issues.

1.3 BACKGROUND

In January 1992, the first assessment of the need for additional hot test facilities and infrastructure to support TWRS tank waste pretreatment and immobilization process development was initiated. That work culminated in March 1993 with a report (Howden 1993) that surveyed the hot cells on the Hanford Site and assessed their suitability for a long-range hot testing support mission.

In March 1993, a recommendation was sent to the U.S. Department of Energy, Richland Operations Office (RL) (Hansrote 1993) to support immediate engineering work on development of a hot test facility and supporting infrastructure. The uncertainty about the TWRS technical approach resulting from the impending 1993 *Hanford Federal Facility Agreement and Consent Order* (also known as the Tri-Party Agreement) (Ecology et al. 1994) renegotiation (that began shortly thereafter) resulted in a decision to delay proceeding with the development of a hot test facility until a new technical strategy for waste tank remediation and disposition was established.

The fourth amendment to the Tri-Party Agreement, as approved by the stakeholder representatives in January 1994, significantly redirected and expanded the previous Hanford Site cleanup goals and objectives. The Tri-Party Agreement added the single-shell tanks to the work scope and redirected the disposition of low-level waste (LLW) from a grout to a vitrified glass waste form.

With the signing of the revised Tri-Party Agreement in January 1994, this study was initiated by the TWRS Projects Department to redevelop an understanding of the technology issues and process development testing support needs of the new technical strategy (Alumkal 1994) based on the revised Tri-Party Agreement.

1.4 REPORT OBJECTIVES

This report identifies the process development issues for each of the candidate pretreatment processes as of January 1994 for pretreatment, low-level vitrification, and a summary assessment of the high-level vitrification issues. Each issue also will receive a global-level assessment of the level of testing required to resolve that issue and provide/confirm needed design information.

Subsequent reports will address the strategy(ies) for conducting the tests identified in the report and assessing the Hanford Site and DOE complex facility capabilities to conduct the tests.

1.5 TECHNICAL BASIS

The basis for this study is the TWRS Pretreatment Program technical strategy as developed by Westinghouse Hanford Company (WHC) and RL. The pretreatment technical strategy was developed as part of the TWRS rebaselining effort in 1993, culminated in an agreed to strategy in November and December 1993, and is described in WHC-SA-2140-FP, *Hanford Tank Waste Remediation Systems (TWRS) Waste Pretreatment Program Strategy and Issues* (Gasper 1994a). The technical strategy agrees with the fourth amendment to the Tri-Party Agreement and is graphically illustrated in Figure 1-1. This strategy provides the following functional descriptions for the mission:

- "Prepare tank wastes to provide suitable feeds to LLW pretreatment and HLW pretreatment processes."
- "Pretreat prepared supernate to produce feed for the LLW immobilization." (This function includes removal of radionuclides and product concentration to remove bulk chemicals including water.)
- "Condition HLW sludges and TRU tank waste sludges for immobilization and eventual disposal in a designated geological repository."
- "Place separated radionuclides into a form that may be blended with pretreated HLW solids to become feed for HLW immobilization."

Key assumptions of the pretreatment technical strategy are summarized as follows.

- Current tank waste characterization information is sufficient for planning purposes.
- Sludge washing, leaching, and blending will be adequate to achieve an acceptably low HLW volume and composition. Acid dissolution and advanced separations are not required. Organic destruction is not required for organic content reduction.
- Sludge washing and leaching (including enhanced sludge washing) will be performed within the double-shell tanks (DST).
- Waste will be blended to increase waste loading in the LLW and HLW forms.
- The LLW feed stream to the LLW immobilization facility will be acceptable if the cesium-137 (^{137}Cs) is reduced to 1 Ci/m^3 in the resulting LLW glass and strontium-90 (^{90}Sr) is removed when necessary.
- Evaporators in the pretreatment facility will perform the volume reduction function.

Figure 1-1. Tank Waste Remediation System Pretreatment Block Diagram.

This study is based on the following assumptions.

- Primary HLW/LLW separation will be carried out in existing underground waste tanks.
- The supernate LLW feed stream will require separation of fine solids before other pretreatment functions.
- Removal of cesium (Cs) and strontium (Sr) are the primary radioactive isotope pretreatment functions. Technetium removal may be required and for planning purposes is required.
- For planning purposes, candidate organic destruction processes for waste tank safety were assumed applicable for radionuclide separation such as Sr and TRU. The 4 candidate processes considered in this report were selected from an initial group of 11 by WHC-SD-W236B-ES-001, *Engineering Study - Initial Pretreatment Module, Project W-236B* (Bailey 1992), and the Initial Pretreatment Module (IPM) Technology Selection Meeting (Roth 1993).
- Pretreatment product stream volume reduction is required but does not require development effort.

2.0 ASSESSMENT METHODOLOGY

An initial survey of the testing issues was initiated using a multipath approach to develop an overall understanding of the test work needed to support pretreatment, LLW and HLW vitrification. This survey was followed by a series of workshops to more fully identify the issues for each technical area that would need cold or hot testing for resolution. Figure 2-1 illustrates the strategy for the overall study. A series of preliminary surveys were initiated as parallel activities, and were followed by five workshops to more fully define the issues that required testing for resolution. The following sections summarize these activities.

2.1 INITIAL SURVEY

Task A--The Office of Technology Development was enlisted to provide an independent assessment of the testing needs of the pretreatment processes being developed at the National Laboratories and the Hanford Site. The results of this effort were published in LAUR-94-1140, *Experimental Infrastructure and Logistics Required to Support TWRS Technology Development* (Farish 1994). A summary of the report is provided in Section 3.1.

Task B--The IPM Project Architect-Engineer (A-E), Raytheon/British Nuclear Fuels, Ltd. (BNFL), was asked to survey the available advanced technologies and provide preliminary findings on candidate technologies and the potential testing requirements. A summary of the responses (Fox 1994) is provided in Section 3.2.

Tasks C and D--The TWRS Process Engineering/Process Technology group was enlisted to provide an investigation and assessment of the testing needs of the following:

- Enhanced sludge washing technology
- LLW vitrification process development
- HLW vitrification process development
- Product qualification testing of LLW and HLW vitrification
- Process instrumentation development (state-of-the-art devices).

The results of this effort were provided in a letter report (Powell and Riebling 1994) and are summarized in Section 3.3.

Task E--An assessment of advanced sludge process test requirements was initially considered for inclusion in this work scope. However, because this area of process development was outside the scope of the Tri-Party Agreement it was deleted from the scope of this study. This area is mentioned here, however, to maintain awareness that should in-tank processing not meet performance requirements and "advanced sludge processing" become necessary, it could represent a significant added testing support (facilities and infrastructure) requirement.

Figure 2-1. Testing Requirements Study Flowsheet. (sheet 1 of 2)

Figure 2-1. Testing Requirements Study Flowsheet. (sheet 2 of 2)

BNFL = British Nuclear Fuels, Ltd.
 FAR = Functions and requirements
 HLC = High-level waste
 ILC = Instrumentation and control
 LANL = Los Alamos National Laboratory
 LLW = Low-level waste
 TAP = Tanks Advisory Panel
 USTID = Underground Storage Tank Integrated Demonstration

Task F--In December 1993, the U.S. Department of Energy chartered a subpanel of its longstanding High-Level Waste Tanks Advisory Panel (TAP) to focus on the technical issues surrounding Hanford Site tank waste pretreatment and the pretreatment system interface with retrieval and immobilization. The pretreatment Sub-TAP was chartered to provide independent assessments and predecisional recommendations on critical issues to U.S. Department of Energy staff in the following areas:

- Status and current application of state-of-the-art process technologies
- Process technology selection methodology and performance measures
- Feasibility of alternative and emerging technologies
- Critical technological needs and data gaps
- The overall concept of pretreatment and immobilization.

As this study has progressed, Sub-TAP and other members of the TAP were provided briefings on the study progress and were given tours of candidate hot testing facilities on the Hanford Site. The Sub-TAP has also reviewed the first draft of this report and provided comments and recommendations. The full text of the panel's comments (Campbell 1994) on the draft and other issues and the study team responses have been documented (Gasper 1994b).

2.2 TESTING ISSUES WORKSHOPS

To further develop the depth of information available on each technical area, five professionally facilitated workshops were organized and conducted that addressed the following process areas:

1. In-tank processes and feed preparation
2. Pretreatment processes
3. Organic destruction processes
4. LLW vitrification process
5. HLW vitrification process.

The participants selected for each workshop represented the WHC technology development groups, the TWRS Process Engineering functions, the participating National Laboratories (Pacific Northwest Laboratory, Los Alamos National Laboratory [LANL], Sandia National Laboratory [SNL]), the IPM Project A-E, and the Hanford Waste Vitrification Plant (HWVP) Project A-E. Westinghouse Hanford Company staff with significant experience in design and operation of nuclear-related chemical process facilities also participated. Appendix A provides a biographical sketch on each workshop participant.

Several preworkshop planning sessions were held with the Pacific Northwest Laboratory's Decision Analysis staff and WHC's Value Engineering staff to develop and clarify the workshop goals, strategy, format, and agenda. Additionally, the workshop planning team performed the following activities during the planning sessions.

- Developed and ranked a "dictionary" of testing (see Table 3-1) for use by the workshop teams. The dictionary ranked the testing definitions from "least" to "most" in time, complexity, and cost. For example, "least" test #1 was a "nonradioactive laboratory test" and "most" test #12 was a "large, radioactive pilot plant."
- Prioritized the technologies for the workshop discussions so that if a workshop team ran out of time, the highest-priority technical issues would be discussed.
- Developed a "standard" data collection format, the Test Requirements Record (TRR) data sheet, to facilitate the recording of issues and test requirements in the concurrently run workshops.

Each of the workshop sessions started with an overview of the goals and objectives of the workshop, and the expected product of the session. The strategy for running the workshops was to take one technology at a time and use qualified brainstorming techniques to identify all technical or safety-related issues that could only be solved by combinations of cold and hot testing.

The technical issues were evaluated, accepted as identified, combined, or eliminated to develop an acceptable composite list of issues for that technology. The entire team then worked to develop a consensus on the level of tests (as defined by the dictionary in Table 3-2) required to resolve the open issues. The process was repeated for each technical issue. No attempt was made to compare technologies, rate their relative merits, or perform downselection analyses.

The data collected from the workshops are summarized in Section 3.0 and discussed in Section 4.0. Appendix B documents the individual proceedings of the five workshops. Appendix C contains the TRR data sheets for the issues identified. Each TRR data sheet represents one issue for a particular technical area and documents the issue, team consensus of testing needed, risk of not doing the full range of testing, and a brief test strategy for that issue. The TRR data were taken directly from flip chart worksheets that were prepared during the work sessions.

Because of time constraints, some workshop teams did run out of time and that situation has been noted where appropriate. This document also endeavors to capture issues that were identified but were beyond the scope of the workshop (see Appendix D). The LLW Vitrification team discussions were so extensive that they consumed a full 2 days instead of 1 day as planned. This pushed the start of the HLW Vitrification workshop (which shared some membership) into an unplanned, short, third-day session. This situation was considered acceptable and beneficial because the issues requiring testing for LLW vitrification were previously undefined whereas much previous thinking and planning has been documented (May 1992) for the HLW vitrification testing by the HWVP Project group.

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3.0 TESTING REQUIREMENTS

The following sections summarize the findings of the studies and investigations performed during the initial survey of testing support needs described in Section 2.1.

3.1 PRETREATMENT TESTING INFRASTRUCTURE AND LOGISTICS STUDY

In support of this study, the LANL staff prepared a preliminary assessment (Farish 1994) of the pretreatment testing issues and test facility requirements for each of the major process functions shown in Figure 1-1. Also presented was a method of assessing program risk.

The bases for the assessment were the following:

- Fourth amendment to the Tri-Party Agreement (Ecology et al. 1994)
- The TWRS technical strategy as outlined (Alumkal 1994)
- Assumption that development of processes to remove long-lived radionuclides from the LLW stream will continue until a future need determination is made
- Organic destruction will not be required for tank safety issue resolution, but may be required to achieve adequate radionuclide removal.

Data were provided by the study on sizing and requirements for hot cells to perform the pilot-scale testing of process and equipment for each pretreatment function. That data will provide input to the strategy and test siting reports that follow this document and will not be discussed further herein. A methodology of risk assessment was also presented for future possible use when more facility cost estimate data are available.

An assessment of testing issues related to the LLW pretreatment functions shown on Figure 1-1 provided the following:

- In-tank sludge washing and solids/liquids separation testing to date has been based on milliliter-sized samples of actual tank waste. The following open issues were identified. (NOTE: These issues and those listed for other functions below were also discussed and expanded upon in the followup workshops and will not be further discussed herein.)
 - Tank corrosion during sludge washing
 - Effect of waste pH on Sr solubility
 - Filter design and operation criteria.
- The following Cs removal open issues were identified:
 - Solid/liquid separation efficiency (particle size removed) required to support Cs removal

- Resin degradation under operating conditions
- Resin thermal and mechanical stability under operating conditions
- Effect of sodium, potassium, and aluminum in caustic solution.
- The organic/nitrate destruction function may only be necessary in 10% to 30% of the total wastes processed.
- Cold testing of candidate organic destruction processes have been accomplished (as of March 1994) as follows:
 - Calcination at 5.7 L/min (1.5 gpm)
 - High-temperature hydrothermal destruction at 0.75 L/min (0.2 gpm)
 - Low-temperature hydrothermal destruction at 0.2 L/min (0.1 gpm).
- Open technical issues for the three calcination processes assessed were noted as follows:
 - Calciner corrosion and dissolution of aluminum in actual waste feed
 - High corrosion rates and high stress levels in hydrothermal process equipment
 - Synergistic effects of mixed organic feeds to the hydrothermal process equipment.
- The report noted that alkaline processes for Sr/TRU removal were the least developed of the candidate processes with basic hot laboratory work having just started in January 1994. Key issues noted were whether sufficient decontamination could be achieved with alkaline processes and synergistic effects of feed variations.
- Technetium removal capability is expected to be used on a limited number of waste tanks and as such was not ranked as a core technology. The key issues in development of Tc removal were identified as follows:
 - The safety aspects of using an 8M HNO₃ eluant with a strongly reducing resin (Reillex-HPQ*)
 - The secondary stream disposal problem of a highly acidic eluant
 - The critical dependence of the decontamination factor on feed adjustment

*Reillex-HPQ is a trademark of Reilly Industries, Inc.

- Lack of adequate analysis techniques/instrumentation for Tc concentration measurement.
- Low-level waste evaporator technology was considered fairly well established based on commercial experience. It was noted that Argonne National Laboratory is doing some LLW evaporator development. Technical issues were identified as the ability to achieve a high decontamination factor of up to E7 and up to 50% suspended solids in the evaporator liquor. The subsequent workshop on pretreatment in prioritizing its time and work gave the LLW evaporation the lowest priority and did not consider it further. These issues will be reevaluated in later phases of this study.

3.2 ASSESSMENT OF ADVANCED TECHNOLOGIES

The A-E for the IPM Project, Raytheon/BNFL, surveyed the technologies being developed under the Underground Storage Tank Integrated Demonstration (USTID) Program. The A-E also was asked to provide a preliminary assessment of the testing needed to support development of the current candidate pretreatment technologies and applicable new USTID-sponsored technologies. No new USTID technologies were identified by the A-E. However, a preliminary assessment of testing to support each pretreatment function shown on Figure 1-1 was provided (Fox 1994). Table 3-1 provides a tabulation of the A-E's initial assessment of the needed level of testing to support design of the IPM.

3.3 ENHANCED SLUDGE WASHING, LLW AND HLW VITRIFICATION, INSTRUMENT DEVELOPMENT

Also in support of this study, Powell and Riebling (1994) prepared an assessment of the testing needs for LLW, HLW vitrification, process instrumentation development, and enhanced sludge washing (Figure 2-1, Tasks C and D). Kepner-Tregoe decision analysis techniques were used to assess the relative risks of alternative courses of action. Their evaluations were based on the following assumptions:

- The fourth amendment of the Tri-Party Agreement (Ecology et al. 1994)
- Restrictions on LLW hot pilot plants noted in the revised Tri-Party Agreement were disregarded to enable an unbiased technical evaluation
- The TWRS technical strategy (Alumkal 1994)
- Vitrification product quality requirements were assumed to be as restrictive as the requirements for near-surface land disposal in grout vaults.

*Kepner-Tregoe is a trademark of Kepner Tregoe, Inc.

Table 3-1. Architect-Engineer Initial Assessment of Pretreatment Technology Development Needs.

Process	Cold test					Hot test	
	Lab	Pilot	Full-scale mockup	Lab	Unit operation	Integrated test	
Sludge wash	4	2	4	1	4	2	
Solid/liquid separation	4	4	4	1	2 ^a	2 ^a	
Cs removal	1	2	4	2	4	1 ^b	
Organics effects (Cs, Sr, TRU, caustic recycle)	1 or 3 ^c	2 ^d	1 ^d	1 ^c	2 ^d	4	
Enhanced (caustic) sludge wash	4	4	4	1	3	2	
Glass "do bads" (Cr, U, P, heavy metals)	4	4	4	1	3	2	
Corrosion studies	1	4	4	3	2 ^e	2 ^e	
Tc removal	1	2	4	1	1 or 2	1 or 2	
Training for Operations and European technology demonstration	4	4	2	4	4	3	
DOE-HQ integrated demonstration	4	4	4	4	4	3	
TOTALS	28 or 30	32	35	19	29 or 30	22 or 23	

NOTES:

a. The integrated test and the unit operation are essentially the same facility (at the tank).
 b. Essential for a contact maintenance low-level waste vitrification facility. Would be Category 2 (high risk) if the low-level waste vitrification facility was not contact maintenance.
 c. The hot laboratory test must be done first. Category of cold laboratory test will depend on results of hot laboratory test.
 d. The need for these tests will derive from the laboratory tests and trade studies.
 e. Corrosion studies and post-laboratory work would be built into unit operation or integrated facilities as appropriate.

- Rankings:
 1. Essential
 2. High risk if not done
 3. Desirable
 4. Not required

Source: C. H. Fox, March 24, 1994, Initial Pretreatment Module Hot Test Requirements (Letter No. 1PM-PD-94-127, Raytheon/BNFL, to E. A. Nelson), Westinghouse Hanford Company, Richland, Washington.
 Cs = Cesium
 Cr = Chromium
 DOE-HQ = U.S. Department of Energy-Headquarters
 P = Phosphorus
 Tc = Technetium
 TRU = Transuranic
 Sr = Strontium
 U = Uranium

The conclusions and recommendations provided by the study were as follows.

- Radioactive laboratory testing and testing in existing DSTs should be sufficient to meet enhanced sludge washing program needs and requirements. Pilot-plant scale radioactive testing of the enhanced sludge wash process outside the waste tank environment was not recommended at this time.
- Further assessments of issues related to the LLW vitrification process should be made to verify the need for an LLW vitrification pilot-scale test capability.
- High-level waste hot pilot-plant testing should be performed. Until the HLW melter is selected, there will be uncertainty about the hot testing requirements (e.g., melter size, feed requirements). Work on defining the HLW pilot-plant sizing, feed, and utility requirements should continue.
- Non-melter process equipment will be critical for process control and feedback. It is recommended that a functional hot testing capability be established for testing equipment and process control instrumentation in a non-melter process.
- Disposal requirements will dictate that the HLW and LLW vitrified products be tested to determine product quality during plant startup and early operation. It is recommended that process and product testing equipment be added to the first radioactive vitrification pilot plant to ensure that product testing is effective and that the test equipment is appropriate for the production plant.

The preliminary information gathered above provided a planning base for the subsequent workshops. In the workshops, each technology was reevaluated to ensure that all known significant issues were defined and characterized for level of testing by the methods described in Section 2.2.

3.4 TESTING REQUIREMENTS WORKSHOP DATA PRESENTATION

In conducting the workshops on testing requirements, the technical issues that could only be resolved by testing (as compared to those that could be resolved by literature searches, etc.) were recorded individually on TRR data sheets with the consensus of needed test work to resolve the issue. Each data sheet included an assessment of the risk of not implementing the highest level of testing and a strategy statement (where appropriate) on implementing the test work. The data sheets are provided in Appendix C and are grouped into one of the following process function categories:

1. Solids Processing (Primarily In-Tank)
2. Pretreatment Processes
3. Organic Destruction and Miscellaneous Processes
4. LLW Vitrification
5. HLW Vitrification.

Table 3-2 provides a dictionary of testing levels used in the workshops to characterize the testing requirements of each issue. Table 3-3 is a spreadsheet that summarizes the test requirements for all issues associated with the technical issues addressed. Referring to Table 3-3, the testing requirements for the "Solids Processing Function, Settling Technology" indicate that hot laboratory testing and testing within a retrieval waste tank are needed to resolve the open technical issues. Appendix C1.0 contains details on the individual settling technology issues and test requirements. For the pretreatment processes, a combination of hot (laboratory and bench-scale) and cold (bench scale and large pilot-scale) testing is needed to address the identified technical issues.

Table 3-3 shows the testing requirements for competing technologies for the organic destruction and LLW/HLW vitrification technical issues. It is anticipated that, in most cases, technical self-elimination will occur as testing within a functional group, such as organic destruction, proceeds through the testing sequence. As a result, not all candidate technologies for that function will be tested in the more advanced testing levels even though shown on the spreadsheet.

The Blending and Evaporation functions shown in Figure 1-1 were not considered in this assessment of testing requirements because neither one was believed to require any extensive hot bench- or pilot-scale testing to provide design information. Should an integrated pretreatment/LLW vitrification pilot plant/demonstration be considered appropriate, however, one or both functions may need to be included.

Table 3-2. Tank Waste Remediation System Testing
Requirements Dictionary.

Testing Definitions

1. Nonradioactive (cold) laboratory testing includes investigations based on waste simulant and laboratory-scale nonradioactive testing. Mixing in beakers and crucible melting of simulants are examples.
2. Cold bench-scale testing will use laboratory equipment and may use some scale process equipment to simulate parts of the process to establish certain critical parameters using simulant feed.
3. Small, cold pilot plant is in the one-tenth to one one-thousandth size range that uses waste simulant and scale equipment to simulate major portions of the process.
4. Waste characterization is testing of the radioactive waste to determine physical and chemical parameters of interest.
5. Radioactive (hot) laboratory testing includes actual radioactive waste used in laboratory equipment to make products and establish basic processes.
6. Large, cold pilot plant is a one-tenth to full-scale unit that uses essentially all the equipment and controls of the full-sized hot unit.
7. Testing using existing double-shell waste tanks includes either inserting equipment into the tank or pumping waste solution up to nearby equipment to test equipment or process. Testing may include processing the entire volume of the tank waste.
8. "Functional" hot pilot plant tests only critical portions of the process, not the entire process. It may be set up for one or several specific testing tasks and uses radioactive waste. The plant is normally limited in its scope, and much smaller and less expensive than a full-sized unit.
9. Hot bench-scale may use some scaled process equipment to establish certain critical parameters using radioactive feed. Not all the equipment is scaled down from that which will be used in the process. Usually, this would fit in a small hot cell or a hood.
10. Full-scale cold pilot plant (self-explanatory, see large scale).
11. Small, hot pilot plant uses a majority of the scaled-down process equipment used in a full-sized plant. Radioactive waste is used as a feed. A small pilot plant is usually one-tenth to one one-thousandth scale of the full-sized unit.
12. Large, hot pilot plant is greater than one-tenth scale and uses radioactive waste as the feed. The equipment is normally the same type envisioned for the full-scale unit (with modifications to make it more flexible than the full unit.)

Table 3-3. Testing Requirements Summary.

Tank waste remediation system tank waste requirements summary for pretreatment, low-level waste, and high-level waste vitrification.												
Function	Technology	Testing										
		1	2	3	4	5	6	7	8	9	10	11
1. Solids Processing	Settling	--	--	--	--	X	--	X	--	--	--	--
	Enhanced Sludge Washing	X	--	--	X	X	--	X	--	--	--	--
	Sludge Washing	X	--	--	X	X	--	X	--	--	--	--
	Filtration	X	X	--	--	X	--	X	X	H	X	--
	Centrifugation	X	--	--	X	X	X	X	--	--	--	--
	Ce, Removal, IX	X	X	--	--	X	X	X	--	--	X	--
	TRU, Tc, Sr, IX	X	X	--	X	X	X	X	--	--	X	--
	Sr Precipitation	--	--	--	X	X	--	--	--	--	--	--
2. Pretreatment Processes	Calcination	X	X	--	--	X	X	X	--	--	--	--
	Steam Reforming	X	X	X	X	--	X	X	--	--	X	--
	High-Temp Hydrothermal	--	X	X	--	X	--	X	C	X	--	--
	Low-Temp Hydrothermal	X	X	X	--	X	--	--	X	C	X	--
3. Organic Destruction	In-Tank Organic Destruction	--	--	--	--	X	--	--	--	--	--	--
	Joule-Heated Melter	X	X	X	X	X	X	X	--	--	X	--
	All Melters	X	X	X	X	X	X	X	--	--	X	--
	Vitrification	X	X	X	X	X	X	X	--	--	X	--
4. Low-Level Waste	Joule-Heated Melter	X	X	X	X	X	X	X	--	--	X	--
	All Melters	X	X	X	X	X	X	X	--	--	X	--
5. High-Level Waste Vitrification	Joule-Heated Melter	X	X	X	X	X	X	X	--	--	X	--
	All Melters	X	X	X	X	X	X	X	--	--	X	--

C-denotes cold test.
H denotes hot test.
* Not required but highly desirable
Not evaluated in sufficient detail to determine need

DST = Double-shell tank
IX = Ion exchange
Sr = Strontium
Tc = Technetium
TRU = Transuronic

4.0 TESTING REQUIREMENTS DATA ANALYSIS

The following sections summarize the findings of the study team. Sections 4.1, 4.2, and 4.3 provide a discussion of pretreatment, and LLW and HLW requirements, respectively.

4.1 PRETREATMENT

Pretreatment testing requirements were examined against the following pretreatment functional breakdown.

Solids Processing

- In-tank processes
 - Settling (solid/liquid separation)
 - Sludge washing/dissolution
 - Enhanced sludge washing/dissolution
 - Flocculation (determined to be an enhancement to other technologies during the workshop, not a separate technology)
- Out-of-tank processes
 - Centrifugation (solid/liquid separation)
 - Enhanced sludge washing/dissolution
 - Filtration

Pretreatment Processes

- Cs removal by ion exchange
- TRU removal by ion exchange
- Tc removal by ion exchange
- Sr removal by precipitation/isotopic dilution
- Sr removal by ion exchange

Organic Destruction

- In-tank organic destruction (heat and digest)
- Calcination
- High-temperature hydrothermal destruction
- Low-temperature hydrothermal destruction
- Steam reforming.

The overall testing scenario to address each of these technical issues is described in some detail in the following sections and in Appendix C, but can be summarized as follows:

- Extensive laboratory testing and bench-scale testing using simulants and actual waste to perform the following activities:
 - Quantify the chemistry, physical properties, and variability of the waste
 - Develop the process chemistry and quantify safety data

- Selective large-scale cold pilot-plant testing on ion exchange and organic destruction processes where scaleup of process or equipment problems is considered too risky
- In-tank or near-tank pilot-plant demonstration of solids pretreatment processes and technologies to prove equipment and full-scale tank operation performance.

The study group was careful to minimize the extent of testing to that which was required to resolve issues that could not be resolved by other methods, and, if not carried out, imposed significant risk to the performance of the function. It was the group's consensus that pretreatment testing needs could be met without the need for large-scale hot test facilities, other than in-tank or near-tank testing of solids pretreatment processes on one or more DSTs at large pilot-plant scale.

The risk associated with not undertaking the testing identified above is that the pretreatment processes are unlikely to perform as predicted when faced with the variability of tank waste characteristics. The specific risks are likely to be a combination of the following:

- Failure to meet LLW product specifications
- Failure to meet throughput rates and hence increased production costs and missed Tri-Party Agreement milestones
- Lack of adequate data to support safety assessment requirements leading to difficulty or failure to obtain regulatory approvals
- Escalating cost through time lost and plant rework
- Increased volumes of HLW
- Facility may not operate.

4.1.1 Solids Processing

The testing needs for the "solids processing" function are described in some detail for each of the identified technologies. These needs can be summarized into the following categories:

- Laboratory testing to gain a wider understanding of variability and solubility characteristics of the tank wastes
- Laboratory and in-tank testing, inspection, and monitoring of DST condition and corrosion performance
- In-tank and/or local-to-tank pilot to full-scale testing and monitoring of processes to confirm laboratory data and demonstrate process and equipment performance.

4.1.1.1 In-Tank Solids Settling. The key issues against in-tank solids settling were those associated with understanding the range and performance of the solids wastes across the tank inventories. Test data needs included the following:

- Settling rates
- Radionuclide distribution in the solids with respect to particle size
- Percent settled solids
- Effect of tank mixing on particle size and subsequent settling.

The study group noted that there is experience at the Hanford Site, Savannah River Plant, and West Valley Demonstration Project on working with actual tank waste that may provide valuable settling process data (Hamm et al. 1983, Ator 1984, Gerboth 1987, Rassmussen 1980, Rodenhizer 1987). The one area requiring further laboratory testing on actual waste was radionuclide distribution. The data are required to gain a clearer understanding of the potential for radionuclides associated with submicron particles being carried into the supernate and through to the LLW product.

The main outstanding test requirements for each of the key issues are to carry out representative in-tank tests of mixing, settling, and sampling to confirm the laboratory test data.

4.1.1.2 In-Tank Sludge Washing. The key issues for in-tank sludge washing processes are confirmation of the integrity of the DSTs for this work and the performance of the sludge wash process. The key issues, therefore, were as follows:

- Tank corrosion
- Peptization of the sludge solids
- Sludge solubility
- Mass transfer/reaction rates.

The tank corrosion issue requires extended laboratory coupon testing with simulants followed by more limited laboratory coupon testing on actual waste, together with an ongoing program of in-tank inspection and monitoring.

The wash process performance issues require laboratory testing on a wide range of actual waste core samples to examine the issues listed. Representative in-tank testing is also required to confirm mass transfer rates under actual tank conditions and scale.

4.1.1.3 In-Tank Enhanced Sludge Wash. The same range of issues arise for enhanced sludge wash as those identified for sludge washing. The tank corrosion issue has greater emphasis due to the more aggressive processes involved. Laboratory testing of the hot caustic wash process is required on a wide range of actual waste samples and confirmation in a DST.

4.1.1.4 Flocculation. Flocculation may assist a number of the solids/liquid separation processes and should therefore be considered as an enhancement to

these processes, not as a separate function. The processes that may be enhanced by flocculent addition are settling, centrifugation, and filtration. The addition of flocculent should therefore be incorporated in the simulant and actual waste testing programs for those technologies. The impact on LLW and HLW forms and safety issues need to be evaluated.

4.1.1.5 Centrifugation. Centrifugation may be required as backup to the in-tank settling process if settling rates are too slow, if a percentage of suspended solids remains too high, or if the wash volumes are excessive. The addition of flocculents also may be considered in the test program. The following key issues relate to centrifuge performance:

- Throughput rate/removal efficiency
- Maintainability and reliability
- Process control
- Solids discharge methods
- Cake properties.

Centrifuge testing using simulants with flocculent addition, followed by repeat testing with real waste, should be undertaken to determine the effectiveness of this enhancement.

In addition, simulant testing on a range of centrifuges should be undertaken, preferably at the manufacturers's works. This simulant testing should then be confirmed on the preferred centrifuge type at a DST, at pilot to full scale, on actual waste.

Consideration should be given to incorporating the centrifuge into a demonstration of at-tank processes, such as filtration and out-of-tank enhanced sludge washing.

4.1.1.6 Out-of-Tank Enhanced Sludge Washing. The design of a compact out-of-tank enhanced sludge washing process may be required if DST availability, integrity, or process performance precludes in-tank washing. If an out-of-tank process is selected, successful demonstration of the process adjacent to a tank would substantially reduce program risk.

4.1.1.7 Filtration. Filtration will be required to remove fine particles from supernates not separated out by settling (and centrifugation, if used). The issues associated with filtration are similar to those for settling and centrifugation and are as follows:

- Particle size distribution
- Radionuclides in solid particles
- Filter cake properties
- Percent suspended solids.

Additionally, downstream filtration processes also may be required to remove in-process-generated solids from the pretreatment process. This need, and its associated testing needs, will not be known until further flowsheet development and testing work on pretreatment processes is complete.

Laboratory testing of actual waste identified for settling and sludge wash processes will provide the base data for filtration process selection and

development. In particular, simulants should be developed from actual waste testing to enable bench-scale simulant testing of filter types. This testing should be validated using bench-scale testing on actual waste.

4.1.2 Pretreatment Processes

4.1.2.1 Ion-Exchange Processes. The testing requirements for ion-exchange processes for Cs, Sr, Tc, and TRU are essentially the same in nature, although the actual test detail will vary for each radionuclide specie. The test requirement analysis, although conducted separately by the working group, can be summarized in a single section.

The ion-exchange processes examined were as follows:

- Cs removal using a range of ion-exchange media (Cs 100, JB resorcinol, crystalline silicotitanate)
- TRU removal using crystalline silicotitanate
- Sr removal using an organic resin on crystalline silicotitanate.

The group identified a wide range of issues that need resolution by testing and these are listed in Appendix C2.0. The issues can be summarized into the following broad groups:

- Physical and chemical properties and performance of the ion-exchange media under storage and operating conditions
- Performance of the ion exchange and associated equipment systems
- Effect of organics (chelates and immiscible organics)
- Ion-exchange media removal and disposal.

For each resin type and radionuclide specie, the following sequence of testing is required, by separate specie and as a mixed specie feed:

- Laboratory batch (equilibrium) testing using simulants
- Laboratory flow (column) testing using simulants
- Laboratory batch (equilibrium) testing using representative actual wastes
- Laboratory flow (column) testing using representative actual waste
- Large-scale pilot-plant testing using simulants to prove equipment performance and develop remote maintenance/operations requirements.

For Sr and TRU removal, the performance of the processes on these species bound up in organic complexants also will need to be examined as part of the series of laboratory tests on simulants and actual waste.

4.1.2.2 Sr Removal by Precipitation. Strontium removal in-tank, by precipitation, may be possible using one of several possible precipitating agents. The key issues identified against these processes were as follows:

- Identification of the form and variability of Sr in the tank wastes
- Identification and testing of possible precipitation processes
- Effects of other processes with particular emphasis on potential effects of the different chemical and physical regimes in these processes (e.g., redissolution caused by chemical addition, temperatures, pH, etc.).

It was noted that testing is already in progress, and no further testing is required at this stage until these tests are completed and the results are evaluated.

4.1.3 Organic Destruction and Miscellaneous Processes

Development and testing work has continued on several organic destruction processes based on the need to alleviate safety issues in a number of watch list tanks. Work conducted elsewhere has shown that these safety issues can be mitigated by other methods, and development of organic destruction processes is no longer required for safety issue resolution purposes other than as backup.

However, the presence of organics may have adverse effects on the pretreatment processes and the LLW form, principally Sr and TRUs bound up with these organics as complexants. As a consequence, they may not be removed by the pretreatment processes. This could cause LLW form and LLW vitrification plant shielding and confinement problems if not dealt with.

As a consequence, there is a need to redefine the requirements for removal of other nuclides to provide a basis for testing and development to continue on a range of processes to meet these redefined requirements. Because the requirement may be less stringent (i.e., total destruction of the organics may not be required) it may be possible to use less technically challenging processes.

The testing needs of the following organic destruction processes have been examined based on this revised requirement.

4.1.3.1 In-Tank Organic Destruction (Heat and Digest). Testing work is already underway on this process. However, the following key issues were identified and need to be addressed within the existing test program:

- Process performance (chemistry, kinetics)
- Tank waste characteristics (solids, volume/surface area ratio, sodium nitrate levels, high aluminate/caustic concentration, mixing effects)

- Safety issues (process temperatures, tank integrity, corrosion, offgas).

The test strategy should extend the present range of tests to include these issues and change the emphasis to Sr and TRU removal, rather than gas generation. Consideration also should be given to using the product material from these tests in other pretreatment tests to look for interrelationships between process flowsheets (e.g., isotopic dilution).

4.1.3.2 High-Temperature Hydrothermal Organic Destruction. Development and testing work on this process has been underway for some time. The study group identified the following issues and test strategy, which need to be incorporated in the existing program.

Key issues:

- Chemistry development
- Equipment development
- Overall process development.

Test strategy:

The high temperatures and pressures involved in this process present a considerable engineering challenge. Extensive equipment and integrated process testing will be required to develop this process to a production capability.

The chemistry development issue requires the following test steps.

- Sample solids and supernates to determine Sr and TRU distribution.
- Using a range of simulants, conduct bench-scale testing to establish the solubility of Sr and TRUs.
- Conduct further bench-scale tests on a range of actual waste to confirm cold test data and variability of feed to the process.

Equipment and overall process engineering development should continue in parallel with chemistry development and include performance and endurance testing of the pressurization system, pumps, reactors, and controls. Operability and maintainability under remote operation conditions should be a key part of the development program. Bench-scale component and system testing using simulants and actual waste should be followed by full-scale testing of the critical areas of the process. Full-scale testing using simulants only should be adequate because it should be possible to produce representative simulants from the actual waste test and sample data.

4.1.3.3 Low-Temperature Hydrothermal Organic Destruction. The only essential difference between this process and the high-temperature process is that the lower temperature and processes give rise to less difficult engineering and safety issues, although these are still substantial. The range of issues and test requirements is therefore essentially the same as for the high-temperature process.

4.1.3.4 Calcination. Cold testing of this process has been performed on equipment available at a private testing facility. The following key issues have been identified and need resolution by further testing:

- Chemistry development (e.g., kinetics, offgas expectations, TRU/Sr separations)
- Engineering development (e.g., firing optimization, corrosion)
- Equipment and systems development.

Preliminary engineering and equipment systems development should be conducted in parallel with cold bench-scale chemistry development tests. Most of this testing can be accomplished with cold simulants with limited hot laboratory work to confirm the behavior of Sr and americium cold simulants.

4.1.3.5 Steam Reforming. Cold bench- and pilot-scale testing of the steam reforming process has been conducted at SNL. Technical issues identified by the workshop study group included the following:

- Chemistry development (e.g., organic and nitrate kinetics, exothermal reactions, volatility of radionuclides, TRU and Sr solubility in carbonate product solution)
- Process and engineering development (e.g., optimization of feed spray patterns, mastic formation recovery, ceramic ball-handling and solids recovery system)
- Equipment development issues (e.g., remote operability/maintainability size minimization, radionuclide buildup).

System development will require small and large, cold, pilot-scale testing and small, hot, pilot-scale testing to validate the cold test work with simulants. Hot pilot-scale testing will be required to verify control of radionuclides and distribution of TRU.

4.1.3.6 Miscellaneous Processes. A caustic recycle process also was included in this section under miscellaneous processes but the working group agreed that an engineering study was required to determine process feasibility before a testing program was developed.

During July 1994, a further downselection of the candidate organic destruction processes was conducted (Roth 1994) and the low-temperature, hydrothermal organic destruction process was selected as the recommended IPM baseline process with electrochemical organic destruction as the backup process. (Electrochemical organic destruction was not a consideration when this study was in progress and is therefore not included in this assessment of testing support requirements. It will be considered in future reports.)

4.2 LLW VITRIFICATION

It is planned that LLW vitrification will process 140 metric tons/day of vitrified material for disposal onsite in LLW disposal vaults. It is

envisioned that there will be two 100 metric ton/day melters to process this waste. The candidate types of melting technology envisioned for this process include the following:

Melter technology	No. of LLW Vitrification Issues
• Joule heated	56
• Combustion	6
• Electric arc	See Appendix C, HLW Session 4
• Plasma	See Appendix C, HLW Session 4

A further broad breakdown of key vitrification technology issues included the following:

- Melter feed preparation
- Melter systems
- Melter offgas
- Product quality
- Miscellaneous.

The final onsite disposal vault testing needs were not discussed in this workshop due to time limitations, and they were not likely to interface or affect waste pretreatment.

In general, many testing issues listed under joule-heated melters are generic in nature and can be applied to all vitrification technologies. Joule-heated and combustion melter technologies were the most strongly represented by experts at the workshop and, as a consequence, were the most thoroughly analyzed for open issues. The other melter technologies were not as strongly represented. However, many testing issues listed under joule-heated melters are generic in nature and are applicable to all vitrification technologies. There are likely to be specific melter testing issues that could be more completely captured for some technologies. Additional workshops could be advantageous to further explore testing issues.

4.2.1 Test Evaluation Process

Joule-heated melter technology was evaluated first, followed by other melter technologies. The issues were documented on flip charts and in TRR data sheets. Generally, the TRR data sheets were more detailed and collected more of the reasoning behind the test choices. Because the brainstorming portion of the session produced many more testing issues than anticipated, it was determined that only the issues that would force the testing to the most expensive and complex areas would be evaluated. From the large list of issues noted in Appendix B, only a few were selected for evaluation and discussion. The selected issues are further discussed in the following sections.

Initially, several technology issues were evaluated in the large group to provide examples of the input that was sought. Then the group was divided into teams to work on the key issues in the following major sections:

- Melter feed

- Melters
- Offgas issues
- Product quality.

After evaluating the main issues in that session, the small groups reported to the main group and presented their findings. It is noted on the TRR data sheets whether these small groups presented their results to the large groups. Time did not allow all the issues evaluated in the small groups to be presented to the large group.

4.2.2 TRR Evaluation

The evaluations of TRRs are conducted by issue description, as discussed in the following sections. The first general issues addressed were the critical melter feed issues.

4.2.2.1 Electrode Selection. A major issue affecting joule-heated melters is the selection of electrodes for the melter. Molybdenum is the preferred material due to its higher operating temperature limits (above 1150 °C). Inconel* is the backup material (up to 1150 °C). The required testing is corrosion of the electrodes for long periods of time in a continuous pilot plant. The composition of feed will affect the choice of electrodes and operating conditions. If small pilot-plant testing is not completed, there is a high risk that redesign and modification of the production-scale melter will be necessary for new electrodes. In addition, the product will have to be reformulated and tested to ensure acceptance at the disposal area. These changes could cause long operating delays.

4.2.2.2 Redox Control. The redox environment must be reducing to use molybdenum electrodes. To obtain a reducing environment, the nitrate and nitrite salts must be reduced or removed. Reductants such as sugar, glycolic acid, and powdered aluminum metal may be added to the formation to obtain these conditions. To determine the redox potential in the melter and electrode life requires several small, cold, pilot-scale tests. Risks are similar to those described in Section 4.2.2.1.

4.2.2.3 Volatility and Entrainment of Radionuclides and Halogens. The fate of radionuclides and reactive halogen compounds compose this issue. The compounds may be collected and perhaps corrode the offgas system, escape to the environment, be captured in the product, or form a new secondary waste stream.

The minimum testing needed is a cold pilot plant; the maximum, a hot pilot plant. Heat transfer and volatility do not necessarily scale up well, so it is recommended that a large, cold, pilot-plant test (#6) be performed. Testing on this level is necessary for mass balance, dose (safety), regulatory, and operational considerations.

*Inconel is a trademark of International Nickel Company.

If good nonradioactive surrogates cannot be found for critical radionuclides, it will be necessary to proceed to radioactive pilot plants to confirm the compositions of secondary waste streams.

4.2.3 Small Teams and the Large Group

The following issues were originated in small groups, and discussed in the large group. Substantial information was normally added to the small group evaluation by the larger group. The results are shown on the TRRs and summarized below.

4.2.3.1 Particulate Recycle. Particulates are generated from the melter and deposited in the offgas system. This may generate a stream for recycle, reuse, or disposal. The tests needed include those for chemical and radionuclide definition of the secondary waste streams. Dose issues and composition concerns are associated with the fate of these streams. Small-scale pilot-plant testing is needed to determine general composition. Larger testing is necessary for mass balance and more specific composition. Risks are moderate if large, cold, pilot-plant testing is unavailable. Small pilot-plant testing is critical for resolution of these major issues.

4.2.3.2 Chemical Modification of the Feed. As shown on the TRR data sheets, this major issue had many smaller issues inherent in it; therefore, it was evaluated slightly differently. The interrelated issues were assigned letters to make it easier to deal with them. In the TRRs, the issue letters are shown next to the testing levels that are needed for resolution. The following issues should be evaluated in a hot pilot plant:

- Electrode performance
- Foaming
- Feed rheology
- Offgas decontamination factors.

The more variable the feed composition and the nearer the processing limits, the more important it is to perform a hot pilot test. The risk is that the product will not have the desired characteristics, and there will be significant recycle. The other risk area includes regulatory requirements and propagation of secondary waste streams.

4.2.3.3 Organic Destruction. Ecology incinerator requirements may vary depending on the melter technology chosen. The melter (incinerator) must demonstrate significant organic destruction and removal efficiency. The organics that are not fully oxidized must be shown to meet safety and health requirements. Testing will include offgas sampling for organics and NO_x. Failure to perform sampling at pilot-plant levels will prevent startup by failure to resolve safety issues, possibly regulatory issues, and may not detect offgas design concerns for plugging and fouling. Hot pilot-plant testing is desirable to resolve the unknown organic issue in the hot waste. The strategy is to develop organic and nitrate and nitrite issues on cold bench scale. A larger cold pilot plant will use an integrated melter system for demonstration testing.

Nitrate and nitrite disposal will have to first be addressed through best available control technology evaluations. Pretreatment to remove nitrate and nitrite before the melter also should be evaluated to determine if it is appropriate. Destruction of NO_x in the offgas is well-established technology and should not require major testing.

4.2.4 Small Groups

The issues listed below were discussed in small groups only. For documentation purposes, they are listed here for reference without further commentary:

- Radionuclide volatility
- Radionuclide buildup
- Refractory life
- Phase separation
- Condensable material fouling at the melter exit
- Corrosion in offgas equipment
- NO_x control in offgas.

4.2.5 General Issues--All Melters

4.2.5.1 Short-Term Product Quality Verification for Feedback Control. This issue assumes that the feed composition is variable and that feedback control of some type is needed to limit recycle of product. To adequately test this concept, some type of small-scale pilot plant with an integrated control system is necessary. The minimum quality control equipment might consist of visual inspection of the hot product to detect foaming, wall brick, or plugging. Feedback to control the process could be in the form of controlling feed and flow rate, changing feed, controlling pool and plenum temperature, or changing residence time of the product in the melter. It is critical to test the product verification equipment and the product under the conditions in which it is expected to operate, so a hot pilot would be appropriate. It is desirable to test the complete control system with hot waste and this could be performed in a cold pilot facility.

4.2.5.2 Verification of Long-Term Product Acceptability by Short-Term Quality Tests. The established week-long product consistency test is an example of a leach test that could be conducted before disposing of the product. Alternate tests may have to be developed depending on the lag time of temporary product storage. Hot product quality tests are desirable to confirm cold product quality tests. These product quality tests could be confirmed by functional hot pilot test production of the vitrified products.

4.2.5.3 Verification of Long-Term Product Quality by Testing. To dispose of a vitrified product onsite, the product must meet minimum product quality requirements provided by a performance assessment. These requirements will probably include a leach test, at a minimum. This is best done by producing a product in a hot continuous pilot plant. Risks of not ensuring product quality meets requirements include increased recycle of product and delay of production to qualify the waste form.

4.2.5.4 Other Melters. Combustion, electric arc, and plasma melter technologies also were evaluated. The melter type and unit operations required will tend to force any undeveloped melter technology to a large, cold, pilot plant. This is necessary to develop and scale up the technology and the process control.

Product quality issues, secondary waste streams, and radionuclide buildup issues similar to those with joule-heated melters support bench-scale, hot, pilot-plant operations. Resolution of the above issues will require more than hot crucible tests, but may not require the full pilot-plant complex with offgas equipment. Variable feed composition will support hot pilot-plant operation by establishing the limits of the effects of radiation, minor chemical components, and synergistic effects on the process. Special testing issues with each melter technology are shown in Appendix B.

Product quality issues force use of a small, complete, hot pilot plant to establish that the product meets requirements. More stringent product requirements will support more complete and extensive hot pilot-plant testing.

Development of conservative LLW product quality specifications are needed as soon as possible. This will allow a product quality goal to be established for the process, help determine process parameters, and speed product quality equipment development. Product quality requirements are necessary to establish testing requirements.

4.2.6 LLW Vitrification Discussion

The large number of issues to be resolved (56) in LLW vitrification indicate that there are many questions to be answered with the testing program. These issues will have to be closed at some point in the development, design, and startup process. The issues identified will provide a starting point for safety analysis, technical investigations, and Readiness Reviews.

Cold, large, pilot plants are required for the LLW vitrification effort. The large-production capacity of the final LLW melter requires that scaleup questions be answered. A small, hot, bench-scale pilot plant is required for the LLW vitrification effort to confirm or establish electrode composition, foaming potential, feed rheology, product quality, and offgas decontamination factors. A small, complete, hot pilot plant is highly desirable for the same reasons as the bench-scale pilot, and final testing of product quality, synergistic effects, and offgas issues.

Comparison of data from a small cold pilot to a hot pilot of the same size will significantly reduce the risk that the performance of actual waste feed will be different from that of simulated waste feed. Much of the need for the hot pilot comes from the expectation of variable feed.

Conservative LLW product quality specifications need to be developed as soon as possible in order to establish process parameters. Product quality requirements are needed to finalize testing requirements.

4.3 HLW VITRIFICATION

In general, HLW vitrification will process 8 to 20 metric tons/day of vitrified material for offsite disposal. The types of melting technology envisioned for this process include the following. (NOTE: Additions to the list presented in LLW, Session 2, may pertain only to HLW.)

Melter technology	No. of HLW Vitrification Issues
• Joule heated	39
• Combustion	6
• Electric (carbon) arc	4
• Induction	11
• Plasma arc (non-transferred)	4
• Plasma torch (transferred)	4

Because the LLW vitrification workshop took 2 days instead of the 1 planned, and several of the members also were in the planned HLW vitrification workshop, an unscheduled, third-day session was added to enable the HLW workshop. The limited length and scope of the HLW workshop lead the team members to decide that only melter feed preparation, melter systems, melter offgas, and product quality would be discussed. Other general issues, such as performance assessments and feed preparation, were not included in the scope of the workshop.

4.3.1 Test Evaluation Process

The brainstorming portion of the HLW session added considerably to the issues that the LLW vitrification session generated (see Appendix B). About 39 new issues were generated for joule-heated melters, and lower amounts for other technologies. The work group agreed that the same issues that applied to LLW vitrification also applied to HLW vitrification, but with a different emphasis. Many of the new issues applied only to HLW, not LLW. This combined (LLW and HLW) issues list (Appendix C) represents the most complete compilation of issues done to date.

Because there was limited time available to do an extensive evaluation process, the work group determined that the only issues that would be discussed would be the ones that pushed the testing to the most expensive and complex areas. These issues were documented in TRR data sheets. From the list of issues noted in Appendix B, the product quality issues were selected for evaluation and discussion. All discussion was done in the large group, instead of breaking into small groups as was done in LLW vitrification.

The first evaluation completed was performed on joule-heated melter technology. The results of the evaluation may be applied to any other melter technology because the issue was product quality. In general, product quality requirements will be the same independent of the melter technology.

4.3.2 Summary of LLW and HLW Vitrification Feed and Product Differences

The basic differences between LLW and HLW vitrification are listed below to better baseline the present perceived differences between the two streams. These differences were presented to all attenders at the start of the workshop during the first day of presentations.

- The anticipated waste level loading for vitrified LLW is about 25 wt%; that for HLW could be as high as 50 wt%.
- The HLW will contain the vast majority of radionuclides in the settled sludge, and virtually all the TRU.
- The vitrified HLW production will be 6% to 14% of the vitrified volume of the LLW.
- It is anticipated that the HLW will be put in canisters and stored on an interim basis at the Hanford Site before being transported to the repository. The LLW may be made into cullet and disposed of onsite in near-surface vaults.

4.3.3 TRR Evaluation

Two TRR evaluations were documented for product quality. Although the TRRs were written for joule-heated melters, they are applicable to all melter technology. The TRR information does not really capture the discussion, which included two (or three) different operating philosophies and intents. The major product quality philosophies follow.

- Feedback control is the primary means to control product quality, which uses online product quality testing and observation to influence the process and production of the product. This assumes that some recycle of the off-specification product will occur.
- Feed-forward control relies on extensive characterization of the feed and demonstration of appropriate operating conditions to make a good product. The final product will be tested in the first few canisters, but provides limited quality control testing of the product thereafter. Recycling the product is an option, not a requirement.

These two control strategies can be combined to produce a control system that has feed forward and feedback elements. This combination of control schemes may have the best chance of successful, long-term, continuous acceptable operation because of its flexibility.

The opinion was noted that present commercial glass melters have feedback control even though the usual online product evaluation is visual inspection. It was also noted that a combination of feed forward and feedback had always been envisioned for previous operating concepts. The degree of emphasis of one operating philosophy compared to the other was probably the real area of difference in the discussions.

4.3.3.1 Product Quality--Short-Term Product Quality Determination for Feedback Control. This approach emphasizes that the product is the critical factor in production, and that it must be tested to establish acceptability. A key in the process is that feedback from the product is necessary to adjust the process parameters. A summary of testing needs is as follows.

- A small, hot (radioactive) pilot plant should be the same size as the cold pilot plant to demonstrate performance equivalency between hot and cold waste. Without establishing a basis for hot equaling cold pilot plants, the process of cold scaleup cannot occur with assurance that it relates to the real process. Issues such as offgas corrosion, behavior of surrogate radionuclides in the melt, and in the offgas will not be established. Similitude of simulant waste performance needs to be established, within limits, before establishing similitude of scaleup. Expressing it another way: if it cannot be established that hot equals cold, how useful is it to establish that small equals large? Equal-sized small pilots have been an accepted planning strategy for HLW pilots for several years (May 1992). Introduction of this strategy to LLW is new.
- Part of the equipment needs include online product quality equipment development and testing.
 - Visual observation is the minimum required to establish feedback to the process. The observation process should be able to detect wall brick in the product, foaming, or plugging in the melter outlet.
 - More sophisticated instrumentation is needed to develop quantitative quality control for feedback to the process. It is necessary to develop online instrumentation relating to leach testing and other product quality gages.
- A large-scale, cold pilot plant is needed to ensure scaleup factors are appropriate.

Risks of not testing to these limits include delay of startup until all interested parties can be convinced that the product is going to be acceptable. Variations in the waste feed may require adjustment of the process and the vitrification formulation. It may be necessary to reuse hot pilot plants to adjust to variations in the feed. It also may be necessary to establish limits of operation with cold pilots and confirm operational acceptability with hot pilots.

4.3.3.2 Product Quality--Long Term for Repository Approval. This approach tends to assume the product is correct unless the feed or process system has gone out of control in some manner. It uses feed-forward control with an optional recycle loop for off-specification products. Like the feedback testing approach, the highest testing needs are as follows.

- A small, hot (radioactive) pilot plant should be the same size as the cold pilot plant to demonstrate performance equivalency between actual waste and waste simulant.

- Equipment development and testing are required to analyze the incoming feed on a real-time basis. Without equipment development for the feed, it would be difficult to obtain the rates needed for processing.
- A large-scale, cold pilot plant is needed to ensure scaleup factors are appropriate.

Some groups at the workshop thought that U.S. Department of Energy approval would not be obtained without demonstration of an acceptable product from a hot pilot plant. In addition, a hot/cold pilot comparison is required to show equivalency between hot and cold waste using a continuous process within acceptable parameters. If feed changes, a hot pilot would be required to show product acceptability limits. Therefore, the large cold and small hot and cold pilot plants are the minimum testing levels that would be acceptable.

4.3.4 HLW Vitrification Discussion

Because the HLW vitrification workshop was less than half the amount of time of the LLW vitrification workshop, the large number of HLW vitrification issues (39) compared to the LLW vitrification issues (56) indicates that HLW vitrification is potentially more problematic. Many of the issues are appropriate to HLW vitrification and LLW vitrification but with different emphasis.

Workshop participants did not agree on the use of feed-forward or feedback control systems (or a combination) in this workshop. It is apparent that there are strong advantages to both methods. Fortunately, the overall testing needs for product quality control were the same level of testing for any melting system or operating philosophy. Equipment development and the testing emphasis at different levels of testing will be significantly different between the two extremes of operating philosophies.

Variability of the feed will have a large effect in the choice of a long-running hot pilot using different feeds, or a once-run pilot. Without establishing waste simulant performance equivalency with hot waste performance in a continuous hot pilot plant, it is probable that vitrification facility startup will be significantly delayed.

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5.0 CONCLUSIONS AND RECOMMENDATIONS

This section provides a recapitulation of conclusions and recommendations mentioned in Section 4.0 and overall conclusions and recommendations by the contributing authors.

5.1 PRETREATMENT

5.1.1 Conclusions

Waste pretreatment testing requires primarily small-scale laboratory and bench-scale testing to provide data needed for design and safety analysis of its processes. The only needs for large-scale, hot pilot facilities were those associated with DST in-tank or near-tank processes. The need for hot-pilot plant scale testing (as defined in Table 3-2) to resolve technical issues for pretreatment facility design has not been clearly identified.

The capability to pretreat actual tank wastes on a pilot scale may be required to supply suitable feed for HLW, and possibly LLW, vitrification pilot-plant equipment and vitrified waste product development and qualification. If feed variability is a significant area of concern for the vitrification systems (requiring preproduction test runs during the life of the vitrification systems), this capability may be needed on a long-term basis.

Tank corrosion and the dynamics of in-tank washing (solids suspension solubility, mass transfer, and reaction rates) are significant issues requiring resolution to confirm in-tank processing as a baseline part of the pretreatment process.

As a backup, centrifugation may need to be developed to ensure that needed processing rates can be achieved and that a solids/liquid separation process requiring less wash solution is available should this become a significant issue.

Development of filter technology is needed to enhance the product stream quality from in-tank processing where the product becomes the feed for ion-exchange processes.

Work on identifying and developing less-technically challenging organic destruction processes to support radionuclide separation processes should continue. The original criteria for organic destruction processes specified near-complete destruction of organics in support of tank safety objectives and that other pretreatment processes such as Cs removal would not precede organic destruction. Organic destruction for continued safe tank storage is not required (Gasper 1994c). The requirements for organic destruction need to be redefined in keeping with a potential radionuclide removal support mission.

5.1.2 Recommendations

- Bench-scale hot testing requirements for Cs ion exchange indicate the need for supernate samples that exceed the current capability of 250 mL because of the high-loading capacity of the resins (Bray et al. 1990 and 1993; Holton 1994).
- Solids pretreatment processes (in-tank) should be demonstrated at large pilot-scale using DSTs.
- The in-tank organic destruction testing strategy should include the issues identified in this report and shift emphasis from gas generation issues to Sr and TRU removal. Current work in development of Sr removal by precipitation should continue.
- Recycle of caustic (sodium hydroxide) was originally included in the agenda, but was not covered during Session 5 because discussion appeared premature and because of the time required to support other technologies that are more clearly within the Tri-Party Agreement scope. Preliminary overall flowsheets for TWRS activities project a need for large quantities of purchased caustic (42,000 metric tons, or 7.2 million gal of 50 wt% sodium hydroxide). All of this added sodium would eventually have to be converted to low-level glass. It is recommended that an engineering study be initiated to investigate the feasibility of recycling caustic and to identify potential processes for further development/testing.
- Cesium removal should precede the removal of other radionuclides or organic destruction to minimize radiation exposure hazards. Consequently, the hot testing for Tc, Sr, and TRU removal processes can, and should be, coordinated with Cs removal hot testing to efficiently use low Cs waste test products and testing facilities (laboratories and hot cells).

5.2 VITRIFICATION CONCLUSIONS AND RECOMMENDATIONS

5.2.1 Vitrifaction Conclusions

The workshop successfully presented testing issues and analyzed a select number of the most pressing issues for testing needs and risks. About 95 issues were compiled for LLW and HLW joule-heated melters. Some of these issues included items that pertained to all other melting technologies. Joule-heated melter issues were most familiar to the participants due to the HWVP Project efforts in the past. The first issues that were brainstormed were for joule-heated melters; those issues were intended to identify some of the generic issues inherent in all other vitrification technology areas.

Combustion melting technology brainstorming activities determined 12 issues, carbon arc melting produced 4 issues, and plasma torch and arc (transferred and nontransferred arcs, respectively) developed 4 common issues. For specific HLW melting technologies, the induction melting brainstorming produced 10 issues and the stirred melter efforts identified 7 issues.

Vitrification product quality will be strongly influenced by the process control approach applied in design of the vitrification systems (e.g., feed-forward, feedback, or a combination). An engineering effort to define and develop these approaches is planned to help define vitrification feed requirements.

After Phase 1 LLW melter selection, a resumption of the workshops on vitrification issues is recommended. Another workshop could continue to address the many issues that were not covered during these workshops, and could assist Phase 2 melter selection.

Early definition and funding of the LLW and HLW vitrification program cold and hot testing requirements are needed to enable synergistic benefits to be realized in integrating the testing needs of the two vitrification programs and achieving integration with the pretreatment program.

The following areas need better definition.

- Development of product quality specifications for HLW and LLW needs to be completed as soon as possible. (Product specifications for HLW are developed by the repository.) This will help determine process control philosophy, speed equipment development, and provide direction for the project. Based on LLW program experience, it would be prudent to plan to significantly exceed the preliminary specifications with the final product because requirements will probably become more stringent in time.
- The variability of the feed composition to the melter needs to be defined. The variability of the feed to pretreatment has to be determined before determining the feed composition to the melter. This work is in progress.
- Secondary waste streams generated from the melter offgas have not been defined, or contingency made for them in the current planning. These streams must be better defined and contingency made for recycle, reuse, or disposal.
- Development of good surrogates as feed for cold testing are needed and should have a high priority.
- The need for pretreated hot feed to radioactive vitrification testing has not been integrated into the cross-function planning. The extent of pretreatment of pilot-plant feed should be evaluated.
- The type of LLW and HLW melter must be established as soon as possible to better determine pilot-plant needs.
- The availability and methods of obtaining feed for LLW and HLW radioactive testing pilot plants should be reviewed and updated.
- A testing strategy should be documented for LLW and HLW programs as it was for the HWVP.

The major issues that drive the vitrification program to radioactive pilot-plant scale testing include product quality, secondary waste stream definition, radionuclide buildup, and variable feed composition. Product quality is a major driver for HLW and LLW. The HLW product is anticipated to contain a higher percentage of radionuclides and heavy metals than the LLW product. This may cause HLW vitrification to be more sensitive to perturbations in the process than LLW vitrification.

The difficulty of processing LLW to an acceptable vitrified product does not appear to be as great or radiologically hazardous as does the HLW. This is because the type of feed in LLW is more manageable (supernate versus sludge), the anticipated composition is less sensitive (lower waste loading in the glass), and the radionuclide content is much lower with LLW.

A large, cold pilot plant is required to demonstrate operability and scaleup parameters for HLW and LLW. Equally sized, small, cold and hot pilot plants are needed to demonstrate simulant equivalency in continuous processes for HLW. Small, hot, pilot-plant testing for HLW is required to ensure product quality. Hot bench-scale testing is required for LLW. This bench-scale testing may not include all the components of a full pilot plant. For assurance of product quality, a small, hot, pilot plant for LLW is highly desirable, but not required.

The higher level of radioactive testing in a small pilot plant is not as well justified for LLW as it is for HLW. Further investigations should be conducted to determine if there is sufficient justification to perform continuous hot pilot testing with LLW. The workshop participants seemed to agree that while the LLW vitrification hot pilot was not required, it was highly desirable to confirm that the process would operate as envisioned and to ensure that the issues listed would not cause large delays in the LLW disposal effort.

5.2.2 Vitrification Recommendations

- A hot pilot plant is highly desirable for the LLW vitrification effort. Much of the need for the hot pilot comes from the expectation of variable feed and the need to verify product quality. Following hot startup, the more variable the feed and the closer the process equipment limits to the formulation boundary, the more important the availability of hot pilot test capability. A small and large cold pilot plant is required for LLW vitrification, as well as hot crucible testing. Also required are a hot bench-scale pilot for LLW vitrification. The bench-scale pilot may not need to reproduce the entire vitrification system.
- Small hot and cold pilot plants are critical for HLW vitrification product quality confirmation. High-level waste scaleup should be performed with a large, cold pilot plant.
- Development of conservative product quality specifications for LLW and finalization of those for HLW are needed as soon as possible. This will define the product for both vitrification facilities, and

is required to finalize testing needs. In addition, engineering studies should be performed to cover the areas recommended in Section 5.1.

- A resumption of the workshops on vitrification issues is recommended to continue addressing the many issues that could not be covered during the workshops.

5.2.3 General Recommendations

- Within the technologies identified, development of the testing capability/infrastructure strategy (Figure 2-1, block #4) should include flexibility to accommodate technical issues that are likely to arise as experience dictates, as development of the TWRS processes and facilities continue.

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8.0 GLOSSARY

ABBREVIATIONS AND ACRONYMS

A-E	Architect-Engineer
BNFL	British Nuclear Fuels, Ltd.
DOE-HQ	U.S. Department of Energy-Headquarters
DST	double-shell tank
F&R	functions and requirements
HLW	high-level waste
HWVP	Hanford Waste Vitrification Plant
I&C	instrumentation and control
IPM	Initial Pretreatment Module
IX	ion exchange
LANL	Los Alamos National Laboratory
LLW	low-level waste
RL	U.S. Department of Energy, Richland Operations Office
SNL	Sandia National Laboratory
TAP	Tanks Advisory Panel
TRR	Test Requirements Record
TRU	transuranic
TWRS	Tank Waste Remediation System
USTID	Underground Storage Tank Integrated Demonstration
WHC	Westinghouse Hanford Company

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APPENDIX A

WORKSHOP PARTICIPANT BIOGRAPHIES

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A1.0	PRETREATMENT SESSIONS	A-3
A2.0	LOW- AND HIGH-LEVEL WASTE VITRIFICATION SESSIONS	A-7

APPENDIX A

WORKSHOP PARTICIPANT BIOGRAPHIES

A1.0 PRETREATMENT SESSIONS

Barton, W. Blaine

M.S. Engineering, Chemical Engineering
Westinghouse Hanford Company (WHC)

Seventeen years' experience in nuclear chemical processing with emphasis on waste processing. Currently Lead Engineer for pretreatment. Previous responsibilities have included cesium and strontium recovery and purification process troubleshooting and operations, design of plutonium processing system, spent fuel dissolver system startup, and project definition for retrieval and pretreatment projects.

Bray, Lane A.

B. A. Chemistry, 1950

Pacific Northwest Laboratory (PNL)

Joined the Hanford project in 1950 and has been involved in chemical analysis, quality control, and process development. Involved in development of processes for the recovery and purification of metals through use of solvent extraction, ion exchange, and precipitation, including cesium, strontium, americium, rare earths and copper. Other areas of activity have included nuclear fuel reprocessing and nuclear waste treatment processes. Mr. Bray holds 14 patents.

Brooks, Kriston P.

B.S. Chemical Engineering, 1990

M.S. Chemical Engineering, 1992

PNL

Experience in design of CPU cesium ion-exchange system and assessment of PNL experimental ion-exchange data.

Bullock, Maurice J.

B.S. Mechanical Engineering, 1959

Raytheon/British Nuclear Fuels, Ltd. (BNFL)

Widely based engineering background spanning 35 years, of which the last 15 years have been in the nuclear industry. Nuclear experience has been gained as a senior member of BNFL staff in the United Kingdom where responsibilities included design, procurement, and installation of the Thermal Oxide Reprocessing Plant (THORP) reprocessing plant chemical and waste management processes at Sellafield in the United Kingdom. Responsibilities included overall technical content of THORP processes, completion of the overall construction and commissioning of THORP, and operation of a number of support hot waste management processes. Currently Deputy Project Director of the Raytheon/BNFL team on the Initial Pretreatment Module Project.

Bustard, Larry D.

Ph.D. Physics, 1979

Sandia National Laboratories

Experience in developing and testing steam-reforming processes for treating Hanford Site tank wastes. Involved with cesium separations using crystalline silicotitanate ion-exchange materials. Managed Sandia's programs associated with commercial nuclear power plant life extension. Contributor in the area of qualifying safety equipment for nuclear power plant facilities.

Delegard, Calvin H.

B.S. Chemistry

WHC

Fourteen years' experience at the Hanford Site in plutonium separation and waste management operations support and process development. Currently developing methods for waste pretreatment.

Dell'Orco, Philip C.

B.S. Chemical Engineering, 1989

Ph.D. Civil Engineering, 1994

Los Alamos National Laboratory

Working with the Hydrothermal Processing Program. Experience in operating and maintaining hydrothermal processing pilot-scale facility and determining engineering design parameters for the hydrothermal treatment of Hanford Site tank wastes.

Eager, Kevin M.

B.S. Chemical Engineering

WHC

Experience in cesium removal process development, cold pilot-plant development for a cesium ion-exchange process. Developing a process flowsheet for cesium ion exchange.

Eggers, Robert F.

WHC

A total of 35 years' experience in engineering and scientific areas. Twenty years' experience at the Hanford Site, 15 years of fluid mechanics and heat transfer experience, 2 years' experience in nuclear waste management, and 15 years in nuclear material safeguards and security.

Elmore, Monte R.

PNL

Experience with PNL since 1978 has included hazardous and radioactive waste remediation investigations and process development studies. Primary responsibility includes assessing the ability of low-temperature hydrothermal processing to destroy organics in tank wastes, using samples of actual radioactive tank wastes.

Hand, Richard L.

WHC

Twenty years' experience in quality programs for CERCLA cleanup projects, the definition of the Title III acceptance inspection program requirements, and verifying implementation of the construction inspection program for the Hanford Waste Vitrification Plant.

Hendrickson, Douglas W.

B.S. Chemical Engineering

WHC

Experience in calcination technologies for the Tank Waste Remediation System. Extensive work in tank waste characterization, treatment, and disposal methods. Experience as an enforcement engineer with the U.S. Environmental Protection Agency.

Herting, Daniel L.

B.S. Chemistry, 1974

Ph.D. Inorganic Chemistry, 1979

WHC

Fifteen years' experience in Hanford Site waste tank chemistry in the Process Chemistry Laboratories. Process Chemist in all aspects of Hanford Site tank waste storage, treatment, safety, and disposal.

Howden, Gary F.

B.S. Mechanical Engineering, 1959

WHC

Twenty-three years' experience in all phases of advanced planning, design construction, and startup of nuclear facilities and remotely operated systems for process operation and process system maintenance.

Hyatt, Monica G.

B.S. Chemical Engineering, 1992

PNL

Experience in sludge washing development.

Johnson, Michael E.

B.S. Chemical Engineering, 1981

WHC

Thirteen years' experience in the management of nuclear waste and plutonium processing. Experience in development of an ion-exchange process for the separation of strontium from Hanford Site tank wastes, and operational support to an ion-exchange process for separation of cesium from Site tank wastes.

Klem, Michael J.

B.S. Chemical Engineering

WHC

Twenty-eight years' experience at the Hanford Site in waste management technology, plutonium and fission product recovery plants, and new facility projects.

Kurath, Dean E.

B.S. Chemical Engineering, 1978

M.S. Chemical Engineering, 1986

PNL

Experience with in-tank processes and feed preparation.

MacLean, Graham T.

B.S. and M.S. in Chemical Engineering
WHC

Sixteen years' experience in research and process development, hazardous waste treatment, incineration, and inorganic chemicals processing, biological and chemical oxidation, ion exchange, carbon adsorption, filtration, flocculation and settling, aqueous scrubbing and stripping, and combustion processes.

McKeon, T. M.

B.S. and Ph.D. Chemical Engineering
Raytheon/BNFL

Responsible for process and facilities design. Manager responsible for maintaining BNFL's technology base, identifying appropriate new technologies, and managing generic development programs. Department Head responsible for process design and development of BNFL, nuclear fuel reprocessing, radioactive effluent treatment, and waste management (vitrification/cementation). Manager for Effluent Treatment Plant in THORP.

Person, James C.

B.A. Chemistry and Physics, 1958
Ph.D. Physical Chemistry, 1964
WHC

Experience in measuring gas generation and effects of heat on complexants in actual waste for tank 101-SY.

Place, David E.

B.S. Chemical Engineering
WHC

Eighteen years of Hanford Site experience in nuclear fuels reprocessing and waste treatment.

Schmidt, Andrew J.

B.S. Chemical Engineering, 1986
M.S. Chemical Engineering, 1987
PNL

Task Manager with PNL for the Alternative Organic Destruction Technology Development Task.

Walser, Ronald L.

B.S. Chemical Engineering, 1961
WHC

Thirty-two years' experience primarily as Process Engineer in fuels development, plutonium processing, and tank farm operation.

A2.0 LOW- AND HIGH-LEVEL WASTE VITRIFICATION SESSIONS**Gibby, Ronald L.**

B.S. Ceramic Engineering

Ph.D. Metallurgy

WHC

High-level waste vitrification development testing technical oversight; cognizant engineer on radioactive bench-scale melter planning and testing.

Higley, Bruce A.

B.S. Chemistry, 1971

B.S. Chemical Engineering, 1976

WHC

Eighteen years' experience in tank waste management, waste form properties and waste form treatment processes, and pilot plant and equipment testing.

Janzen, James M.

B.S. Chemical Engineering, 1977

WasteChem, Inc.

Responsible for "hot cell" procurement packages with special emphasis on melter systems and associated systems design. Managed design changes to the Defense Waste Processing Facility basis melter for the Hanford Waste Vitrification Plant, led effort for increased production capacity evaluation advanced melter design (includes evaluation of advanced melter designs), and led study effort for melter impacts on facility and process during facility configuration evaluation.

Jensen, George A.

B.S. Chemical Engineering, 1958

M.S. Chemical Engineering, 1965

Ph.D. Engineering Science, 1973

PNL

High-Level Waste Equipment/Process Evaluation Task Manager with PNL Vitrification Technology Development Project; Senior Research Engineer, Waste Process Engineering Department with Battelle Northwest Laboratories; licensed Professional Chemical Engineer in Washington and Alaska.

Karnesky, Richard A.

B.S. Metallurgical Engineering, 1974

M.S. Materials Science and Engineering, 1980

M.S. Engineering Management, 1994

WHC

Extensive expertise in all areas dealing with design and performance of mixed-oxide, nitride, carbide, metal alloy, and oxide fuel systems in fast and thermal flux reactors. Experience with fabrication, irradiation performance, performance evaluation and modeling, destructive and nondestructive examination, and development of waste disposal systems.

Kelly, Steven E.

WHC

Experience in vitrification development, with current assignment in low-level waste vitrification.

Ombrellaro, Patrick A.

B.S. Chemical Engineering, 1989

WHC

Five years' experience with hot cell facility operation.

Powell, William J.

P.E.

B.S. Chemical Engineering, 1976

WHC

Hanford Site experience since 1983. Directed technology investigations with special emphasis on aerosol physics, corrosion, and double-shell tank leaks. Pilot-scale experience includes waste gas burning, grout production of double-shell tank waste, cleanup of contaminated water, and others.

Randklev, Edward H.

B.S., M.S., and Ph.D. Ceramic Engineering

WHC

Ten years' experience in high-level waste form and processing development with emphasis on a vitrified waste form, process/product control development for a high-level waste vitrification process, and waste form and packaging qualification for repository waste form.

Riebling, Eugene F.

B.S. Chemistry

Ph.D. Inorganic/Physical Chemistry

WHC

Forty-one years' experience. Experience in vitrification processes/process technology development. Worked on a pilot-plant program to environmentally immobilize high-level radioactive defense wastes in glass. Conducted studies of high-temperature oxide liquids and their glasses. Conducted basic research on the structure of high-temperature glass-forming oxide liquids and their resultant glasses and crystals.

Shade, John W.

B.A. Geology, 1960

Ph.D. Geochemistry, 1968

WHC

Thirty years' experience in geochemistry and materials science with 20 years' experience in nuclear and hazardous waste environmental concerns. Experience with in-situ vitrification and glass chemistry, including waste glass formulation. Currently contributing to low-level waste vitrification development in the areas of waste simulant development, glass formulation and characterization, glass durability, and disposal system performance assessment.

VanderCook, Robert E.

B.S. Chemical Engineering, 1951

WHC

Extensive experience in application of new technology to plants that process radioactive materials. Includes all aspects from development planning to plant operations, including ensuring safe plant operations.

Whyatt, Greg A.

M.S. Chemical Engineering, 1986

PNL

Experience in pilot-scale melter testing. Responsible for melter offgas aerosol sampling and characterization of melter source and performance of offgas devices including submerged bed scrubber, high-efficiency mist eliminator, and high-efficiency metal fiber filter. Experience in pilot-scale testing of melter plenum vacuum control system.

Wilson, Charles N.

P.E.

B.S. Materials Science, 1969

Ph.D. Materials Science, 1974

WHC

Experience in low-level waste vitrification technology testing.

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APPENDIX B

WORKSHOP LETTER REPORT

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From: Value Engineering
Phone: 376-5312 H5-25
Date: June 20, 1994
Subject: FACILITATION OF THE TESTING REQUIREMENTS FOR TANK WASTE
REMEDIATION PROCESS

7F650-94-005

To: G. F. Howden G3-20*

cc: M. J. Bullock G3-02
R. E. Flora H5-25*
D. E. Lutz H5-25*
P. A. Ombrellaro G3-20*
D. E. Place L4-75*
J. V. Polomsky H5-25*
W. J. Powell L4-75*

* Attachments sent on CC:Mail

As you requested, Value Engineering facilitated workshops on the Testing Requirements for Tank Waste Remediation Process. The five functions selected for individual facilitation sessions were: 1. In Tank Processes and Feed Preparation, 2. Low Level Waste Vittrification Process, 3. Pretreatment Processes, 4. High Level Waste Vittrification Process, and 5. Organic Destruction. Each of the functions were broken into technologies and then into testing issues. Attached is the report and the results of the five function areas and the issues associated with the technology and testing that will be required for each one.

Value Engineering certainly appreciates the resources you provided including talented workshop participants. It was a challenging but enjoyable task for the facilitators.

If you should have any questions, please do not hesitate to call Richard Flora on 376-5201, John Polomsky on 376-1374, or Don Lutz on 373-0637.

S. P. Desai
Manager

daw

Attachments

BACKGROUND INFORMATION

Testing Requirements IPM

Value Engineering was called by P. A. Ombrellaro and G. F. Howden to help the Tank Waste Remediation Program firm up their Testing Requirements Assessment Document in accordance with Attachment 1. The five functional areas that need testing data information are in-tank processes, pretreatment processes, organic processes, and high- and low-level waste vitrification. Each function was divided into technologies, and testing issues were retrieved for the technology. It was decided we would use a facilitated meeting process that would be conducted on May 16 and 17, 1994. The recording method was to use large tablets and data sheets converted to computer immediately following the meeting. More than 50 diverse, multidisciplined participants attended the 2-day sessions parlaying their expertise into a more diverse understanding of the processes and personal contacts. The participants are listed in the sessions they attended.

Before the facilitated sessions, each of the five functions was divided into technologies and ranked by importance. A Tank Waste Remediation System (TWRS) Testing Requirements Dictionary (Attachment 2) ranked the testing process from test #1, which is a "nonradioactive laboratory test," through test #12, which is a "large radioactive pilot plant."

The facilitation started with G. F. Howden, M. J. Bullock, W. J. Powell, and R. E. Flora introducing the subjects, methodology, and expected results. Each individual session started with an overview of TWRS, what the session would cover, and what the expected outcome would be. The highest-priority technology within the functions was described and a qualified brainstorming session was used to identify issues. These issues were evaluated, combined, eliminated, and piggybacked to show the testing that was to be required to complete the technology. If the issue did not result in a test, it was eliminated from the list. The entire team worked to force fit each issue into one or more of the testing categories from the TWRS Dictionary, and then determined the risk for not performing the highest level of testing and a testing strategy, if applicable. This process example is shown in Attachment 3.

Sessions 2 and 4 are high-level waste (HLW) and low-level waste (LLW) vitrification processes and are distinctly different from Sessions 1, 3, and 5 which are the pretreatment processes. There are cross-issues and compatibility issues between HLW and LLW vitrification, the pretreatment issues, and between vitrification and pretreatment. Sessions 2 and 4 were facilitated by Dr. J. V. Polomsky and D. E. Lutz, with Team Leader W. J. Powell and were completed May 18, 1994. Sessions 1, 3, and 5 were facilitated by R. E. Flora with Team Leaders G. F. Howden, D. E. Place, and M. J. Bullock and were completed May 17, 1994.

During the qualified brainstorming sessions, more than 400 issues were identified. These were pared down to more than 150 tests that were identified during the five sessions. The five sessions are displayed in Attachment 4.

Attachment 1

STATEMENT OF WORK

Today's date: May 11, 1994

May 5, 1994 Meeting: R. E. Flora 376-5201
P. A. Ombrellaro 372-1858
G. F. Howden 372-3809

Project W-236B, Initial Pretreatment Module (IPM)/EM-30

PURPOSE: Determine issues and strategy of testing for the specified functions listed in the scope section.

CRITERIA: For each function, identify the issues (minimum information needs) and the technology used that can only be met by testing. To ensure that the testing is needed to ensure it will meet the required performance level in terms of process performance, equipment performance, safety, cost, and schedule. For each issue, determine the testing methods to be used describing briefly the purpose of the test and the potential consequences of not carrying out the test. Possibly rank each issue within the function.

SCOPE: The functions will not be compared or ranked between each other. The issues within the function may or may not be ranked depending on the time constraints. The functions are limited to Group 1: Solid/Liquid Separation; Sludge Wash; Enhanced Sludge Wash; Filtration; and Group 2: Cesium Removal; Strontium Removal; Technetium Removal; Transuranic (TRU) Removal; Complex Strontium (Sr)/TRU (Organics) Removal. If there is time, the following four issues will be worked by both teams in a group: LLW Vittrification Melter; HLW Vittrification Melter; LLW Vittrification Nonmelter Equipment and Instrumentation; and HLW Vittrification Nonmelter Equipment and Instrumentation.

METHODOLOGY: The group will be divided into two groups each having base functions to work. Some of the Value Engineering techniques will be used to identify the items within the functions. Once the items are identified for the function, they will be inserted on a Matrix Form, evaluated for testing, ranked if determined necessary, and documented.

Preparation Meeting: May 5, 1994 1-3 p.m. May 11, 1994 2-4 p.m. (canceled)
May 12, 1994 TBD Dry run May 13, 1994 TBD

Special Analysis Session: May 16, 1994 7:30 a.m. to 4:00 p.m.
May 17, 1994 9:30 a.m. to 4:00 p.m.

VALUE ENGINEERING TEAM: Two or three facilitators, responsible principal investigators, senior engineers with work history in this process, process engineers, chemical engineers, and others needed from Westinghouse Hanford Company, Raytheon, British Nuclear Fuels Ltd., and others.

REFERENCES: Pretreatment testing strategy

CONSTRAINTS: Two-day facilitation, no ranking of technology, no specific costing, no specific scheduling; however, they must be kept in mind qualitatively not quantitatively.

Attachment 1

STATEMENT OF WORK

- QUESTIONS:**
1. What are the issues, the minimum information needs, and the technology used that can only be met by testing?
 2. How do these issues relate to each other within the function?

Attachment 2

TWRS TESTING REQUIREMENTS DICTIONARY

Testing Options

1. Nonradioactive (cold) laboratory testing includes investigations based on waste simulant and laboratory-scale nonradioactive testing. Mixing in beakers and crucible melting of simulants are examples.
2. Cold bench-scale testing will use laboratory equipment and may use some scale process equipment to simulate parts of the process to establish certain critical parameters using simulant feed.
3. Small, cold pilot plant is in the one-tenth to one one-thousandth size range that uses waste simulant and scale equipment to simulate major portions of the process.
4. Waste characterization is testing of the radioactive waste to determine physical and chemical parameters of interest.
5. Radioactive (hot) laboratory testing includes actual radioactive waste used in laboratory equipment to make products, and establish basic processes.
6. Large, cold pilot plant is a one-tenth to full-scale unit that uses essentially all the equipment and controls of the full-sized hot unit.
7. Testing using existing double-shell waste tanks includes either inserting equipment into the tank or pumping waste solution up to nearby equipment to test equipment or process. Testing may include processing the entire volume of the tank waste.
8. "Functional" cold/hot pilot-plant tests only critical portions of the process, not the entire process. It may be set up for one or several specific testing tasks and may use radioactive waste. The plant is normally limited in its scope, and much smaller and less expensive than a full-sized unit.
9. Hot bench-scale may use some scaled process equipment to establish certain critical parameters using radioactive feed. Not all of the equipment is scaled down from that which will be used in the process. Usually, this would fit in a small hot cell or a hood.
10. Full-scale, cold pilot plant (self-explanatory, see large scale).
11. Small, hot pilot plant uses a majority of the scaled-down process equipment used in a full-sized plant. Radioactive waste is used as a feed. A small pilot plant is usually one-tenth to one one-thousandth scale of the full-sized unit.

Attachment 2

12. Large, hot pilot plant is greater than one-tenth scale and uses radioactive waste as the feed. The equipment is normally the same type envisioned for the full-scale unit (with modifications to make it more flexible than the full unit.)

Attachment 3

Session Introduction

Testing Requirements IPM

EXAMPLE

Step 1: What is an issue?

A concern, a problem, a question that asks: What data do you need that can be resolved by testing only?

With regard to:

- Feed and product data
- Process performance
- Equipment performance
- Operability
- Reliability/maintainability
- Safety.

Step 2: Brainstorming rules

- Generate as many issues as possible.
- Do not evaluate, criticize, or judge issues.
- Consider all issues.
- Combine and piggyback issues.

Function: Supernate Pretreatment (Example)

Technology: Cesium Removal

Step 3: Brainstorm issues

- 1) ~~Resin Degradation~~ 9
- 2) Channeling
- 3) Effect of organics
- 4) Fouling
- 5) Solids blinding
- 6) ~~ION exchange performance~~ Too general
- 7) A loading capacity
- 8) Radiation degradation
- 9) Chemical degradation
- 10) Scale up
- 11) Attrition (resin)
- 12) ~~Homogeneous~~ Packing density
- 7B Loading profile
- 7C Elution efficiency.

Attachment 3

Session Introduction

Testing Requirements IPM

EXAMPLE

Step 4: Evaluate, combine, and eliminate the issues

Function: Supernate Pretreatment (Example)

Technology: Cesium Removal

Test category

Issue: Channeling Test: No test necessary because literature searches are sufficient	6
Issue: Effect of organics Test: • Cold load and unload stimulants in lab • Hot test load and unload double-shell tank waste Risk: Cesium removal may not meet requirements, reduced capacity	1 5
Issue: Fouling Test: • Cold loading test (repeating) Not needed • Hot-loading test (repeating) Risk: Resin chargeout - reduced capacity Strategy: • Perform multiple cold tests • Perform minimum hot tests to validate cold tests	1 5

Attachment 4

Session 1

Testing Requirements IPM

In/Out-Tank Process

Session 1 May 16, 1994 (7:30 a.m.-12:00 p.m.) May 17, 1994 (2:00-4:00 p.m.)

Function: In-Tank Processes and Feed Preparation

- In-Tank
 - Settling
 - Sludge Wash
 - Enhanced Sludge Wash
 - Out-of-Tank (IPM)
 - Filtration
 - # Flocculation
 - # Centrifugation
 - # Enhanced Sludge Washing
- (# = if time permits)

Attendees:	W. B. Barton	M. J. Bullock	R. F. Eggers	R. E. Flora
	R. L. Hand	D. L. Herting	G. F. Howden	M. G. Hyatt
	S. E. Kelly	D. E. Kurath	G. T. MacLean	T. M. McKeon
	D. E. Place	J. T. Slankas	R. L. Walser	

Function: In-Tank Processing

Technology: Settling (Brainstorming)

Issues:

1. Waste types: How much sampling do you need to do, where/what?
2. Blended waste: Effects of waste types on blended waste on settling (4)
3. Settling rates
- ~~4. % solids in sludge - full scale~~
5. % suspended solids
6. Distribution of radioactivity
- ~~7. Solid size 9~~
- ~~8. Effective of thermal currents in tank~~ Test has been done
9. Particle size distribution (7)
- ~~10. What is requirement for particle content in decanted material (remove liquid)~~
11. Monitor settling process?
- ~~12. Is time delay cost benefit of in tank instrumentation a factor?~~
- ~~13. How will settled sludge be affected by decant removing liquid (has been demonstrated)~~
- ~~14. Tank corrosion (sludge wash technology)~~
- ~~15. Structural degradation (sludge wash)~~
- ~~16. Structural abrasion (sludge wash)~~
- ~~17. Pumps and affect particle size 22~~
- ~~18. Gas generation affect settling? (mitigation/Mixing pump)~~
- ~~19. What is the general total requirements for the feed~~
- ~~20. What is the limits of the feed (next session)~~
- ~~21. What is the cost benefit of settling verse filtering-Engineering issue~~
22. Effects of mixing on particle size (17)
- ~~23. Is in tank processing a good choice? Engineering issues~~
24. Types - dilution
25. Sampling
26. Characterization of waste settling

Attachment 4

Session 1

Testing Requirements IPM

In/Out-Tank Process

Function: In-Tank Processing

Technology: Settling

Test category

Issue: Settling Test: Settling rates Risk: Would not be treating waste Strategy: Lab testing is complete - needs in-tank testing to confirm lab data	7
Issue: Percent suspended solids Test: Settling rates test Risk: Would not be treating waste Strategy: Lab testing is complete - needs in-tank testing to confirm lab data	7
Issue: Distribution of radioactivity Test: Lab testing of samples Risk: LLW criteria not met Excessive D&S rates from pretreatment to vitrification Strategy: Integrate these samples with settling rate testing	5
Issue: Particle size distribution Test: Filtration issue Risk:	
Issue: Monitor settling process Test: See settling rates Risk:	
Issue: Effect of mixing on particle size Test: Incorporate with settling rate test Risk: Would not be treating waste Strategy: Lab testing is complete - need in-tank testing to confirm laboratory data	7

Function: In-Tank Process

Technology: Sludge Wash (Brainstorming)

Issues:

- ~~1. Effect of immobilized sludge Retrieval issue~~
2. Tank corrosion
- ~~3. Structural degradation Does not need testing~~
4. Peptization (wash and centrifuge)
5. Solubility of sludge in wash solution
6. Mass transfer rates/reaction rates

Attachment 4

Session 1

Testing Requirements IPM

In/Out-Tank Process

Function: In-Tank Process

Technology: Sludge Wash

Test category

Issue: Tank Corrosion	
Test: • In-tank inspections	7
• Coupon test/cold extend data range	1
• Coupon test hot	5
• Corrosion probe	7
Risk: • Maybe no sludge washing in double-shell tank	
• Tank failure during operation	
Strategy: In-tank inspections and lab tests	

Function: In-Tank Process

Technology: Sludge Wash

Test category

Issue: Peptization	
Test: Core sample (extensive)	5
Reverse test	5
Risk: Waste that would not settle, lower efficiency rate, make more glass high level	
Strategy: Do dilution test on wide variety of samples	
Issue: Solubility of sludge	
Test: This is being done now	4/5
Risk: TRU/uranium/plutonium dissolving--increased high level	
Strategy: Continue with currently planned tests	
Issue: Mass transfer rates/reaction rates	
Test: Not a test	
Conformation of in-tank test	7
Cold lab test for rate parameters	1
Hot lab test for rate parameters	5
Hot lab test for erosion of sludge	5
Cold lab test for erosion of sludge	1
Risk: Increased high-level glass, may modify operations (wash time)	
Strategy: Cold test to techniques, then hot test to confirm	

Function: In-Tank Process

Technology: Filtration (Brainstorming)

Issues: (Keep in mind [cross-flow filtration, pneumatic hydropulse, and deep bed])

1. Particle size distribution
2. Radioactivity on particles
3. Mass of solids
4. Formed solids in process
5. Fouling of filter media
6. Disposal

Attachment 4

Session 1

Testing Requirements IPM

In/Out-Tank Process

7. Filter cake properties
8. Filtration after evaporation

Function: In-Tank Process

Technology: Filtration

Test category

Issue: Performance	
Test: Cold test to prepare for hot test	2
Filter testing on actual supernate	8
Risk: Excessive dose rates	
May not comply with low-level specifications	
Strategy: Do the testing	

Function: In-Tank Process

Technology: Enhanced Sludge Wash (Brainstorming)

Issues:

- ~~1. Effect of immobilized sludge Retrieval issue~~
2. Tank corrosion
- ~~3. Structural degradation Does not need testing~~
4. Peptization (wash and centrifuge)
5. Solubility of sludge in wash solution
6. Mass transfer rates/reaction rates

Function: In-Tank Process

Technology: Enhanced Sludge Wash

Test category

Issue: Tank Corrosion	
Test: • In-tank inspections	7
• Coupon test/cold extend data range	1
• Coupon test hot	5
• Corrosion probe	7
Risk: • May not be able to do sludge washing in double-shell tank	
• Tank failure during operation	
Strategy: In-tank inspections and lab tests	
Issue: Peptization	
Test: Core sample (extensive)	5
Reverse test	5
Risk: Waste that would not settle	
Lower efficiency rate	
Make more glass high level	
Strategy: Do dilution test on wide variety of samples	

Attachment 4

Session 1

Testing Requirements IPM

In/Out-Tank Process

Test category	
Issue: Solubility of sludge Test: This is being done now Risk: TRU/uranium/plutonium dissolving--increased high level Strategy: Continue with currently planned tests	4/5
Issue: Mass transfer rates/reaction rates Test: Conformation of in-tank test Cold lab test for rate parameters Hot lab test for rate parameters Hot lab test for erosion of sludge Cold lab test for erosion of sludge Risk: Increased high-level glass may have to modify operations (time in wash) Strategy: Cold test to techniques then hot test and confirm in tank tests	7 1 5 5 1

Strategy: Same range of tests except peptization (item 4) has a different range of chemical and physical conditions

Function: Out-of-Tank Solids Processor

Technology: Flocculation (Brainstorming)

Issues:

1. Enhancement of settling
2. Enhancement of filtration
3. Enhancement of solids in sludge
4. Enhancement of centrifugation
5. Not a separate technology

Test category	
Issue: Flocculation Test: Cold lab--enhancement of settling Hot lab--enhancement of settling validation of cold testing Risk: Strategy: Look at each of the above areas and add testing for flocculation if necessary	1 5

Attachment 4

Session 1

Testing Requirements IPM

In/Out-Tank Process

Function: Out-of-Tank Solids Processor

Technology: Centrifugation (Brainstorming)

Issues:

- ~~1. % moisture in cake 4~~
- ~~2. Reliability 6~~
- ~~3. Location Engineering~~
4. Cake properties (1)
- ~~5. Centrifuge type Engineering~~
6. Maintainability/reliability
7. Throughput rate/removal efficiency
- ~~8. Horizontal/vertical centrifuge Engineering~~
- ~~9. Continuous/batch operation Engineering~~
- ~~10. Hydrocyclones Will not work~~
- ~~11. Vacuum filtration Engineering~~
- ~~12. Cross flow filter Engineering~~
- ~~13. Removal efficiency 7~~
- ~~14. Test real waste Not an issue~~
- ~~15. Monitoring process 16~~
16. Process control (15)
- ~~17. Dose rate Engineering~~
18. Flocculation/solids discharge
- ~~19. corrosion Engineering~~
- ~~20. Equipment development Not an issue~~
- ~~21. Scale up solids discharge 18~~

Function: Out-of-Tank Solids Processor

Technology: Centrifugation

Test category

Issue:	Cold lab - screen test - flocculation	1
	Hot lab - verify test 1 - flocculation	5
	Large cold pilot - stimulant test at the manufacturer	6
	Testing using double-shell tank waste; include process control instrumentation which is already developed to verify above test	7
Risk:	Would not have an effective solid liquid waste separation	
Strategy:	<ul style="list-style-type: none"> • Use previous testing from settling or waste characterization, if available • Use in-tank equipment or a CPU close to the tank • Do cold and hot lab before large cold pilot • Use turbidity/TRU monitors for process control 	

Function: Out-of-Tank Solids Processor

Technology: Enhanced sludge washing. Chemistry issues are the same as in tank.

Attachment 4

Session 2

Testing Requirements IPM

LLW

Session 2 (LLW) and Session 4 (HLW) are distinctly different from Sessions 1, 3, and 5. There are cross-issues and compatibility issues between LLW and HLW vitrification. It was found that there are four areas common to HLW and LLW vitrification.

<u>Process/Melters</u>	<u>Equipment/Instrumentation</u>	<u>Feed</u>
Joule	Combustion heated	Dry
Combustion	Joule heated	Wet
Carbon arc	Horizontal concentrator	Slurry
Plasma	Other-plasma-induction	Homogeneous

Attendees:	C. C. Chapman	R. L. Gibby	B. A. Higley
	J. M. Janzen (Fluor)	R. A. Karnesky	S. E. Kelly
	D. E. Lutz	P. A. Ombrellaro	J. V. Polomsky
	W. J. Powell	E. F. Riebling	J. W. Shade
	R. E. Vandercook	J. H. Westsik	C. N. Wilson
	G. A. Whyatt		

LLW

May 16, 1994 7:30 a.m.-4:00 p.m.

May 17, 1994 9:30 a.m.-4:00 p.m.

Brainstorm of issues for feed issues

1. LLW is almost the same as HLW--less extensive feed (high level) concerned
2. Frit is the same as high level--but the scale is different

Melters:

- Design for remote operation/casting
- Casting operations/6 to 8 hours canister change
- Facility design needed to perform change
- Instrumentation use higher in high-level vitrification--redundant operations required
- Methods to change electrodes needed to be defined\designed, etc., and tested (high-temperature melter only)
- Temperature, difference low level vs high level
- Noble metals high-level--short-out in melter (see phase separating)
- Bottom sludge buildup second phase precipitation
- Smaller melter size (low level vs high level)

Melter LLW

Offgas Issues

- Corrosion
- NOx control
- Radionuclides buildup
- Condensable fouling
- Particulate recycle
- RNT - Volatile (control or not) condensate/recover
- Film cooler performance (corrosion - plugging - cleaning)

Attachment 4

Session 2

Testing Requirements IPM

LLW

- To recycle to HLW
 - Recycle to LLW
 - On secondary waste form
- Incinerator requires licensing

Product Quality Issues

- Product verification test
 - Composition
 - Homogeneity
 - Cracking
 - Devitrification (crystallization)
 - Annealing process
 - Finding bubbles
 - Waste stream accumulation
 - Waste stream disposal
 - Waste stream recycle
 - Waste stream reuse
 - Long-term durability*
 - Establish product quality requirements
 - Glass/packaging interactions
 - Sampling of vitrified product establish method
 - Long-term package
 - Process control online*
 - Control of radionuclides decontamination factor (online)

Agreed Upon Minimum or Base Case Tests

Minimum test	Test level
1. Small, cold pilot plant	3
2. Radiological lab testing	5
3. Waste characterization	4

Function: LLW Vitrification

Technology: Combustion Heated

Brainstorm Issues - Add-ons to joule list of issues

1. Fuel selection	Testing
• Safety (safety analysis report)	3
• Air vs O ₂ /equipment O ₂ connects	3
2. Volatility/entrainment - same	
3. Offgas issues	
4. Option design - joule and combustion combined to hold up temporarily	

*Savannah River - Denny Birkband (Savannah River Technology Center)

Attachment 4

Session 2

Testing Requirements IPM

LLW

5. Incinerator requirements (regulators)	3+ plant test
• Emissions=issue (organic, etc.)	
6. Initial quenching (plugging) of offgas (test refractory/materials)	3
7. Burner lifeline/scale-down hard	3
8. Feed injector plugging/test fuel size injector	6
9. Feed variability sensitivity low product reasonable time	6
10. Not test	

Common to LLW and HLW

- Feed problems - more severe HLW - more feed problems
- Offgas treatment
- Secondary waste stream
- Volatility of feed and waste components "CE tech: ICL"
- Not common/¹⁴C

Other Concerns

- Performance - assessment
- Disposal system - concern - validity problem

Function: LLW Vitrification

Technology: Applicable to all Types

Test category

Issue: Phase Separation	
Issue: Time and salt = tears down refractory and salt explosions	
Test: Highest test	1
Other tests	
Risks: 1. Shorter melter life	
2. Large decrease in waste loading	
3. Salt - steam explosion - issue	
Strategy: 3-1	
1. Avoid phase separation	
2. Develop speed specifications that melter can receive	
3. Is blending worth it?	

Attachment 4

Session 2

Testing Requirements IPM

LLW

Function: LLW Vitrification

Technology:

Test category

Issue: Long-Term Product Quality	
Issue: Long-Term Product Quality Test: I-very important <ul style="list-style-type: none"> • Do develop test larch, visual, viscosity • Mechanism for product quality • Assumption - product quality test from facility Risks: <ul style="list-style-type: none"> • Removal from vault of product possible long-term shutdown of plant • Long- and short-term work needed Strategy: <ul style="list-style-type: none"> • Performance assessment drives product quality • Long- and short-term test to be established to establish quality 	3-5
Issue: Product Quality - Short-Term/Quality of Glass Test: <ul style="list-style-type: none"> • Test • Desirable Risks: <ul style="list-style-type: none"> • Cannot relate to long term, may have to shut down • Long-term plant shut down • Recovery from vault 	5-3 8-9
Issue: Product Feedback/Quality Control Test: <ul style="list-style-type: none"> • Visual - Fiber optics Risks: Make a lot of bad glass Strategy: Equipment tested will need to be done	3-9-11
Issue: Plenum Temporary Organic Destruction Test: Safety/regulatory minimum test <ul style="list-style-type: none"> • Destruction of organic Risks: <ul style="list-style-type: none"> • Failure to resolve safety issues • Regulatory emission • Control organic reaction Strategy: <ul style="list-style-type: none"> • Denigrate feed • Build a plant incapable of optimum results 	

Attachment 4

Session 2

Testing Requirements IPM

LLW

Function: LLW Vitrification

Technology:

Test category

Issue: Condensable Fouling Test: Minimum test • Potential for clogging at melter exit • Film cooler required • Cleaning system - Prototype mockup - desirable - Confirm scaleup - desirable - Interface between melter/offgas test Risks: • Shut down for clean/replace 6 to 12 months	3 6
Issue: Offgas Corrosion Test: Minimum test • More critical under combustion heat methods Risks: Corrode out coolers Rupture lines 6- to 12-month delay after failure	3

Melter Issues

1. Phase separation
2. Plenum temperature and organic destruction

Offgas Issues

1. Condensable fouling
2. Corrosion

Product Quality

1. Product verification short term
2. Product verification long term

Combustion Issues

- Burner design
- Fuel selection
- Burner life span

Function: LLW Vitrification

Technology: Joule Heated

Brainstorm Issues:

1. Electrodes/molybdenum Inconel* vertical vs horizontal
2. Refractory hot vs cold wall
3. Hot top or joule cold top
4. Volatility/entrainment
5. Verify waste stimulant performance (see other issues)

*Inconel is a trademark of International Nickel Company.

Attachment 4

Session 2

Testing Requirements IPM

LLW

6. Feed issues

- Distribution
- H₂O contents
- Chem modification
- Redox control -N-
- (1) vs (2) stream
- Uniformity
- Phosphate, carbon, sulfate, chloride, nitrate, nitrite
- Hydroxide
- Erosion
- Glass formers vs frit
- ~~• Lag storage inventory Not a testing area~~
- ~~• Lag storage product Not a testing area~~
- ~~• Lag storage in process inventory Not a testing area~~

7. Product recycle

8. Wet feed vs dry

Phase Separation/Corrosion

1. Redox
2. No emissions
3. Foaming
4. HLW priority

Function: LLW Vitrification

Technology: Joule Heated

Test category

Issue: Electrodes - molybdenum - Inconel	
Test: Molybdenum	3
• Electrode corrosion rate	2
• Waste analysis characteristics	4
Scaleup issues re: joule analysis	
Risks: Inconel - fall back poor electrodes	
Strategy: Produces more glass - affects throughput	
Issue: Volatility, entrainment	
Test: Effects of trace issue components (scaleup)	3
• Rhenium/PC	6
• Comparison	5
• First-stage test scrubber	8
• Disposition of volatiles	9
Issue: Waste stimulant performance	
Test: Equipment function re: hot material	5
Technetium volatility	

Attachment 4

Session 2

Testing Requirements IPM

LLW

Function: LLW Vitrification

Technology:

Test category

Issue:	Chem Modification (Feed)	
Test:	<ul style="list-style-type: none"> • Redox control • NOx control • Foaming • Ways to stream electrode compatibility • Electrode life (corrosion/production) • Phase separation • Feed specifications • Assumes variable feed 	3 6 9 10 8

Function: LLW Vitrification

Technology:

Test category

Issue:	Feedback Control	
Test:	<ul style="list-style-type: none"> • Sampling different ways • Product recycle (a must) some form • What difference to general control of feed preparations control systems • Real-time feedback? Instantaneous or weeks. 	1-3-6
	Several tons of LLW vs few tons of HLW	5-11

Function: LLW Vitrification

Technology:

Test category

Issue:	Product Verification Test	
Test:	<ul style="list-style-type: none"> • To ensure product quality test interval • Demonstrate we have composition control • Adequate feed type (scale test) • Radioactive small hot pilot (cold and hot) 	1-3-6
Risks:	(If no number 11 test) <ul style="list-style-type: none"> • Startup permission doubtful - not sufficient verification 	5-11
Strategy:	Thermal scaling <ul style="list-style-type: none"> • Product recycle • Several turnovers is goal to good results; five-fiftieth not adequate for integrated system • 4-2.5 pilot scale is a sensible range 	

Attachment 4

Session 3

Testing Requirements IPM

Supernate Pretreatment

Session 3 May 16, 1994 12:30-3:30 p.m.

Function: Supernate Pretreatment Process

- Cesium-ion exchange (CS100), Bibler resorcinol, crystalline silicotitanate
- TRU ion exchange (crystalline silicotitanate)
- Tc ion exchange (organic)
- ~~Tc precipitation (sulfide)~~
- Sr removal - precipitation/isotopic dilution
- Sr ion exchange (organic resin, crystalline silicotitanate)
- Other

Attendees:	W. B. Barton	L. A. Bray	K. P. Brooks
	M. J. Bullock	K. M. Eager	R. E. Flora
	D. L. Herting	G. F. Howden	M. E. Johnson
	M. J. Klem	T. M. McKeon	D. E. Place
	J. T. Slankas	R. L. Walser	

Session 3: Supernate Pretreatment Process

Function: Supernate Pretreatment Process

Technology: Cesium ion exchange CS100 - Bibler resorcinol, crystalline silicotitanate

Brainstorming

1. Swelling and shrinking of various ionic states and materials (31)
2. Mechanical abrasion (41, 29)
- ~~3. Sodium molarity 5~~
- ~~4. Potassium molarity 5~~
- ~~5. Competing cations 3, 4~~
6. Precipitation of feed (29, 7)
- ~~7. Solids forming 29, 6~~
- ~~8. Temperature effect/capacity of exchange 35~~
9. Resin quality
- ~~10. Commercial availability No test needed~~
11. Procurement specification (20, 21)
12. Resin stability in high-molarity acid
13. Safety issues/exothermic hydrogen generation, etc. (30)
- ~~14. Elution vs non-elution (37)~~
15. Secondary waste generation
- ~~16. Efficient removal of resin (28)~~
17. Disposal of resin
18. Resin storage
19. Effect if organics, key chelate, immiscible (32, 34, 1)
- ~~20. Resin bed size 35~~
- ~~21. Aspect ratio 35~~
- ~~22. Cesium leakage (37)~~
23. Change kinetics (36)
- ~~24. Density 11~~
- ~~25. Particle size 11~~
- ~~26. Resin life 38, 39~~
27. Meet specifications of LLW

Attachment 4

Session 3

Testing Requirements IPM

Supernate Pretreatment

28. Resin removal efficiency (16)
29. ~~Column pressure drop~~ (42)
30. ~~Off gas of resins~~ (13)
31. ~~Channeling~~ (1)
32. ~~Effect of organics~~ (19)
33. ~~Fouling~~ (34, 19)
34. Solid binding (33)
35. Loading capacity/temperature/competing ions (20, 21, 8, 5, 3, 4)
36. ~~Loading profile~~ 23
37. Elution efficiency (22, 14)
38. Radiation degradation (26)
39. Chemical degradation (26)
40. ~~Scale up~~ Too general
41. ~~Attrition (resin)~~ 2
42. Packing density (29)

Test Strategy Cs ion exchange

1. Simulant lab batch equilibrium
↓
2. Simulant lab column test
↓
5. Actual waste batch equilibrium
↓
9. Actual waste Lab column tests
↓
6. Cold pilot plant (large - scale)

Technology Cesium Ion Exchange

	1	2	5	6	9
Swelling-shrinking of various ionic states	done X	for free	for free	done X	for free
Mechanical abrasion Assume it will happen and look for confrontation if 6 is necessary - small issue				X	
Precipitation of feed			min.		X
Resin quality	X	X			
Procurement specifications	X	X			
Safety issues/exothermic hydrogen generation, etc.	X	X			
Resin storage (shelf life) chemical radiation degradation	X		X		
Effect of organics/Immiscible	X	X			X

Attachment 4

Session 3

Testing Requirements IPM

Supernate Pretreatment

Technology Cesium Ion Exchange	1	2	5	6	9
Meet specification of LLW	X	X	X	X	X
Loading capacity - temp-competing	X	X	X		X
Elution efficiency	X	X	X		X
Radiation degradation	X	X			
Chemical degradation	X	X			
Exchange kinetics		X			X
Resin removal efficiency				X	

Category 9 is the lowest category unless 5 shows problems.

TRU, Tc, and Sr Ion Exchange

Issues: As for Cs plus

	1	2	3
Chelate - Sr and TRU	X	X	X
Colloid	X	X	X
Soluble + Tc	X	X	--

Function: Supernate Pretreatment Process

Technology: Sr Removal by Precipitation

Test category

Issue: Sr Removal	
Test: Sr Removal by Precipitation	5
What is the form of Sr in the waste	5
Variability of Sr in the tanks	5
Are there one or more processes that will remove Sr?	5
Redissolution	5
Temperature	
Parameter effects	5
Risk:	

Other Technology

- Sodium titanate Sr and Pu
- Fractional crystallization

Function: Organic Process/Destruction

Technology: In-Tank Organic Destruction

Brainstorming Issues

1. Kinetics (10)
- ~~2. Caustic concentration 13~~
3. Volume ratio to surface area

Attachment 4

Session 3

Testing Requirements IPM

Supernate Pretreatment

4. Corrosion of tank wall
5. Effect of air
6. Sodium nitrite
7. Chemistry
8. Safety - under 120 °C centigrade
9. Offgas system
- ~~10. Heating 1~~
11. Mixing
12. Waste type
13. Effects of high-aluminate waste/caustic (2)
14. Time

Strategy:

- Continue to test using actual waste
- Catch these above issues in the current testing
- Change emphasis to Sr and TRU behavior rather than gas generation
- Consider using product material in other Sr/TRU removal work such as isotopic dilution
- If successful, develop more rigorous testing plan

Attachment 4

Session 4

Testing Requirements IPM

HLW Vitrification

Session 4 (HLW) and Session 2 (LLW) are distinctly different from Sessions 1, 3, and 5. There are cross-issues and compatibility issues between HLW and LLW Vitrification.

Session 2 (LLW) was worked for two days then Session 4 (the HLW group) reviewed the LLW material on May 18. W. J. Powell directed the group into the areas that needed special attention. It was found that there are four areas common to HLW and LLW vitrification that needed to be worked.

<u>Process/Melters</u>	<u>Equipment/Instrumentation</u>	<u>Feed</u>
Joule	Combustion heated	Dry
Combustion	Joule heated	Wet
Carbon Arc	Horizontal concentrator	Slurry
Plasma	Other-plasma-induction	Homogeneous

Attendees: R. L. Gibby J. M. Janzen (Fluor) G. A. Jensen
D. E. Lutz J. V. Polomsky W. J. Powell
E. H. Randklev E. F. Riebling

Session 4

May 18, 1994 7:30-11:30 a.m.
12:30-2:30 p.m.

HLW Vitrification Process (Equipment and Instrumentation Development)

1. Combustion heated
2. Joule heated
3. Horizontal concentrator (80% solids)
4. Other-plasma-induction-arc (cold wall)

NOTE: Compare types of testing not technology.
Function - technology - issue - testing
What is an issue/concern/problem?

Data needed to be resolved by testing:

- Feed/product data
- Process performance
- Equipment performance
- Operability
- Reliability, maintainability
- Safety

Four major issues by choice

1. Chemical modification
2. Phase separation and TRU concentration/criticality
3. Radionuclides volatility
4. Product verification test and process control

Attachment 4

Session 4

Testing Requirements IPM

HLW Vitrification

Information Dump

Brainstorm of issues for feed issues:

1. HLW is almost the same as LLW - more extensive feed (HLW) concerned - (larger range more species viscosity-slurry)
2. Frit same as LLW - but scale is different

Melters:

- Design for remote operation/casting
- Casting operations/6 to 8 hours canister change
- Facility design needed to perform change remotely
- Instrumentation use higher in high-level vitrification - redundant operations required
- Methods to change electrodes needed to be defined\designed, etc., tested
- Temperature, difference LLW vs HLW
- Noble metals HLW - shortout in melter (see phase separating)
- Bottom sludge buildup second phase precipitation
- Smaller melter size (LLW vs HLW)

Function: LLW/HLW Vitrification

Technology: Joule heated

Brainstorm Issues:

- Electrodes/molybdenum Inconel vertical vs horizontal
- Refractory hot vs cold wall
- Hot top or joule cold top
- Volatility/entrainment
- Verify waste stimulant performance (see other issues)
- Feed issues
 - Distribution
 - H₂O contents
 - Chem modification
 - Redox control -N-
 - (1) vs (2) stream
 - Uniformity
 - Phosphate, carbon, sulfate, chloride, nitrate, nitrite
 - Hydroxide
 - Erosion
 - Glass formers vs frit
 - ~~— Lag storage inventory~~
 - ~~— Lag storage product~~
 - ~~— Lag storage in process inventory~~
- Product recycle
- Wet feed vs dry

Phase separation/corrosion

1. Redox
2. No emissions
3. Foaming
4. HLW priority

Attachment 4

Session 4

Testing Requirements IPM

HLW Vitrification

Brainstorming - Melter Issues

- Holdup
- Electrode consumption noc/feeding
- Refractory life
- Contact maintenance
 - Draining decon
 - Shielding - equipment vs radionuclides accumulation
 - Radionuclide accumulation
 - Decon and disposal 1
 - TRU assume - LLV concentration/criticality
 - Mats. confinement
 - End use decon - melter!
 - Control of atmosphere (top of furnace) all the time
 - Plenum temperature and organic destruction
 - Verification of process sensors
- Glass redox/atmosphere related/feed additives
- Monitoring system degradation
- Process rates
- Scaleup (pilot to big unit)
- Processing halts
- Melter life/tons per unit life
- HLW priority

Agreed Upon Minimum or Base Case Tests

Minimum test	Test level
1. Small, cold pilot plant	3
2. Radiological lab testing	5
3. Waste characterization	4

Function: LLW/HLW Vittrification

Technology: Combustion Heated

Brainstorm Issues--Add-ons to joule list of issues

1. Fuel selection	Testing
3
• Safety (SAR)	
• Air vs O ₂ /equipment O ₂ connects	3
2. Volatility/entrainment - same	
3. Offgas issues	
4. Option design - joule and combustion combined to hold up temporarily	
5. Incinerator requirements (regulators)	3+ plant test
Emissions=issue (organic, etc.)	
6. Initial quenching (plugging) of offgas (test refractory/materials)	3
7. Burner lifeline/scale-down hard	3
8. Feed injector plugging/test fuel size injector	6

Attachment 4

Session 4

Testing Requirements IPM

HLW Vitrification

9. Feed variability sensitivity low product reasonable time 6
10. Not test

No difference - common to LLW and HLW

1. Feed problems - more severe HLW - more feed problems
2. Offgas treatment
3. Secondary waste stream
4. Volatility of feed and waste components "CE tech: ICL"
5. Not common/¹⁴C

Other Concerns

- Performance - assessment
- Disposal system - concern - validity problem

Melter LLW/HLW

Offgas issues

- Corrosion
- NOx control
- Radionuclides buildup
- Condensable fouling
- Particulate recycle
- RNT - volatile (control or not) condensate/recover
- Film cooler performance (corrosion - plugging - cleaning)
- To recycle to HLW
 - Recycle to LLW
 - On secondary waste form
- Incinerator requires licensing

Product Quality Issues

- Product verification test
 - Composition
 - Homogeneity
 - Cracking
 - Devitrification (crystallization)
 - Annealing process
 - Finding bubbles
 - Waste stream accumulation
 - Waste stream disposal
 - Waste stream recycle
 - Waste stream reuse
 - Long-term durability*
 - Establish product quality requirements
 - Glass/packaging interactions
 - Sampling of vitrified product establish method
 - Long-term package
 - Process control online*
 - Control of radionuclides decontamination factor (online)

*Savannah River - Denny Birkband (Savannah River Technology Center)

Attachment 4

Session 4

Testing Requirements IPM

HLW Vitrification

Offgas Issues High-Level Vitrification

- Heat balance (all melters)
 - Water in feed
 - Because of leakage
 - Cooling jackets
- Prove remotability HLW - general issue all types, tolerance critical
- Identifications of all corrosive constituents pertaining to materials compatibility
- Design of melter bellows testing needed; more needed Hanford Waste Vitrification Plant not enough
- Canister bellows vent time - how long vented before removing bellows (Cs problem)
- Rate of buildup of radioactive containments of filters?
- Plugging of canisters bellow vent line
- Recycle of filter liquid stream of containments LLW also cleanout
- Component selection for offgas system all melters LLW and HLW
- Metal fiber filters - problem areas

Product Quality

- Performance assessment requirement for onsite storage testing of request
- Canister decontamination
- Waste form qualification - canisters glass
- Canister size, sealing, geometry
- Canister fill level detection - must detect fill level (~~canister active PNL film~~) - develop tests for this (all melters)

Combustion-Heated HLW

- Issues for HLW are identical to LLW (see sheet 5)
- What are different or unique?
- Ability to replace in modular form test pieces instead of changing whole unit. Example, injection valves/counter rotating v and cyclone induction

Stirred Melter

One electrode

Body electrode

- Control draining for canister pouring
- Reliability of valve for pour control
- Surface reliability replaceability of stirrer (concept now can be cloned remotely)
- Stirrer operability problems (height adjustment, agitator speed, propeller geometry)
- Feeding problem = foaming at top from suction crown
- Refining - see LLW notes
- More instrumentation for high-level vitrification

Issues: Induction melter

- Feed
- Calciner product
- Calciner plugging
- Calciner brick degradation/remote replacement
- Calciner seal degradation (graphite)

Attachment 4

Session 4

Testing Requirements IPM

HLW Vitrification

- Product volatility by nature of chemical
- Calciner life?

Melter Issues

- Offgas issues
- Glass formulation (LLW and HLW)
- Waste feed types (LLW and HLW)

Function:

Technology: Plasma Torch

Test category

Issue: Plasma Torch	
Test: • Volatility entrainment	3
• Torch life and maintenance	6
• No design for glass proven	6
• High % of operational reliability	6
- Depends on individual experience	

Function:

Technology: Plasma Arc

Test category

Issue: Plasma Arc	
Test: • Volatility entrainment	3
• Torch life and maintenance	6
• No design for glass proven	6
• High % of operational reliability	6
- Depends on individual experience	

Carbon Arc

- Redox control oxidation - burn electrodes
- Electrode feeding (control of)
- Brick (refract) degradation due to arcing
- Sensitivity to water

3+
6
6
6
6

Attachment 4

Session 5

Testing Requirements IPM

Organic Processes

Session 5 May 17, 1994 9:30-11:30 a.m. and 12:30-2:00 p.m.

Function: Organic Processes

- In-tank organic destruction (Sr and TRU precipitation) elevated temperature hydrolysis
- Caustic recycle - organic destruction (for Sr and TRU removal only)
- Calcination
- High-temperature hydrothermal
- Low-temperature hydrothermal
- Stream reforming

Attendees:	M. J. Bullock	L. D. Bustard	C. H. Delegard
	P. C. Dell'Orco	M. R. Elmore	R. E. Flora
	D. W. Hendrickson	G. F. Howden	M. J. Klem
	T. M. McKeon	J. C. Person	D. E. Place
	J. T. Slankas	R. L. Walser	

Session 5: Organic Processes

Function - Organic Processes/Destruction

Assumption:

- Testing of supernate only
- Filtration and Cs removal will be completed before this process
- Determine which TRU is affected by complexants

Technology: Stream Reforming (Brainstorming)

Issues:

1. Chemical development
2. Organic and nitrate kinetics
3. Offgas expectations
- ~~4. Solubility of residuals~~
5. Volatility (radionuclide)
6. TRU and Sr separations on residuals
- ~~7. Mass & energy descriptions~~
- ~~8. Safety~~
- ~~9. FeCN (ferrocyanides)~~
10. Exothermic reactions accumulation

Attachment 4

Session 5

Testing Requirements IPM

Organic Processes

Function: Organic Process/Destruction

Technology: Stream Reforming

Test category

Issue: Chemical Development	
Test: Cold bench test organic and nitrate kinetics, offgas, volatility, Sr, and TRU solubility, etc.	2
Hot bench test to verify cold bench testing, sample solids to determine the TRU distribution	5
Risk: Not finalizing mass energy balance	
LLW form specification not met	
High dose rates in LLW vitrification plant	
Reduced production	
Strategy: Complete testing	

Process Engineering Development (Brainstorming)

Issues:

- ~~1. Optimization of spray patterns, ceramic flow patterns 7~~
- ~~2. Recovery from up set conditions (MASTIC) 7~~
- ~~3. Pneumatic recirculation of ceramic balls recovers of waste residuals 7~~
4. Balance of plant, control of radionuclides, offgas (mostly nitrate), and particulate
- ~~5. Safety exothermic~~
- ~~6. Need cold test~~
7. Demonstrate optimize pneumatic design (1, 2, 3)

Function: Organic Process/Destruction

Technology: Stream Reforming

Test category

Issue: Process Engineering Development	
Test: Small cold pilot plant to demonstrate/optimize pneumatic design	3
Full-system demonstration	3
Large-scale cold pilot	6
Small hot pilot plant to demonstrate high risk areas of the process	11
Risk: Process may not perform properly or as anticipated	
Possible higher dose/rate	
Reduced production	
Strategy: Procure/assemble/tests. Small, hot pilot plant is for conformation and does not need to precede design	

Attachment 4

Session 5

Testing Requirements IPM

Organic Processes

Function: Organic Process/Destruction

Technology: Stream Reforming

Equipment Development (Brainstorming)

Issues:

1. Corrosion/abrasion on material selection - metal - ceramic
- ~~2. Shielding consideration equipment selection & seating~~
3. Radionuclide building
4. Remotability
5. Size minimization

Function: Organic Process/Destruction

Technology: Stream Reforming

Test category

Issue: Equipment development	
Test: Large, cold pilot plant test for remote operation and maintenance	6
Finalize material selection of ceramics, metals, and determine radionuclides buildup (cold Cs or Sr)	1
Risk: Overexposure, mechanical plant down TRU	
Strategy: Use cold stand-ins for radionuclides (Cs, Sr, Am, Nd)	

Function: Organic Process/Destruction

Technology: High-temperature hydrothermal (Brainstorming)

Issues:

- ~~1. Corrosion 20~~
- ~~2. Solid formation 20~~
- ~~3. Scaling 20~~
- ~~4. Reliability major components 19~~
- ~~5. Cover most difficult organic~~
- ~~6. Kinetics 15~~
- ~~7. Gas formation 15~~
- ~~8. Pressure generation & let down 19~~
- ~~9. Component solubilization~~
- ~~10. Safety 20~~
- ~~11. Process control 19~~
- ~~12. Erosion 19~~
- ~~13. Remote maintenance 19~~
- ~~14. Equipment size 19~~
15. Chemistry of process development (16, 5, 6, 7, 17, 18)
- ~~16. Chemical controls 15~~
- ~~17. Feed variability 10,15~~
- ~~18. Feed preparation 20,15~~
19. Equipment development (14, 13, 8, 4, 12, 1)
20. Process development/engineering development (17, 18, 1, 2, 3, 10)

Attachment 4

Session 5

Testing Requirements IPM

Organic Processes

Function: Organic Process/Destruction

Technology: High-Temperature Hydrothermal

Test category

Issue: Chemistry development	
Test: Low-temperature/cold bench test to establish solubility Sr/Am (range of stimulants) (range of compositions)	2
Hot bench test to confirm cold testing and feed data on a range of samples	9
Sample solids and supernate to determine TRU/Sr distribution	5
Risk: LLW form specification is not met	
High dose rates in vitrification plant	
Strategy: Start 5 quickly - continue 2 (extensively) then 9	
Issue: Process Engineering Develop	
Test: Bench-scale cold process control how to let down the pressure, etc.	2
Small-scale cold to validate 2 above	3
Risk: No safety documentation available	
Process may not perform properly	
Strategy: Do the testing	
Chemistry development with hot waste will enable process engineering development to be done with cold stimulant	
Issue: Equipment development	
Test: Pressure, pump, reactor systems, controls, and other Remotability	Cold 8
Risk: Plant will not work properly - delay operations - may need complete modification	
Strategy: Do the testing	

Function: Organic Process/Destruction

Technology: Low Temperature Hydrothermal

Test category

Issue: Low-Temperature Hydrothermal	
Test: Chemistry lab cold batch	1
Chemistry bench cold (flow) include air injection	2
Chemistry hot batch/lab	5
Process development cold pilot (flow) include air injection	Cold 8
Equipment development cold pilot (flow) include air injection	Cold 8
Chemistry hot bench (flow) include air injection	9
Risk: No safety documentation available	
Process may not perform property	
Strategy: Equipment development will be less than high-temperature hydrothermal equipment development	

APPENDIX 1

May 30, 1994

CANDIDATE HIGH-LEVEL WASTE MELTER GROUPINGS AND DESCRIPTIONS

This document briefly describes the various groups and subgroups of melters being considered as candidates for the Hanford Site high-level waste vitrification plant. The primary grouping was done based on the energy source for the melters: joule heating, combustion, induction, etc. The subgroupings are different for each primary group because of the diversity of the various groups.

1.0 JOULE-HEATED MELTERS

Joule-heated melters, also referred to as electric melters, are heated by passing alternating electric current through glass via submersed electrodes. The alternating current is conducted between two or more electrodes by mobile ions in the molten glass. The resistance of the glass produces a heat-generating effect known as joule heating. Electric melters in the commercial glass industry are either all-electric or electric-assisted. Electric-assisted melters have energy supplied by joule heating of the glass as well as from torches above the glass batch. The advantages of electric melting are that it reduces volatilization of the melt constituents, reduces the offgas system requirements, and allows melting of black glasses where radiant heat transfer is limited. The temperature limit of a joule-heated melter is determined by the materials of construction for the refractory and electrodes. Most joule-heated melters are ceramic lined although a few are metal lined. The metal melters either operate at a low temperature (<1200 °C) or are water cooled such that the metal liner is protected by a frozen layer of glass. The electrodes in a joule-heated melter can be inserted into the glass from the top, sides, or bottom of the melter. Because glass is not conductive at room temperature, joule-heated melters must have auxiliary heating for initial startup. This is usually provided by electrical resistance heaters or torches placed in the plenum space above the glass surface. Other startup methods include laying conductive starter paths between the electrodes and using microwave heat sources.

1.1 LOW-TEMPERATURE, JOULE-HEATED MELTERS

Low-temperature, joule-heated melters are classified here as melters whose maximum operating temperature is below 1200 °C. These melters usually use electrode materials whose melting point does not allow high-temperature operation. Inconel 690,* a high-chromium nickel alloy, is the electrode material most often used for waste melters because of its resistance to corrosion.

*Inconel is a trademark of International Nickel Company.

1.1.1 Ceramic-Lined, Low-Temperature, Joule-Heated Melters

The ceramic-lined, joule-heated melter has been selected for high-level waste vitrification in the United States (Savannah River and West Valley), Germany, Japan, and Russia. These melters have two or more layers of refractory inside a water-cooled containment box (see Figure 1). The glass-contacting refractory is usually a high chromia fusion-cast ceramic (either Carborundum K-3 or a chrome AZS). This is a particular area of deviation from commercial glass industry. High chrome refractories are avoided in the commercial glass industry except in high wear areas (e.g., throat blocks) because of the strong coloring effect of chrome. One exception is the fiberglass industry. The high-level waste melters are able to use the chrome refractories throughout the melter because the color of the product glass is not important. At 1050 to 1150 °C, reported corrosion rates for Carborundum K-3 were 10 to 20 $\mu\text{m}/\text{day}$ in the most aggressive areas and 4 to 8 $\mu\text{m}/\text{day}$ on the pilot-scale ceramic melter at Pacific Northwest Laboratory (Larson 1989). The electrical conductivity of glass-contacting refractory is important in joule-heated melters. If the refractory is too conductive (i.e., the chrome content is too high) it is possible to short circuit between the electrodes via the refractory. This is only a concern with low-conductivity glasses.

Figure 1. Low-Temperature, Joule-Heated Melter.

Because the fused cast refractory is not very insulative, it is usually backed with layers of more insulative ceramics such as high-alumina castable ceramics and ceramic board.

1.1.2 Metal-Lined, Low-Temperature, Joule-Heated Melters

The use of metal-lined, joule-heated melters has been limited. Stir-Melter, Inc. has introduced the West Valley series of Stir-Melters* that use Inconel 690 in all glass contacting areas (see Figure 2). As the name implies, the Stir-Melter is mechanically agitated using an Inconel impeller. The use of this material limits the operating temperature to 1100 °C. The glass is heated by passing alternating electric current between the agitator and the tank walls. Auxiliary heaters are provided for startup.

1.2 HIGH-TEMPERATURE, JOULE-HEATED MELTERS

High-temperature, joule-heated melters are classified here as melters whose maximum operating temperature is above 1200 °C. Most commercial electric melters fall into this category. The main difference between low- and high-temperature electric melters is the electrode materials of construction. Electrode materials of construction for melters above 1200 °C include molybdenum, graphite, tin oxide, platinum, iron, and other metals and metal oxides. Molybdenum electrodes are used in most commercial electric melters except for glasses that contain oxidizing species such as lead and arsenic. This may be a problem for the Hanford Site melter because the reference glass contains several metal oxides that are above molybdenum on the electrochemical series. Molybdenum electrode stems must be either cooled or sealed from the atmosphere because molybdenum rapidly oxidizes in air above 600 °C. Several electrode holders have been designed to protect molybdenum electrodes from air oxidation. Tin oxide does not have the oxidation problems of molybdenum but it does have other problems. Tin oxide electrodes must be larger than molybdenum electrodes because the maximum current density is lower (0.5 A/cm² versus 2 A/cm² for molybdenum). This causes a problem because tin oxide is difficult to manufacture and available sizes are very limited. Tin oxide also has a low-tensile strength such that feeding of electrodes is difficult. Graphite is limited by its low allowable current density (0.2 A/cm²) and its incompatibility with oxidizing glasses.

1.2.1 Ceramic-Lined, High-Temperature, Joule-Heated Melters

Ceramic-lined electric melters are very similar to their low-temperature counterparts (see Figure 3). The refractories will be the same, high-chrome ceramics. The only difference will be the expected lifetime of the refractories. It has been reported that refractory corrosion rates double for every 50 to 100 °C of temperature increase (Woolley 1991) but this is for the same glass composition such that this correlation cannot be used when changing to a harder glass. The corrosion tests for K-3 are currently being conducted for high-level waste glass simulants at high temperatures. This is not

*Stir-Melter is a trademark of Stir-Melter, Inc.

Figure 2. Stirred Melter.

Figure 3. High-Temperature, Joule-Heated Melter.

assumed to be a problem considering the fact that commercial glass melters operating at 1500 °C can operate 2 to 10 years between rebuilds using AZS refractories.

1.2.2 Metal-Lined, High-Temperature, Joule-Heated Melters

The use of metal-lined, high-temperature electric melters has been limited. Corning* has designed a molybdenum-lined decagonal furnace for producing high-quality borosilicate glasses at high specific melting rates (Trier 1987). The Corning melter had three top-entering molybdenum electrodes that allowed operation at 1700 °C.

2.0 COMBUSTION MELTERS

Combustion or fuel-fired melters supply energy to the glass batch by direct or indirect contact with combustion flames. The traditional fuel sources have included coal, oil, and natural gas. Presently, natural gas is the principal fuel for glass melting in the United States. Coal is seldom, if ever, used and oil is mainly used as a backup fuel (Tooley 1974). As mentioned earlier, some melters have combustion heating from the top surface as well as electric boosting from within the melt. These melters are sometimes referred to as electrically boosted melters or mixed melters.

2.1 CONVENTIONAL COMBUSTION MELTERS

Conventional combustion melters supply energy to the glass by directing a flame over the top of the melt surface (see Figure 4). These melters rely on heat transfer (mainly radiation and natural convection) from the top glass surface for heating of the bulk of the glass. Usually, dry feed is introduced at one end of the melter where it forms a batch blanket that is slowly melted. From here the glass flows into an area for fining (removal of bubbles). This area is not covered by batch material because convection currents within the tank keep the batch blanket near the front wall. Finally, the glass flows into a separate section for further homogenizing and cooling in preparation for forming. Some melters employ mechanical agitators to aid in homogenizing.

There are three main types of combustion melters: regenerative, recuperative, and direct-fired. The first two types use the hot flue gas to preheat the combustion air before mixing with the fuel. This reduces the overall energy consumption by 50 to 70%. The only difference between these two types of melters is the method of heat exchange. Direct-fired combustion melters do not recover heat from the flue gas. The inefficiency of a direct-fired fuel melter is balanced by the reduced capital and maintenance costs associated with regenerators and recuperators.

*Corning is a trademark of Corning Glass Works.

Figure 4. Conventional Fuel-Fired Melter.

Commercial combustion melters (as well as commercial electric melters) generally use fusion-cast AZS for the glass-contacting refractories. As mentioned earlier, high-chrome refractories are avoided in the commercial glass industry except in high-wear areas (e.g., throat blocks) because of the strong coloring effect of chrome. The high-level waste melters will be able to use the more durable chrome refractories (e.g., Carborundum K-3* or chrome AZS) throughout the melter because the color of the product glass is not important.

2.2 CYCLONE COMBUSTION MELTERS

Cyclone or vortex combustion melters increase heat transfer over conventional combustion melters by directly contacting the incoming batch with the hot combustion gases. The preheated air and fuel are introduced tangentially into a cyclone where combustion takes place. The fuel can be either coal, oil, or natural gas. The combustion chamber can be either

*Carborundum is a trademark.

cylindrical or conical. The batch materials are introduced into the combustion chamber such that they are suspended in the cyclone and melted in the hot combustion gases. The heavier molten glass agglomerates fall out of the bottom of the cyclone into a receiving basin or soak tank. This concept was introduced in a paper by Alexander Ferguson in 1923 (Pincus 1980). Variations of this technology are currently proposed by Babcock and Wilcox and Vortec (see Figure 5).

3.0 PLASMA/ARC FURNACES

This category can be divided into three subgroups: plasma torches, transferred plasma arc melters, and arc furnaces.

3.1 PLASMA TORCHES

Plasma torches (nontransferred arc) operate by injecting a pressurized gas into a dc electric arc. The resulting vortex of hot plasma gases emerge at a very high speed to form the stabilized plasma. The heart of the plasma torch is two water-cooled electrodes arranged closely to each other (sometimes coaxially) such that an arc is created when current is applied to the system. The anode usually serves as the torch nozzle. A pressurized gas (argon, air, nitrogen, oxygen, etc.) is introduced through the arc gap between the electrodes and is ionized to form the hot plasma. Melters designed around plasma torches rely on impinging the torch on a crucible and passing the material to be melted through the crucible or simply passing the material through the plasma. The crucibles are usually constructed from graphite, refractory material, or water-cooled metal. The melters can operate in either a batch or continuous mode at high temperatures (up to 3000 °C). The torch tips usually have a very short life such that they need to be replaced after approximately 100 hours of use. The crucibles are usually shallow because the heat is supplied from the top surface and radiant heat transfer is poor through most wastes.

3.2 TRANSFERRED PLASMA ARC MELTERS

Transferred plasma arc melters operate under similar principals to plasma torches except that either the melted material or the crucible serves as one of the electrodes. This allows for more equal distribution of heat as well as joule heating of the material. Typically, the electrode is still water-cooled metal, although this configuration does allow the electrode to be constructed out of a material that does not have to be water cooled (e.g., graphite). By using nonmetallic electrode materials the operating current density can be increased substantially, thereby increasing the energy transfer while still maintaining a short arc length. Operating with shorter arcs minimizes the energy losses, concentrating the heat into the material to be melted. In addition, graphite electrodes allow operation in a submerged mode, thus minimizing volatilization losses that are usually substantial for such systems.

Figure 5. Cyclone Combustion Melter.

3.3 ARC FURNACES

Arc furnaces operate very similarly to transferred plasma arc melters except that pressurized gas is not passed through the electrode. The plasma gas is either the surrounding air or cover gas if the vessel is blanketed. These furnaces can use either ac or dc to create the arc. Three-phase ac systems are commonly used for production of alloys, silicon, etc. Because most of these systems use carbon or graphite electrodes, the furnaces are usually run under a reducing atmosphere. The resulting product is usually reduced and somewhat crystalline.

4.0 REFERENCES

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Trier, W., 1987, *Glass Furnaces*, p. 218, Society of Glass Technology, England.

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APPENDIX 2

PRETREATMENT PROCESS DESCRIPTIONS

1.0 HYDROTHERMAL PROCESSING

High-temperature hydrothermal processing (Figure 1) refers to a waste treatment technique in which an aqueous waste stream is fed through a chemical reactor at elevated temperatures and pressures to effect desired chemical transformations and separations. The waste in water is pressurized and heated. If complete nitrate destruction is required in addition to organic destruction, a reducing agent is added. The waste solution is maintained at the desired reaction temperature for a time sufficient to achieve complete destruction of the organics and nitrates. The mixture is then cooled and depressurized, and the gaseous, liquid, and solid components separated. At sufficiently high temperatures and pressures ($>475^{\circ}\text{C}$ and 400 to 15,000 psi) organics and nitrates are destroyed in seconds, producing primarily simple products such as CO_2 , H_2O , N_2 , and NaOH . Under these conditions, the waste is a fluid with densities high enough that reasonable process throughput can be achieved, but its transport properties are like those of a gas, allowing rapid chemical reaction. Oxidation takes place at lower temperatures than those of incineration, limiting the production of NO_x and char. The reaction is carried out entirely in an enclosed pressure vessel and in dilute concentration, so that the heat of reaction is absorbed by the solvent and the temperature can be maintained at any desired level, typically in the range of 300 to 550°C .

Low-temperature hydrothermal processing (Figure 2) is a thermal-chemical processing method to destroy organic and ferrocyanide constituents in tank waste using the abundant existing oxidants in the tank waste such as nitrite and nitrate. Low-temperature hydrothermal processing effectively destroys organics at temperatures from 250 to 400°C to eliminate safety hazards and improve further processing.

2.0 CALCINATION/DISSOLUTION (Figure 3)

Calcination/dissolution refers to heating tank waste in excess of 800°C to destroy organic, ferrocyanide, and nitrate/nitrite compounds, and subsequently leaching the residue with water to remove all soluble materials. The solid residues produced during the thermal treatment consist primarily of sodium hydroxide, aluminum compounds, and metal oxides. The high-temperature treatment in molten sodium hydroxide is expected to convert aluminum oxide and hydroxide phases present in the waste to water-soluble sodium aluminate salt. Because water leach dissolves in the sodium hydroxide from the calcined product, the aqueous treatment is actually a strong caustic dissolution which also helps solubilize the sodium aluminate, in addition to other easily dissolved species. Because the actinides are nearly insoluble in basic

Figure 1. High-Temperature Hydrothermal Processing.

solution, the selective dissolution leads directly to a simple transuranic/nontransuranic split, i.e., high-level waste/low-level waste with the actinides remaining with the solid fraction.

3.0 STEAM REFORMING

Steam reforming is a chemistry that has been used for six decades to produce molecular hydrogen from simple hydrocarbons. It has been studied exhaustively for three decades as an important process in the gasification of coal. Steam reforming has been investigated extensively during the last decade as a way to destroy or generate energy from cellulosic wastes (Figure 4).

Destruction of organic wastes is a two step process. First, the hydrocarbons in the waste are evaporated in a waste feed evaporator process unit that can have a variety of forms depending on the type and form of the waste. In the waste feed evaporator, the hydrocarbon vapors are first exposed to superheated steam at temperatures from 315 to 593 °C, and at these temperatures steam reforming chemistry starts to occur. The steam reforming of the hydrocarbons forms CO, CO₂, H₂O, H₂, and a small amount of CH₄.

Figure 2. Low-Temperature Hydrothermal Processing.

Figure 3. Plasma Arc Equipment.

Figure 4. Organic Waste Destruction.

These gases exit the waste feed evaporator where they are heated to higher temperature (approximately 1232 °C) and mixed with excess superheated steam as they are pulled into the main reactor where their destruction is completed.

APPENDIX C

DATA SHEETS FROM WORKSHOPS

CONTENTS

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APPENDIX C
DATA SHEETS FROM WORKSHOPS
C1.0 SOLIDS PROCESSING

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Solids Processing

Technology: Settling

Issue No. 1 Issue Description:

The rate of solids settling following mixing needs confirmation.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A In-tank studies of settling rates to validate computer simulation and cold lab work with simulants.	7	
B Checkout/verification of turbidity/radiation instrument measurements of settling process.	7	
C		
D		

Describe risk if not tested at highest level of testing category:

Would not have settling rate data needed for in-tank production processing of tank waste.

A base of information and models is needed to predict settling time (time to achieve a predetermined supernatant quality/clarity level) and more generally, to predict supernatant quality/clarity as a function of settling time.

Strategy for issue resolution:

Lab testing is complete and computer simulation studies are continuing. Need large-scale in-tank test to confirm cold test data and engineering studies.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Solids Processing

Technology: Settling

Issue No. 2 Issue Description:

Identify/characterize suspended solids following mixing of tank, including percent suspended solids.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Perform in-tank settling rate test in tank 101-AZ.	7	Performed by in-tank instrumentation-measurement of turbidity and sampling.
B Characterize suspended solids.	5	Samples to be taken at various depths.
C		
D		

Describe risk if not tested at highest level of testing category:

Would not have suspended solids data needed for in-tank production processing of tank waste.

It will not be possible to predict whether supernatant clarity objectives can be met and how long a settling period will be required to meet them. Particle settling periods are quite long and have a definite impact on waste retrieval and pretreatment schedule.

Strategy for issue resolution:

Perform in-tank testing to validate cold testing (with simulants) of turbidity instrumentation. Number of dip samples at different elevations to calibrate instrumentation to be determined (TBD).

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Solids Processing

Technology: Settling

Issue No. 3 Issue Description:

Determine the likely distribution of radioactivity between liquid and solids and between particles of different sizes.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Lab testing of samples.	5	
B		
C		
D		

Describe risk if not tested at highest level of testing category:

Low-level waste (LLW) criteria not met. Excessive dose rates in LLW vitrification operations may result.

Strategy for issue resolution:

Integrate these sample tests with in-tank testing for this technology.

TWRS PROCESS DEVELOPMENT Test Requirements Record

Function: Solids Processing

Technology: Settling

Issue No. 4 Issue Description: _____

The effect of mixing in-tank on sludge particle size distribution is uncertain.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Identify change in particle size distribution caused by mixing of the tank sludge/supernate.	5	Cold testing of centrifugal pump with tip speed matching mixer pumps has been completed.
B		
C		
D		

Describe risk if not tested at highest level of testing category:

- Test not required if mixed tank settles within a few days. If settling does not occur as expected, dip samples will be needed to determine subsequent plan.
- Slow settling/production delays.

Strategy for issue resolution:

Core samples have been taken to characterize the tank. No further hot lab testing unless tank does not settle as expected. Integrate with in-tank testing. Take dip samples for hot lab testing as needed.

TWRS PROCESS DEVELOPMENT Test Requirements Record

Function: Solids Processing

Technology: Sludge Wash

Issue No. 1 Issue Description: _____

The effect of in-tank washing on tank corrosion is unknown.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Visual evaluation of tank for corrosion.	7	
B Coupon test/cold. Extend database.	1	
C Evaluate corrosion on coupons with tank sampling.	5	
D Evaluate corrosion rate in tank.	7	Use coupons/instrumentation.

Describe risk if not tested at highest level of testing category:

- May not be able to do sludge washing in double-shell tank (DST).
- Other tank failure during operation--programmatic impact.

Strategy for issue resolution:

Perform cold/hot lab tests and in-tank inspections and coupon tests.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Solids Processing _____

Technology: Sludge Wash _____

Issue No. 2 Issue Description: _____

Failure of solids to settle after repeated washing due to low ionic strength of waste solution (peptization).

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Determine degree of washing required to initiate peptization.	5	Material from a wide range of core samples might be required.
B Reversibility if phenomenon were to occur.	5	
C		
D		

Describe risk if not tested at highest level of testing category:

Waste may be encountered that will not settle well after washing, resulting in lower production efficiency and more high-level glass.

Strategy for issue resolution:

Perform dilution tests with a wide spectrum of samples.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Solids Processing

Technology: Sludge Wash

Issue No. 3 Issue Description:

The solubility of the sludge is uncertain.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Determine solubilities by washing actual waste.	4/5	Work in progress.
B		
C		
D		

Describe risk if not tested at highest level of testing category:

If transuranic (TRU) components of sludge are readily dissolvable, advanced sludge processing (acid phase) and/or increased high-level waste (HLW) glass logs may be required.

Strategy for issue resolution:

Continue current test work at Westinghouse Hanford Company (WHC)/Pacific Northwest Laboratory (PNL).

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Solids Processing

Technology: Sludge Wash

Issue No. 4 Issue Description:

Mass transfer rates/reaction rates.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Cold lab test--to get rate parameters.	1	
B Hot lab test.	5	
C In-tank testing.	7	
D		

Describe risk if not tested at highest level of testing category:

Unable to predict washed sludge compositions.

Strategy for issue resolution:

Perform cold and hot lab testing with confirmatory in-tank testing.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Solids Processing

Technology: Enhanced Sludge Wash

Issue No. 1 Issue Description:

The effect of enhanced in-tank washing (with greater than 3M NaOH) on tank corrosion is unknown.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Coupon test/cold. Extend database.	1	
B Evaluate corrosion on coupons while leaching tank samples with sodium hydroxide at elevated temperatures.	5	
C		
D		

Describe risk if not tested at highest level of testing category:

- May not be able to do enhanced sludge washing in DST.
- Tank failure during operation - programmatic impact.

Strategy for issue resolution:

Perform cold/hot lab tests. Need to emphasize chemical compositions that actually will be encountered.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Solids Processing

Technology: Enhanced Sludge Wash

Issue No. 2 Issue Description:

The solubility of the sludge components in caustic solutions is uncertain.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Determine solubilities by washing actual waste with sodium hydroxide.	4/5	Work in progress.
B Determine if wash solution changes the characteristics of the sludge and its resistance to mobilization by mixer pumps/sluicers.	See Issue 3	This is important to DST Retrieval Engineering.
C		
D		

Describe risk if not tested at highest level of testing category:

If uranium (U)/TRU/strontium (Sr) components of sludge are soluble, advanced sludge processing (acid phase) may be needed. Projections for HLW glass quantity may be inaccurate if washing efficiencies for aluminum (Al), chromium (Cr), and phosphate are not accurately known. More difficult sludge mobilization.

Strategy for issue resolution:

Continue current test work at Westinghouse Hanford Company/Pacific Northwest Laboratory.

TWRS PROCESS DEVELOPMENT Test Requirements Record

Function: Solids Processing

Technology: Enhanced Sludge Wash

Issue No. 3 Issue Description:

Solids dissolution rate (mass transfer rates/reaction rates).

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Cold lab test, to get dissolution rate parameters (time, temperature and OH concentration), and sludge erosion rate after exposure to wash solution.	1	See Issue 2 comments.
B Hot lab test, to get solids dissolution rate parameters (time, temperature, and OH concentration), sludge erosion rate after exposure to wash solution.	5	
*C Sludge mobilization after washing.	1/5	Large (approximately 25 L) sample needed.
D In-tank testing to confirm results of above.	7	
*Item C is retrieval issue.		

Describe risk if not tested at highest level of testing category:

- Will not be able to mobilize sludge (with mixer pump/sluicer) beyond radius achieved with unwashed sludge.
- Increased HLW glass.
- Time lost in modifying operations.

Strategy for issue resolution:

Perform cold and hot lab dissolution/mobilization testing with final mobilization testing at approximately 25-L scale. Techniques to be perfected during cold tests. Confirm with in-tank testing.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Solids Processing

Technology: Filtration

Issue No. 1 Issue Description:

Filter efficiency in solids removal.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Cold bench testing of filter media with simulants.	2	
B Test filter efficiency with actual supernate.	8	
C		
D		

Describe risk if not tested at highest level of testing category:

- Excessive dose rates
- Feed specifications for LLW vitrification may not be met.

Strategy for issue resolution:

Use cold bench testing to prepare for hot testing with actual supernates.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Solids Processing

Technology: Filtration

Issue No. 2 Issue Description: _____

A correlation between TRU concentration on particles and solids particle size would need to be developed if filtration performance measurement is based on solids concentration in the filtrate. Currently assuming that the TRU concentration in solids is relatively constant within a given tank and is not a function of particle size (may not be good assumption).

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Performance test of TRU monitor.	7/8	
B		
C		
D		

Describe risk if not tested at highest level of testing category:

Issue only important if TRU in the product is not measured directly.

Strategy for issue resolution:

Measure TRU directly rather than attempting to develop correlations.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Solids Processing

Technology: Filtration

Issue No. 3 Issue Description: _____

Mass of solids that must be removed by the filtration system:

- Amount of solids determines filtration system design
- High solids content would work against selection of precoat filters.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Measure solids content of settled supernate.	5	Should be done with sludge wash work.
B Measure solids capacity of selected filters.	2/8	Done as part of Issue 1 activities.
C For precoat filters, understand the stability of the precoat material under process conditions.	1	
D		

Describe risk if not tested at highest level of testing category:

May overspecify the filtration system, too large, too costly. May predict excessive HLW glass.

Strategy for issue resolution:

- Perform trade study between enhanced settling (longer residence time or use of flocculents) versus increased filtration requirements.
- Establish acceptable level of precoat use.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Solids Processing

Technology: Filtration

Issue No. 4/8 Issue Description:

Solids forming during processing.

NOTE: Changing process conditions may cause the formation of solids during the process steps (evaporation, pH adjustment, water addition, etc.).

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Extended testing at small scale with actual waste to identify slow-growth issues.	8/9	Could be done with Issue 1 testing.
B Identify process conditions which form solids (evaporation, water addition, etc.).	2/5	Work with sludge wash tests.
C		
D		

Describe risk if not tested at highest level of testing category:

Failure to perform in plant (filter blockage).

Strategy for issue resolution:

Perform testing.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Solids Processing

Technology: Filtration

Issue No. 5 Issue Description:

Are there constituents (e.g., small particles) present which will result in premature plugging of filters or short cycle time between backwash/chemical cleaning? Fouling of filter media (also see Issue 4/8).

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A See Issue 4/8, Item A.	2/ 8-9	
B Demonstrate filter media chemical cleaning.	2/8	
C		
D		

Describe risk if not tested at highest level of testing category:

- Same as Issue 4/8.
- Filter media throughput will degrade with time unless chemical cleaning methods are developed.

Strategy for issue resolution:

Same as Issue 4/8.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Solids Processing

Technology: Filtration

Issue No. 6 Issue Description:

Disposal of filter - not a testing issue at present. May develop into need for cold pilot scale or larger tests after system is designed.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A None required at this time.		
B		
C		
D		

Describe risk if not tested at highest level of testing category:

Strategy for issue resolution:

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Solids Processing

Technology: Filtration

Issue No. 7 Issue Description: _____

Filter cake properties. Do solids form a reasonable cake for filtration, discharge, and disposal purposes? Are filter aids needed? If so, are they reasonably stable under process conditions?

NOTE: Deep bed filter types, if used, may require flocculent for efficient operation.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Determine filter cake properties and cake discharge characteristics.	2/8	
B Investigate the use of filter aids or flocculent with filter system.	2/8	
C		
D		

Describe risk if not tested at highest level of testing category:

Inefficient operation, possible TRU contamination of LLW product stream.

Strategy for issue resolution:

Perform test; use results to design filtration cycle.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Solids Processing

Technology: Centrifugation

Issue No. 1 Issue Description:

Centrifuge cake properties.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Percent of moisture in cake/other properties.	4	Data may be available (TBD).
B		
C		
D		

Describe risk if not tested at highest level of testing category:

Required to estimate washing efficiencies and water recycle, and to make effective simulant for large-scale cold testing.

Strategy for issue resolution:

Use previous test results from settling or waste characterization, if available.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Solids Processing

Technology: Centrifugation

Issue No. 2 Issue Description:

Need for flocculation/solids to enhance discharge from centrifuge.

NOTE: Previous testing with a scrolling centrifuge indicates that a flocculent must be added to the centrifuge bowl to achieve high removal efficiency and allow effective solids discharge.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Several flocculents to select optimum.	1	
B Validate test in Item A above.	5	
C		
D		

Describe risk if not tested at highest level of testing category:

May encounter inadequate solid/liquid separation, reduced production plant efficiency, and higher unit operation costs.

Strategy for issue resolution:

Screen flocculents with cold laboratory test. Conduct hot tests of promising flocculents.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Solids Processing

Technology: Centrifugation

Issue No. 3 Issue Description: _____

Solids/liquid separation performance:

- Throughput rate/removal efficiency
- Maintainability/reliability
- Process control.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A System performance with simulants.	6	
B Validate cold test system performance.	7	
C		
D		

Describe risk if not tested at highest level of testing category:

- System performance for hot operation may not meet Tank Waste Remediation System production requirements.
- Adequacy of process control instrumentation would not be demonstrated.

Strategy for issue resolution:

- Conduct large-scale pilot-plant testing with simulant at manufacturing site.
- Use in-tank equipment or compact processing unit close to tank to verify with actual waste.
- Use radiation/TRU/turbidity monitors developed for in-tank settling for process control.

TWRS PROCESS DEVELOPMENT Test Requirements Record

Function: Solids Processing

Technology: Flocculation

Issue No. 1 Issue Description:

It was determined that flocculation was not a separate technology, but rather an potential enhancement for the following:

- Settling
- Filtration
- Solids density in settled sludge
- Centrifugation.

NOTE: After the workshop, it was determined that (1) flocculents are not needed for in-tank settling operations (Norton and Torres-Ayala 1993), and (2) flocculents would not improve the density of settled solids (the opposite effect is probable).

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A		
B		
C		
D		

Describe risk if not tested at highest level of testing category:

Strategy for issue resolution:

Flocculation will be considered with each of the above technologies and added to the testing needs for those technologies, if appropriate.

C2.0 PRETREATMENT PROCESSES

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Pretreatment Processes

Technology: Cesium (Cs) Removal, Ion Exchange

Issue No. 1 Issue Description:

Swelling/shrinking of ion-exchange resin in its various ionic states (organic resins only).

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Cold ion-exchange column tests.	2	Will get data along with other test activity.
C Measure effect of resin swelling/contraction on mass transfer (i.e., channeling) on larger scale.	6	
D Hot ion-exchange column tests.	9	Will get data along with other test activity.

NOTE: Cold batch equilibrium tests are already complete.

Describe risk if not tested at highest level of testing category:

Information needed for design of ion-exchange columns.

Strategy for issue resolution:

Obtain necessary data from hot/cold testing performed for other purposes.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Pretreatment Processes

Technology: Cs Removal

Issue No. 2 Issue Description:

Physical attrition of resin by mechanical abrasion.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Determine change in resin particle size distribution and resin losses from column.	6	
B		
C		
D		

Describe risk if not tested at highest level of testing category:

Reduced Cs removal efficiency due to carryover of resin fines.

Strategy for issue resolution:

Assume it will happen and design accordingly. Be alert for indicators of a resin attrition problem during other testing with actual wastes.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Pretreatment Processes

Technology: Cs Removal

Issue No. 3 Issue Description:

Precipitation of feed components (e.g., Al) in column.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Batch tests--visual observation/ filtration of solution after extended period.	5	Minimal concern (extremely low probability).
B Column ion-exchange tests--observe for indications of resin pluggage or solids formation.	9	
C		
D		

Describe risk if not tested at highest level of testing category:

Ion-exchange column plugging due to suspended solids in feed.

Strategy for issue resolution:

Minimal concern, but need to be alert for solids formation during ion-exchange testing.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Pretreatment Processes

Technology: Cs Removal

Issue No. 4 Issue Description:

Resin loading capacity of ion-exchange material. Effect of:

- Temperature
- Competing ions
- Aspect ratio of column.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Cold batch distribution tests.	1	Trace quantities of ^{137}Cs may be used.
B Cold bench-scale ion-exchange column tests.	2	Trace quantities of ^{137}Cs may be used.
C Hot batch distribution testing.	5	
D Hot ion-exchange column testing.	9	

Describe risk if not tested at highest level of testing category:

- May not meet Cs removal requirements or properly design equipment for needed capacity.
- High dose rates at LLW vitrification facility.
- Production delays.

Strategy for issue resolution:

Conduct extensive cold and hot tests (lab batch equilibrium → simulant lab column tests → actual waste batch equilibrium → actual waste lab column tests → cold, large-scale pilot plant).

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Pretreatment Processes

Technology: Cs Removal

Issue No. 5 Issue Description:

Ability to remove Cs from resin with reasonable quantities of acid eluant.

NOTE: Applicable to regenerative ion-exchange systems only.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Cold batch equilibrium testing.	1	Trace quantities of ¹³⁷ Cs may be used.
B Cold ion-exchange column testing.	2	
C Hot batch equilibrium testing.	5	
D Hot ion-exchange column testing.	9	

Describe risk if not tested at highest level of testing category:

Inadequate Cs removal during elution, resulting in excessive Cs in LLW vitrification feed, higher exposure rates, and possibly exceeding LLW vitrification feed specifications.

Strategy for issue resolution:

Conduct extensive testing to optimize/demonstrate adequate elution of Cs from the resin.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Pretreatment Processes

Technology: Cs Removal

Issue No. 6 Issue Description:

Resin radiation degradation.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Batch distribution testing of irradiated resin.	1	
B Ion-exchange column testing of irradiated resin.	2	
C		
D		

Describe risk if not tested at highest level of testing category:

May select resin with inadequate radiation resistance, resulting in frequent resin changeouts and production delays.

Strategy for issue resolution:

Perform tests (batch and column) on irradiated resin.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Pretreatment Processes

Technology: Cs Removal

Issue No. 7 Issue Description:

Resin chemical degradation by feed, eluant, and regenerant.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Batch testing, long-term chemical resistance.	1	
B Cold ion-exchange column testing--repetitive cycling.	2	
C Investigate effect of feed deaeration on resin performance/life	2	Test "C" added August 3, 1994. Air oxidation of resin may be a significant factor in resin life.
D		

Describe risk if not tested at highest level of testing category:

May select resin with inadequate resistance to chemical cycling, resulting in frequent resin changeouts and production delays.

Strategy for issue resolution:

Resolve with cold testing (batch and column).

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Pretreatment Processes

Technology: Cs Removal

Issue No. 8 Issue Description:

Resin quality from manufacturers.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Batch distribution tests.	1	
B Ion-exchange column tests.	2	
C		
D		

Describe risk if not tested at highest level of testing category:

Ion-exchange resin performance will be inconsistent between different manufacturing runs.

Strategy for issue resolution:

Continue to work with vendors/researchers. Evaluate their efforts with cold testing.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Pretreatment Processes

Technology: Cs Removal

Issue No. 9 Issue Description:

Resin procurement specifications for followup purchase.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Cold lab testing.	1	
B Ion-exchange column tests.	2	
C		
D		

Describe risk if not tested at highest level of testing category:

Unable to ensure that purchased resin will be of uniform good quality.

Strategy for issue resolution:

Develop essential material specifications/lab procedures.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Pretreatment Processes

Technology: Cs Removal

Issue No. 10 Issue Description:

Safety issues:

- Exothermic reactions
- Hydrogen generation (changes with flow rate)
- Other.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Batch testing of resin/acid reaction rates.	1/2	
B Hydrogen generation testing--ion-exchange resin tests.	5	
C		
D		

Describe risk if not tested at highest level of testing category:

Process cannot be demonstrated to be safe.

Strategy for issue resolution:

Collect data on potential reaction exotherms as necessary. Perform engineering calculations/analysis and adapt design to ensure safety. If necessary, contract with a firm specializing in evaluating and testing for exothermic reaction hazards. Conduct hydrogen generation tests onsite.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Pretreatment Processes

Technology: Cs Removal

Issue No. 11 Issue Description:

Resin storage (shelf life) chemical and radiological testing, pre-use and post-use.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Deterioration before actual use.	1	
B Deterioration of spent resin from residual radioactivity.	5	
C		
D		

Describe risk if not tested at highest level of testing category:

- Difficult to plan resin procurement.
- Spent or disposable resins may degenerate during storage, making subsequent retrieval or treatment difficult.
- Possible safety problems, such as hydrogen generation.

Strategy for issue resolution:

Expose resins to conditions that approximate storage and measure effects on chemical physical properties.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Pretreatment Processes

Technology: Cs Removal

Issue No. 12 Issue Description:

Effect of immiscible organics on resin performance.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Contact resin with tributylphosphate (TBP) normal paraffin hydrocarbon (NPH)--batch testing.	1	
B Contact resin with TBP/NPH, then conduct column tests of ion-exchange resin.	2	
C Contact resin with degraded organics from actual wastes, then conduct ion-exchange column tests to determine effect, if any.	9	
D		

Describe risk if not tested at highest level of testing category:

Organics may poison ion-exchange resin.

Strategy for issue resolution:

Contact resin with organic material, then determine any degradation in ion-exchange performance.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Pretreatment Processes

Technology: Cs Removal

Issue No. 13 Issue Description:

Resin exchange kinetics (overall rate of chemical reaction/mass transfer).

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Determine ion-exchange column breakthrough curves with tests over range of flow rates.	2	
B Repeat ion-exchange column tests with actual wastes.	9	
C		
D		

Describe risk if not tested at highest level of testing category:

Ion-exchange column design may be inadequate, creating production delays.

Strategy for issue resolution:

Conduct combined tests with simulant and actual wastes.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Pretreatment Processes

Technology: Cs Removal

Issue No. 14 Issue Description:

Resin removal efficiency.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Test completeness of resin removal techniques with large column.	6	Consider using Savannah River ion-exchange unit as test setup.
B		
C		
D		

Describe risk if not tested at highest level of testing category:

Degraded resin, which cannot be removed from columns, may cause reduced capacity or lower Cs removal efficiency. The issue is more important if disposable resins are used or if large decontamination factors are required.

Strategy for issue resolution:

Resolve with large-scale cold testing.

TWRS PROCESS DEVELOPMENT

Test Requirements Record

Function: Pretreatment Processes

Technology: Cs Ion-Exchange Removal

Issue No. 15 Issue Description:

Cesium carryover to LLW product as the result of holdup in valves, piping, and other equipment pieces.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Measure effect of solution holdups in valves/piping on Cs recovery efficiency. Cesium carryover from previous ion-exchange cycle causes small, but troublesome, losses. Problem significant if high cesium recovery efficiencies are required.	6	Use actual valves and piping; model to be physically similar to full-scale design.
B		
C		
D		

Describe risk if not tested at highest level of testing category:

Low-level waste product may not meet specification for Cs. Higher radiation levels at LLW vitrification facility.

Strategy for issue resolution:

Measure effects of holdups during cold testing with large column. Possibly use Savannah River skid-mounted unit, but modify as necessary to model expected Hanford Site column design. Coordinate with other large-scale cold tests.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Pretreatment Processes

Technology: Cs Ion-Exchange Removal

Issue No. 16 Issue Description:

Disposal of spent ion-exchange resin.

NOTE: Issue added August 3, 1994, in accordance with Pretreatment Sub-Tanks Advisory Panel review.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Conduct testing of disposal methods identified by engineering study.	1/5	Detailed testing requirements need to be defined by separate engineering study.
B		
C		
D		

Describe risk if not tested at highest level of testing category:

May not have acceptable disposal method available for highly radioactive secondary waste steam.

Strategy for issue resolution:

Complete engineering study of disposal methods for organic resins and crystalline silicotitanate exchanger. Test disposal method on resins used in cold/hot laboratory experiments.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Pretreatment Processes

Technology: TRU, Technetium (Tc), Sr, Ion Exchange

Issue No. 1 Issue Description:

The issues previously identified for Cs ion exchange also apply to Sr, TRU, and Tc removal.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Chelate Sr, TRU.	1,2/ 5	
B Colloidal Sr, TRU.	1,2/ 5	
C Soluble Tc.	1/2 5	
D		

Describe risk if not tested at highest level of testing category:

Inadequate removal of these constituents from waste resulting in exceeding the LLW vitrification feed specifications.

Strategy for issue resolution:

Conduct cold and extensive hot tests.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Pretreatment Processes

Technology: Tc Removal Ion Exchange

Issue No. 1 Issue Description:

Variation in matrices--competition from nitrate ion, other metals.

NOTE: Based on May 19, 1994, discussion with Norm Schroeder of Los Alamos National Laboratory.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Batch tests with simulants.	1	Planned testing. Simulant will use ⁹⁹ Tc.
B		
C		
D		

Describe risk if not tested at highest level of testing category:

Recovery process may be underdesigned, resulting in reduced production throughput and/or low-recovery efficiencies.

Strategy for issue resolution:

Cold tests.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Pretreatment Processes

Technology: Tc Removal Ion Exchange

Issue No. 2 Issue Description:

Quantity of Tc in tank wastes/Tc valence state.

NOTE: Based on May 19, 1994, discussion with Norm Schroeder of Los Alamos National Laboratory.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Characterize tank wastes and determine fraction present as pertechnetate ion.	4	Much of the Tc originally present in reactor fuels may have been already released to the environment thorough process condensates.
B		
C		
D		

Describe risk if not tested at highest level of testing category:

- Technetium may be in wrong form for ion-exchange recovery.
- Technetium levels may be too low to justify recovery effort or too dilute relative to competing ions to be effectively recovered.

Strategy for issue resolution:

Existing characterization program.

TWRS PROCESS DEVELOPMENT Test Requirements Record

Function: Pretreatment Processes

Technology: Tc Sulfide Precipitation

Issue No. 1 Issue Description: _____

The technology was briefly discussed, but it does not appear to be promising as compared to Tc ion exchange. The process can precipitate Tc in the +4 and +7 valence states, but requires a pH of 8 to 9. The French have also found that the precipitate redissolves in 2 to 3 hours. The process could not be performed in large, carbon steel, underground tanks; consequently, attainment of high-production rates would be difficult. Technetium ion exchange of the overheads from LLW/HLW vitrification would be much easier (Burnum 1993).

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A None recommended.		
B		
C		
D		

Describe risk if not tested at highest level of testing category:

Strategy for issue resolution:

No further testing of sulfide precipitation of Tc is recommended. Ion-exchange removal of Tc is a much more promising technology.

TWRS PROCESS DEVELOPMENT Test Requirements Record

Function: Pretreatment Processes

Technology: Sr Removal by Precipitation

Issue No. 1 Issue Description:

This is a relatively undeveloped technology that may allow Sr reduction in the supernates via an in-tank process that does not require destruction of the complexants. The results of limited testing have thus far been mixed.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Determine the form of the Sr in the waste.	4	Being investigated by Pacific Northwest Laboratory in fiscal year 1994.
B Variability of Sr between tanks (each tank is likely to be different).	4	
C Are there one or more processes that will remove the Sr (i.e., precipitation, isotopic dilution, etc.)?	5	
D Confirm that precipitates do not redissolve.	5	
E Determine effects of process parameters (temperature, concentrations, etc.).	5	

Describe risk if not tested at highest level of testing category:

Strontium is too high to meet LLW feed specification. Possibly increased exposure to radiation.

Strategy for issue resolution:

Continue with preliminary testing which is in progress. Develop detailed test plans if preliminary work is successful.

C3.0 ORGANIC DESTRUCTION

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Organic Destruction

Technology: Calcination

Issue No. 1 Issue Description:

Chemistry development:

- Organic and nitrate destruction kinetics
- Offgas expectations (e.g., radionuclide volatility)
- TRU/Sr separations.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Investigate Sr/ameridium (Am) solubility with cold simulants, solid/liquid separation, offgas composition.	1, 2	Determine kinetics. Expected to be rapid.
B Confirm cold test data in Item A above.	5	Install cold test equipment in hood/cell to confirm Sr/Am behavior.
C		
D		

Describe risk if not tested at highest level of testing category:

The feasibility of the process must be demonstrated to justify further development. Validity of cold test data would be questionable for subsequent development work. Would be unable to justify kinetics data.

Strategy for issue resolution:

Verify cold bench-scale testing with hot lab testing using liter-size samples. Added large pilot work (cold and possibly hot) may be required. The mixing heating and turbulence in the full-scale plant cannot be modeled by lab or bench-scale equipment.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Organic Destruction

Technology: Calcination

Issue No. 2 Issue Description:

Process engineering development:

- Firing optimization
- Corrosion/erosion
- Shielding
- Solid/liquid separation.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Solid/liquid separations.	2	
B Verify solid/liquid separation on a large-scale test.	6	
C		
D		

Describe risk if not tested at highest level of testing category:

May be unable to meet LLW vitrification feed specification resulting in greater dose rates, facility downtime, and operating costs.

Strategy for issue resolution:

Develop one-tenth unit for extensive cold testing with potential for hot test use.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Organic Destruction

Technology: Calcination

Issue No. 3 Issue Description:

Equipment/system development:

- Corrosion
- Reactor performance
- Remote operation and maintenance
- Heat source development
- Shielding
- Solid/liquid separation.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Component corrosion.	2	
B Develop full-system operation, maintainability, performance characteristics.	6	
C		
D		

Describe risk if not tested at highest level of testing category:

May be unable to meet the LLW vitrification plant feed specifications.
Equipment may be unreliable or unmaintainable.

Strategy for issue resolution:

Perform testing as part of engineering development activity.

TWRS PROCESS DEVELOPMENT Test Requirements Record

Function: Organic Destruction

Technology: Steam Reforming

Issue No. 1 Issue Description:

Chemistry development:

- Organic and nitrate kinetics
- Offgas expectations
- Volatility of radionuclides
- Exothermic reactions
- TRU and Sr solubility in product carbonate solution.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Organic and nitrate destruction kinetics, offgas expectations, radionuclide volatility, and solubility of treated waste.	2	
B Verify cold-bench testing; sample solids to determine TRU distribution.	9	Single test setup requires Hanford Site tank waste transfer.
C Waste characterization for rheological characteristics and particle size.	4	Data may be at least partially available.
D		

Describe risk if not tested at highest level of testing category:

Could not finalize the mass/energy balance; may fail to meet LLW specifications resulting in high dose rates in LLW vitrification plant.
Reduced production.

Strategy for issue resolution:

Perform testing at Sandia National Laboratory with liter-size tank waste sample. Cask qualification design/qualification cycle will take about 3 to 4 years.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Organic Destruction

Technology: Steam Reforming

Issue No. 2 Issue Description:

Process engineering development:

- Optimization of spray patterns
- Optimization of ceramic ball flow patterns
- Recovery from upset conditions (mastic formation)
- Pneumatic recirculation system/waste residual recovery
- Balance of plant, control of radionuclides, offgas, particulates.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Optimize pneumatic design (1, 2, 4). See ceramic ball heating, metering, waste injection, disposal, and radioactive solids collection and handling.	3	0.5 gal/min.
B Full-system demo.	3	0.5 gal/min.
C Large-scale system demo.	6	5 gal/min throughput.
D Full-system demo for high-risk areas of process.	11	Test setup "B" to hot cell.

Describe risk if not tested at highest level of testing category:

Process may not perform as expected, resulting in higher dose rates in LLW vitrification plant from Sr carryover, reduced production rate.

Strategy for issue resolution:

Procure and assemble testing equipment. Small, hot pilot plant is for confirmation and does not need to precede design.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Organic Destruction

Technology: Steam Reforming

Issue No. 3 Issue Description:

Equipment development:

- Size minimization
- Remote operation and maintenance
- Corrosion/abrasion on material
- Shielding considerations--equipment selection and scaling
- Radionuclide buildup.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Remote operability/maintainability.	6	
B Ceramic and metals material selection. Radionuclide buildup.	1	Use cold stand-ins for Cs, Sr, and Am.
C		
D		

Describe risk if not tested at highest level of testing category:

Higher personnel exposure, plant downtime, and reduced production.

Strategy for issue resolution:

Perform extended test run with cold waste simulants to determine and resolve remote operability maintenance ability issues.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Organic Destruction

Technology: High-Temperature Hydrothermal
(Low-Temperature Hydrothermal Same Issues)

Issue No. 1 Issue Description:

Chemistry development:

- Which organics, degree of test
- Kinetics
- Gas formation
- Feed variability
- Feed preparation.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Establish solubility Sr/Am over range of simulants/compositions.	2	
B Confirm cold bench test and get feed data on range of samples.	9	
C Sample solids and supernates to determine TRU/Sr distribution and bound composition for tests in Item "A."	5	
D		

Describe risk if not tested at highest level of testing category:

Low-level waste form specification is not met. May encounter higher dose rates in LLW vitrification plant from Sr. Substantially reduced production rates.

Strategy for issue resolution:

Perform 5 and 2 (extensive) simultaneously followed by 9 to confirm earlier testing.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Organic Destruction

Technology: High-Temperature Hydrothermal

Issue No. 2 Issue Description:

Process development:

- Feed variability
- Feed preparation
- Corrosion
- Solids formation
- Scaling
- Safety issues.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Process control, pressure letdown, etc.	2	
B Validate Item A above.	3	
C		
D		

Describe risk if not tested at highest level of testing category:

No safety documentation available. Process may not perform as required.

Strategy for issue resolution:

Perform tests specified above. Chemical development with hot waste will enable process engineering development to be done with cold simulants.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Organic Destruction

Technology: High-Temperature Hydrothermal

Issue No. 3 Issue Description:

- Equipment development:
- Component reliability
 - Pumps and valves
 - Controls
 - Erosion
 - Remote maintainability/replacement
 - Equipment size minimization.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Component testing of pumps, valves, reactors, controls, etc.	8	Cold, not hot.
B Maintainability.	8	Cold test only.
C		
D		

Describe risk if not tested at highest level of testing category:

Plant will not work properly, delaying a production startup, and possibly requiring major plant modifications.

Strategy for issue resolution:

Includes cold mockups for maintainability; perform unit cold testing for component development.

TWRS PROCESS DEVELOPMENT Test Requirements Record

Function: Organic Destruction

Technology: Low-Temperature Hydrothermal
(Same Issues as High-Temperature Hydrothermal)

Issue No. 1 Issue Description:

Chemistry development:

- Which organics, degree of test
- Kinetics
- Gas formation
- Feed variability
- Feed preparation.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Establish solubility Sr/Am and range of simulants/compositions.	1	Batch basis.
B Same as Item A above.	2	Flow basis with air injection.
C Sample solids and supernates to determine TRU/Sr distribution and bound composition for tests in Item "A."	5	
D Confirm cold bench tests (including air injection).	9	Flow basis with air injection.

Describe risk if not tested at highest level of testing category:

Low-level waste form specification is not met. May encounter higher dose rates in LLW vitrification plant from Sr. Substantially reduced production rates.

Strategy for issue resolution:

Perform 5, 1, and 2 (extensive) simultaneously followed by 9 to confirm earlier testing with actual waste.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Organic Destruction

Technology: Low-Temperature Hydrothermal

Issue No. 2 Issue Description:

Process development:

- Feed variability
- Feed preparation
- Corrosion
- Solids formation
- Scaling
- Safety issues.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Process control, letdown, etc.	2	
B Validate Item A above.	3	With air injection.
C		
D		

Describe risk if not tested at highest level of testing category:

No safety documentation available. Process may not perform as required.

Strategy for issue resolution:

Perform tests specified above. Chemical development with hot waste will enable process engineering development to be done with cold simulants.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Organic Destruction

Technology: Low-Temperature Hydrothermal

Issue No. 3 Issue Description:

Equipment development:

- Component reliability
- Pumps and valves
- Controls
- Erosion
- Remote maintainability
- Equipment size minimization.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Component testing of pumps, valves, reactor, controls, etc.	8	Cold, not hot.
B Maintainability.	8	Cold.
C		
D		

Describe risk if not tested at highest level of testing category:

Plant will not work properly, delaying a production startup and possibly requiring extensive plant modifications.

Strategy for issue resolution:

Includes cold mockups for maintainability; perform unit cold testing for component development.

TWRS PROCESS DEVELOPMENT Test Requirements Record

Function: Organic Destruction

Technology: In-Tank Organic Destruction

Issue No. 1 Issue Description:

In-tank hydrolysis of organic materials is a relatively new concept and is in the scouting phase. The temperature of the complexed waste is raised to between 100 and 120 °C in the presence of caustic. It is expected that soluble TRU and Sr of complexed wastes would be substantially reduced by the destruction/modification of organics. The following technical data needs were identified:

• Kinetics • Volume-to-surface area ratio • Corrosion of tank wall • Effect of air • Effect of sodium nitrite • Chemistry	• Safety • Offgas system • Mixing requirements • Waste type • Time.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Ability to destroy complexing organics and precipitate TRU and Sr over several months.	5	Tests ongoing. Need to measure TRU/Sr concentrations during future testing.
B		
C		
D		

Describe risk if not tested at highest level of testing category:

Process may not adequately destroy complexing organics, resulting in an LLW feed that does not meet specifications for Sr and TRU.

Strategy for issue resolution:

Continue preliminary testing using actual waste. Change emphasis to Sr and TRU behavior, rather than the fraction of organic destroyed. Do preliminary investigation of the above issues in testing. Consider using product material in other Sr/TRU removal work. If preliminary testing is successful, develop more rigorous testing plan.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: Organic Destruction
Technology: Caustic Recycle
Issue No. 1 Issue Description:

Although placed on the agenda, the issue of caustic recycle had not been developed well enough to discuss testing needs for promising technologies. The Tank Waste Remediation System flowsheet being developed for tank wastes projects the need for 42,000 metric tons of 50 wt% sodium hydroxide (7.2 million gal). Aside from the essential material costs, all of this added sodium would eventually be converted to glass unless processes are developed/implemented to convert a portion of the waste sodium throughput back to sodium hydroxide for recycle. Technologies that might be applicable include calcination or electrochemical processes.

What is test for?	Test cat.	Comments
A Testing needs TBD.		
B		
C		
D		

Describe risk if not tested at highest level of testing category:

Strategy for issue resolution:

Conduct initial engineering study to show that caustic recycle is feasible and cost effective before committing resources to testing. If caustic recycle is viable, develop detailed testing plans based on the results of the engineering study. Note that the Tank Waste Remediation System mission can be completed without caustic recycle.

C4.0 LLW VITRIFICATION

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: LLW Vittrification

Technology: Joule-Heated Melter

Issue No. 1 Issue Description:

Electrode selection:

- Molybdenum (uncoated or coated) (1300 to 1400 °C)
- Inconel* (backup material, <1150 °C).

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Corrosion rate of electrodes.	1	Testing in progress.
B Corrosion rate of molybdenum.	2	
C Analysis of feed into melter system.	4	To develop feed specification for materials testing.
D Corrosion rate of electrodes.	3	Vendor test possible.
E Corrosion rate of electrodes.	6	Desirable to resolve scaleup issues

Describe risk if not tested at highest level of testing category:

Poorly performing electrodes (material or design) require more glass per unit of waste processed; and cause lower plant efficiency, higher unit costs, and higher unit disposal cost to repository. May affect product quality by order of magnitude and cause 20% more glass. If the electrodes have to be changed in full plant, it would mean a minimum 1-year delay and redesign of melter.

Performance of electrodes may be poor:

1. Wrong electrode material could result in a minimum 1-year delay in production operation for melter redesign
2. Multiple changeout

*Inconel is a trademark of the International Nickel Company.

3. Feed modification
4. Change of electrodes to Inconel or ceramic block heaters and lower operation efficiency

Effecting product quality by an order of magnitude and more glass.

Strategy for issue resolution:

Perform cold, pilot-scale tests of both types. Validate cold test with hot testing using actual waste. Electrode fall-back option is Inconel. May be scaleup issues requiring large, cold pilot plant or other equal testing.

Not confirm hot=cold, assume waste simulant may be scaleup issues; need large, cold pilot plant or other testing.

TWRS PROCESS DEVELOPMENT Test Requirements Record

Function: LLW Vitrification

Technology: Joule-Heated Melter

Issue No. Issue Description:

- Redox control, glass redox potential needs to be reducing to use molybdenum electrodes.
- NO_3/NO_2 salts in LLW will result in oxidizing melt conditions if not destroyed or reduced during feed preparation or melter cold cap reactions.

Small groups: C. N. Wilson et al.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Laboratory development of feed preparation and reductant additions.	1	Organics such as sugar and powdered aluminum metal are candidate reductants.
B Bench-scale development/demonstration feed preparation and melter.	2	Organics such as sugar and powdered aluminum metal are candidate reductants.
C Pilot-scale demonstration in integrated melter-feed system.	3	Organics such as sugar and powdered aluminum metal are candidate reductants.
D Characterization of waste to melter.	4	

Describe risk if not tested at highest level of testing category:

- If reducing glass melt cannot be achieved, the fallback is Inconel electrodes (for joule heating) with maximum temperature of 1150 °C which limits glass formulation flexibility.
- Low-temperature glass will reduce waste loading and durability potential.
- If the electrodes have to be changed in full plant, it would mean a long delay change of glass formulation and possibly redesign of melter.

Strategy for issue resolution:

- Develop feed processing to destroy most of NO_3/NO_2 . Add reductant to feed. Redox buffer such as $\text{Fe}_{+2}/\text{Fe}_{+3}$ in glass.
- Demonstrate feed/melter flowsheet on cold bench and pilot scales.
- Select other than molybdenum electrode joule-heated melter if redox control cannot be achieved. Inconel electrodes maximum 1150 °C. Combustion or plasma melter may be required for higher temperature.

TWRS PROCESS DEVELOPMENT Test Requirements Record

Function: LLW Vitrification

Technology: Joule-Heated Melter

Issue No. 2 Issue Description:

Volatility and gas entrainment of radionuclides and halogens (Tc).
Estimate of ^{129}I , ^{14}C , and ^3H , release needed. Decision on control
technologies application needed if less than full release to environment is
selected.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Effects of trace components in feed.	3	Do not undersize tests. Scaleup is easier than scaling down.
B Fate of surrogate for Tc in process.	6	Required because volatility will change with scaleup factors.
C Rhenium (Re)/Tc volatility comparison.	5	To determine if Re can be a surrogate for Tc in the process.
D Tc volatility and fate.	8	Only if Re cannot be a surrogate for Tc.
E Scaleup issues affect volatility.	9	Only if Re cannot be a surrogate for Tc.

Describe risk if not tested at highest level of testing category:

If Re is a good surrogate, then maximum 5 and 6. If not, then all above.
Risk is to redesign offgas system and resulting minimum of a 1-year delay.
Or to have to design a secondary waste stream Tc removal system, resulting
in at least a 1-year delay.

Strategy for issue resolution:

Use nonradioactive surrogates as much as possible. Try to find a good
surrogate for Tc. If cannot find surrogate then test as shown. May have
to recycle Tc to HLW, or keep in LLW, or remove as secondary stream,
depending on the volatility of the Tc.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: LLW Vitrification

Technology: Joule-Heated Melter

Issue No. Issue Description: Particulate Recycle

Establish the composition/methodology for recycle of scrubbed/filtered material from the melter.

Small group: G. A. Whyatt and J. M. Janzen; discussed in large group.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Radionuclide and chemical composition of secondary waste streams.	3	Mass and composition needs.
B Provide more material and better mass balance.	6	Confirmatory testing.
C		
D		

Describe risk if not tested at highest level of testing category:

Potential for accumulation/contact maintenance problems and possible impacts to flowsheets (feed composition), etc. Full scale will be different in that small-scale geometry will affect composition. Large scale can get a better estimate of the mass balance.

Risk is that there will be a waste stream with nowhere to go. Final disposition will be required for regulatory permit.

Strategy for issue resolution:

Determine if recycle, reuse, or disposal options are most appropriate.

TWRS PROCESS DEVELOPMENT Test Requirements Record

Function: LLW Vitrification

Technology: Joule-Heated Melter

Issue No. 3 Issue Description:

Chemical modification of feed

A = Electrode protection

B = Foaming

C = Rheology of feed

D = NOx control/destroy sugar

E = Redox control

F = Phase separation (cold)

G = Decontamination factors

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A A, B, C, D, E, F.	2	
B A, B, C, D, E.	3	>20 ft ² melter internal (inner diameter).
C A, B, C, D, E, F, G.	6	
D A, B, C, G: Verify waste simulant performs similar in melter.	>9	Minimum to get set up for continued operation. Complete pilot is not practical.

Describe risk if not tested at highest level of testing category:

Minimum requirement to prove process will work - more critical the nearer the feed limits get. Assumes "variable" feed.

Strategy for issue resolution:

- Verify hot waste = waste simulant.
- One-fiftieth scale is probably metric 1 ton/day.
- May learn from Defense Waste Processing Facility also.
- Too early to get very definite on feed chemical modifications.
- Do as few hot tests as possible. Maximum cold testing.
- If variability of feed is minor, could reduce hot pilot requirements to functional hot pilot requirements.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: LLW Vitrification

Technology: Joule-Heated Melter

Issue No. Issue Description: Nuclide Volatility

1. Public acceptance of volatile radionuclide release is needed or buy-in to some fractional removal.
2. Estimate of ^{129}I , ^{14}C , ^3H release needed. Decision on control technologies application needed if less than full release to environment is selected.

Small group: G. A. Whyatt and J. M. Janzen.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Determine desired removal (not needed if decision is release to stack except as information for expected release).	3	Any additional testing requirements may be identified depending on technologies selected.
B	6	Desirable, not required.
C		
D		

Describe risk if not tested at highest level of testing category:

Public may not buy into release of all radionuclides. If this occurs when project is relatively mature, a multiyear delay may occur as plant is redesigned/technology tested. Larger cold plant is desirable but not required.

Strategy for issue resolution:

Use simulants for radioactive compounds of interest to help determine fate. Best estimate from the literature and cold tests.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: LLW Vitrification

Technology: Joule-Heated Melter

Issue No. Issue Description: Radionuclide Buildup

1. Static deposits in offgas lines, scrubbers, filters, etc.
2. Recycle causing increasing concentrations of volatile radionuclides.

Both may affect contact maintenance problems.

Small group: G. A. Whyatt and J. M. Janzen.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A With Re simulant, if possible.	3	Extended duration required.
B	6	Confirmatory testing.
C If Re is not good simulant.	9	Confirmatory test.
D		

Describe risk if not tested at highest level of testing category:

Potential for inability to perform contact maintenance. Redesign of portions of the plant would be required if radiation level gets too high. Scaleup is not straightforward.

Strategy for issue resolution:

Simulate radionuclides as far as possible. Do testing to determine dropout points. Scaleup using mathematical factors, performed large-scale testing.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: LLW Vitrification

Technology: All Melters

Issue No. Issue Description: Refractory life

Selection of refractory material for compatibility with waste and glass.
Viability of chilled refractory and cold wall systems.

Small group: B. A. Higley, R. E. VanderCook, and C. N. Wilson.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Crucible melts for material compatibility/temperature dependency.	1	
B Extended tests with coupons placed at critical locations.	2-3	
C		
D		

Describe risk if not tested at highest level of testing category:

Premature replacement/rebuild melter.

Strategy for issue resolution:

Multiweek steady-state tests in melter to determine corrosion and erosion rates.

TWRS PROCESS DEVELOPMENT Test Requirements Record

Function: LLW Vitrification

Technology: All Melter Technologies

Issue No. Issue Description: Organic destruction

Determine regulatory requirements for melter system destruction and removal efficiency for organics. Demonstrate the ability of melter to meet limits, if required.

- Nitrate/nitrite management, regulatory requirements safety, selection of organic reductants
- Source: 1. Organic in LLW (ethylenediaminetetraacetic acid, etc.)
2. Organic additives added during feed processing (i.e., sugar as a feed reductant).

Small group originated and discussed in full group (B. A. Higley, C. N. Wilson, and R. E. VanderCook).

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Crucible/lab tests.	1	Characterize organic decomposition reactions.
B Bench-scale feed preparation development.	2	
C Pilot-scale melter tests (with integrated feed and offgas systems).	3	
D Offgas sampling--organic destruction, NOx control. Ensure adequate time at temperature for organic destruction.	6	Will be required for safety analysis report (SAR) and regulatory.
E Offgas sampling--organic destruction, NOx control.	9	Desirable to confirm organic destruction.

Describe risk if not tested at highest level of testing category:

Failure to resolve safety issues, regulatory issues (incinerator rules), and offgas design (plugging and failing). Major organics in waste are unknown, may require hot testing.

Potential difficulty in permitting facility if not performed. Potential for facility to be unable to meet destruction limits. May have to show that appropriate reactions occur under any reasonable combination of upsets for SAR.

Trial burn is required for incinerator regulations; may be full-scale cold test.

Strategy for issue resolution:

Attempt to resolve organic issues with cold simulant at large, pilot-plant scale.

- Develop feed processing flowsheet to address NO_3/NO_2 and organic (including organics added as reductant) issues on laboratory/bench (nonradioactive) scale.
- In pilot scale, integrate melter system (melter, feed preparation, and offgas systems) demonstration tests.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: LLW Vitrification

Technology: Joule-Heated/Combustion/Plasma/Arc

Issue No. Issue Description:

Phase separation of molten PO_4 , SO_4 , F, and Cl low-viscosity salts in melter will float on top of glass melt and be corrosive to refractories (and to top-entering electrodes). The molten salt layer accumulates with time as feed is processed through the melter.

Small group: B. A. Higley, C. N. Wilson, and R. E. VanderCook.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Lab tests to optimize glass formulation.	1	
B Verification of conditions that avoid phase separation tests.	3	
C Verify previously determined crucible for candidate melter feed concentration limits for PO_4 , SO_4 , Cl, and F.	3	
D		

Describe risk if not tested at highest level of testing category:

Failure to test in melter for extended period, may not find phase separation not observed in crucible melts.

- Shortened melter life
- Large decrease in waste loading
- Salt buildup may result in salt explosions in melter.

Strategy for issue resolution:

Avoid phase separation in the melter:

- Multiweek steady-state test in melter to determine maximum permissible concentrations of PO_4 , SO_4 , Cl, and F to be processed.
- Optimize glass formulation (and melting temperature/melter design) to accommodate PO_4 , SO_4 , Cl, and F.
- Establish feed specifications for PO_4 , SO_4 , Cl, and F (versus waste loading).
- Determine the level of benefit from waste blending.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: LLW Vitrification

Technology: Melters Other than Joule Heated

Issue No. Issue Description:

Pending selection of melter type, flowsheet, maintenance type, scaleup uncertainty, and regulatory issuing, a large-scale integrated pilot test may be needed.

Small group: C. N. Wilson, R. E. VanderCook, and B. A. Higley; discussed in large group.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Integrated system test.	6	
B		
C		
D		

Describe risk if not tested at highest level of testing category:

Plant operability, reliability, and maintainability may not meet program requirements.

Strategy for issue resolution:

Integrated nominal 25% pilot-plant test with prototypical features.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: LLW Vitrification

Technology: Joule-Heated Melter

Issue No. Issue Description:

Condensable material fouling causing potential clogging at melter exit.
Is film cooler required or can design work with quick entrance to quench
tower? Need for cleaning system? Testing of such system.

Small group: G. A. Whyatt and J. M. Janzen.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Film cooler/quench.	3	Development/demonstration.
B	6	Confirmatory.
C		
D		

Describe risk if not tested at highest level of testing category:

Shutdown for replacement/cleaning of melter exit. Potential for severe
limitation on capacity due to frequent maintenance. Not easily scaled up.

Strategy for issue resolution:

Testing will determine design parameters for cleaning, particulate
location, instrumentation.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: LLW Vitrification

Technology: Joule-Heated Melter

Issue No. Issue Description: Corrosion in Offgas Equipment

Potential for film cooler corrosion of offgas line under upset conditions. Temperatures could reach 1300 °C if cold cap melts and any cooling fails. Issue more severe for some other types of melters (normal operating issues).

Small group: G. A. Whyatt and J. M. Janzen.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Corrosion check of offgas system and sustained operation.	3	Long-term testing would provide necessary data.
B		
C		
D		

Describe risk if not tested at highest level of testing category:

Film cooler may not work, quickly corrodes, and needs to be changed out.

Strategy for issue resolution:

Cold testing will adequately simulate the process. Larger scale more desirable.

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: LLW Vitrification

Technology: Joule-Heated Melter

Issue No. Issue Description: NOx Control

Demonstrate effectiveness of reducing agents to reduce emission.
Demonstrate catalyst life and effectiveness on representative offgas.

Small group: G. A. Whyatt and J. M. Janzen.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Demonstrate effectiveness of reducing agents to reduce emission. Demonstrate catalyst life and effectiveness on representative offgas.	3	Safety issues of NOx-organic not an offgas issue; assume capability to confidently scale to capacity.
B		
C		
D		

Describe risk if not tested at highest level of testing category:

Failure to meet regulatory limitations. Failure to prove safety for SAR.

Strategy for issue resolution:

Resolve on cold testing pilot plant, larger is better.

TWRS PROCESS DEVELOPMENT Test Requirements Record

Function: LLW Vitrification

Technology: All Melters

Issue No. Issue Description:

- Short-term product quality - verification for long-term acceptability. Short-term product quality tests need to be correlated with the long-term tests to verify that the short-term test results will be reliable indicators of long-term quality.

Small group: E. F. Riebling, R. A. Karnesky, and W. J. Powell; discussed in large group.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Leach test (product consistency test example).	5/3	Same as long term.
B Leach test to confirm cold testing.	8/9	Desirable.
C		
D		

Describe risk if not tested at highest level of testing category:

- Possible removal/recovery from disposal vault.
- Long-term plant shut down.

Strategy for issue resolution:

- Assumption: product quality tested from facility.
- Performance assessment (PA) drives product quality; need to understand mechanism for PA.
- Do not know what other tests besides leach will be required, some will be.
- Short- and long-term tests correlations/procedures will have to be established to ensure acceptance at the disposal system.

TWRS PROCESS DEVELOPMENT Test Requirements Record

Function: LLW Vitrification

Technology: All Melters

Issue No. Issue Description:

Verification of long-term product quality.

Small group: W. J. Powell, R. A. Karnesky, and E. F. Riebling; discussed in large group.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Leach and TBD.	8	"Desirable," not critical.
B Leach test.	1, 5, 3	Hot crucible certain will need.
C Viscosity, probably fiber elongation.	9	Will need development.
D Visual, includes microscopic exam for bubbles, pieces of brick, and undissolved batch.	9	Will need development.
TBD - Development required for equipment and process control.	8 or 9	Desirable.

Describe risk if not tested at highest level of testing category:

If vitrified product is robust enough, then product quality verification in a continuous process is not required, low risk. If product is shown to be borderline, then high risk of shutdown by regulators; or extensive recycle if short-term tests are effective. Must assume short-term tests are effective, and that failure mechanisms are known or consistent.

- Possible shutdown of plant for extended time due to poor product.

Strategy for issue resolution:

- Assumption: product quality tested at vitrification facility.
- PA drives product quality; need to understand mechanism for PA.

- Do not know what other tests besides leach will be required, some will be.
- Short- and long-term tests correlations/procedures will have to be established to ensure acceptance at the disposal system.

TWRS PROCESS DEVELOPMENT Test Requirements Record

Function: LLW Vitrification

Technology: All Melters

Issue No. Issue Description:

Fast product quality verification for feedback control.

Small group: R. A. Karnesky, E. F. Riebling, and W. J. Powell; discussed in large group.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Visual/IR (possible) Raman Spec/fiber optics.	3	"Musts."
B Equipment and feedback.	9	Test equipment under temperature and radiation conditions.
C Equipment feedback.	11	Feedback needed to test operation of process.
D		

Describe risk if not tested at highest level of testing category:

- Need to test anything put in hot radiation area - it is expected to work and provide feedback.
- May mitigate by testing with ^{60}Co .
- Make too much recycle glass - unmanageable.

Strategy for issue resolution:

Equipment that is well proven in rad services may only require testing with thermally hot pilots. Other equipment will require radioactive testing at the appropriate temperature of operation to ensure continued operation.

C5.0 HLW VITRIFICATION

TWRS PROCESS DEVELOPMENT
Test Requirements Record

Function: HLW Vittrification

Technology: All Melters

Issue No. Issue Description: Product Quality

Capability for fast product quality determination for feedback control.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Demonstrate compositional control. Leach and other product criteria (TBD).	1, 3	
B Demonstrate real-time feedback.	6	
C Leach and TBD, composition.	5	
D Leach and TBD, demonstrate hot=cold.	11	Same size and type as testing Category 3.

Describe risk if not tested at highest level of testing category:

May not need as rigorous a feed composition control. Philosophy may be more appropriate to different feed types. May be able to produce at risk using feedback as a product gauge. May minimize production of poor quality glass. May minimize risk of changing regulatory requirements.

May not establish waste simulant equivalency if all the testing is not performed. Risk is that startup will be delayed to prove to all groups that product will be acceptable.

Strategy for issue resolution:

- Product quality correlations are required to ensure control instrumentation indicates poor product, or tendency toward poor product.
- Product recycle is a requirement.
- Product quality control equipment development is required.

Test continuous process with cold and hot pilot to determine equivalency between waste simulant and actual waste. Must have equal-sized cold and hot pilot plants. Then scale up with cold plants.

Operating philosophy for feedback control:

- Not critical to perform extensive feed testing, more critical to ensure product is acceptable.
- Feed composition and process may change with more chance of good product, recycle of off-specification product critical.
- Unforeseen shutdown and startup can be managed by product testing and recycle.

TWRS PROCESS DEVELOPMENT Test Requirements Record

Function: HLW Vitrification

Technology: All Melters

Issue No. Issue Description: Product Quality

Long-term acceptance for repository approval.

<u>What is test for?</u>	<u>Test cat.</u>	<u>Comments</u>
A Demonstrate composition control falls into acceptable range.	1,3	Establish that formulations perform as expected.
B Leach tests, others TBD.	6	May need several versions; compare with hot pilot.
C Leach tests, others TBD.	5	Establish that formulations work with hot waste.
D Leach tests, others TBD.	11	Same size and type as test Category 3, to establish hot waste=cold simulant.

Describe risk if not tested at highest level of testing category:

May not establish waste simulant equivalency. Plant startup will not occur; U.S. Department of Energy approval will not be obtained. Insufficient validation/verification of startup parameters, which are critical.

Strategy for issue resolution:

For joule-heated melters, cannot go below one-fiftieth scale and get good results (experience from Hanford Waste Vitrification Plant). Concerns are particle size, dimensional parameters, and heat transfer-related parameters.

Test continuous process with cold and hot pilot to determine equivalency between waste simulant and actual waste. Must have equal-sized cold and hot pilot plants. Then scale up with cold plants.

Operating philosophy for feed-forward control:

- Not critical to perform product testing. Must ensure feed is tested and within acceptable ranges.
- If process and feed are within acceptable parameters, product will be acceptable.

C6.0 REFERENCES

- Burnum, S. T., 1993, *Trip Report - Atomic Energy Commission (AEA), Paris, France - British Nuclear Fuels Limited, Sellafield, England* (Letter 93-TRB-050 to B. A. Hays, August 31), U.S. Department of Energy, Richland, Washington.
- Norton, M. V., and F. Torres-Ayala, 1993, *Laboratory Testing In-Tank Sludge Washing* (Summary Letter TWRSP-93-060, September), Pacific Northwest Laboratory, Richland, Washington.

APPENDIX D

OUT-OF-SCOPE ISSUES/QUESTIONS CAPTURED

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APPENDIX D

OUT-OF-SCOPE ISSUES/QUESTIONS CAPTURED

D1.0 RETRIEVAL (SLUDGE EROSION RATES DURING RETRIEVAL)

Double-Shell Tank Retrieval Engineering is extremely interested in determining the effect of sludge exposure to caustic solutions (i.e., enhanced sludge washing) on sludge mobilization and the effective cleaning radius of mixer pumps. To the extent practical, their concerns will be addressed during sludge dissolution testing. However, there is a need for retrieval to further develop procedures for projecting erosion rates from small to moderately large (25 L) samples.

D1.1 SULFUR CONCRETE

Issues surrounding the use and transport of sulfur concrete to encapsulate/stabilize low-level waste were not considered to be within the scope of this work.

D2.0 PRETREATMENT (IN-TANK TESTING OF ENHANCED SLUDGE WASHING)

There are no plans to have mixer pumps installed in double-shell tank 102-AY for the retrieval of single-shell tank 106-C. Because tank 106-C will be the first single-shell tank retrieved and the waste contains significant aluminum, the presence of mixer pumps would allow early demonstration of the enhanced washing process. It is recommended that mixer pumps be installed in tank 102-AY to facilitate the process testing (four pumps are required for AY tanks).

D2.1 PRETREATMENT (SODIUM INVENTORY DISPOSAL OPTION)

The Hanford Site sodium metal inventory is 1.33 million L (350,000 gal), most of which is radioactive. This sodium metal could be converted to sodium hydroxide to supply approximately 11% (2,235 metric tons of the 21,000 metric tons NaOH required [Orme 1994]) of the Tank Waste Remediation System caustic need. However, the *Hanford Site Sodium Management Plan* (Nielsen 1994) calls for completion of sodium disposal activities by 2001, well before the start of pretreatment operations.

D3.0 OUT-OF-SCOPE ISSUES/QUESTIONS--LLW VITRIFICATION

Some of the out-of-scope issues listed below were discussed during the workshop; most were only touched on or not discussed at all. They are listed because they represent potential problem areas that may not have been documented before now. Other issues that are listed have been, and are being, actively worked on and resolved. All the issues will prove to be significant in their influence on Tank Waste Remediation System testing needs.

1. Testing needs for new and old onsite low-level waste disposal vaults have not been addressed.
2. New performance assessments may be required for disposal of onsite vitrified material. These performance assessments will need to provide limits of final product quality requirements.
3. Secondary waste streams will be generated from the melter offgas and have not been defined, or contingency made in planning. These streams must be better defined and contingency made for recycle, reuse, or disposal.
4. The need for pretreated feed to the vitrification pilot plants has not been integrated into the cross-function planning. A decision to pretreat or not pretreat pilot-plant feed should be evaluated.
5. The type of low- and high-level waste melter must be established to better determine pilot-plant needs.
6. The availability and method of obtaining feed for low- and high-level waste hot pilot plants must be addressed.
7. The location of integrated pretreatment, low-, and high-level waste vitrification hot pilot plants has not been addressed.
8. The lifetime variability of the feed from pretreatment to low- and high-level waste vitrification needs to be defined as soon as possible. The number and different types (composition limits) of feed need to be defined as soon as possible.
9. Instrumentation testing needs were not specifically addressed. In some functional domains, testing and development needs will depend on decisions such as melter technology and operating philosophy to emphasize appropriate areas.
10. Concentration of waste before melter feed was not addressed.

D4.0 OUT-OF-SCOPE ISSUES/QUESTIONS - GENERAL

Tri-Party Agreement (Ecology et al. 1994) milestones show that high-level waste and low-level waste pretreatment and vitrification facilities have at

least a 1-year delay between project completion and facility hot startup. This period can be used for equipment checkout and cold testing.

D5.0 REFERENCES

Ecology, EPA, and DOE, 1994, *Hanford Federal Facility Agreement and Consent Order*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

Nielsen, D. L., 1994, *Hanford Site Sodium Management Plan*, WHC-SD-FF-MP-001, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Orme, R. M., 1994, *TWRS Process Flowsheet*, WHC-SD-WM-TI-613, Draft Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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