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7. Abstract Westinghouse Hanford Company (WHC) is conducting a two-phased demonstration testing and evaluation of candidate melter system technologies for vitrification of Hanford Site low-level tank wastes. The testing is to be performed by melter equipment and vitrification technology commercial suppliers. This Statement of Work is for Phases 1 and 2 of the demonstration testing program. The primary objective of the demonstration testing is to identify the best available melter system technology for the Hanford Site LLW vitrification facility. Data obtained also will support various WHC engineering studies and conceptual design of the LLW vitrification facility. Multiple technologies will be selected for demonstration and evaluation. Testing will be conducted using non-radioactive LLW simulants in Seller-specified pilot/testing facilities.		
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CONTENTS

1.0	INTRODUCTION	1
2.0	STRATEGY FOR IMPLEMENTATION OF LLW MELTER TECHNOLOGY	1
2.1	TANK WASTE TREATMENT PLAN AND SCHEDULE	1
2.2	TESTING AND EVALUATION OF VITRIFICATION SYSTEM TECHNOLOGIES	2
2.2.1	Phase-1 Testing	2
2.2.2	Phase-2 Testing	2
2.2.3	Selection for Phase-2 Testing	3
3.0	OBJECTIVES	3
4.0	WORK SCOPE	5
4.1	PHASE 1	5
4.2	PHASE 2	6
5.0	LLW AND SIMULANT CHARACTERISTICS	7
5.1	LLW STREAM ORIGIN AND CHARACTERISTICS	7
5.2	LLW TEST SIMULANTS	8
5.3	SIMULANT CHARACTERISTICS AND PREPARATION FOR TESTING	12
6.0	GLASS FORMULATION	13
7.0	TEST PLAN	14
8.0	TESTING	16
9.0	DATA, SAMPLES, AND ANALYSES	16
10.0	REPORTING	17
11.0	SAFETY AND ENVIRONMENTAL	19
11.1	SAFETY	19
11.2	ENVIRONMENTAL	19
12.0	QUALITY ASSURANCE	19
13.0	ORGANIZATIONAL RESPONSIBILITIES	20
14.0	SCHEDULE	21
15.0	REFERENCES	23
16.0	GLOSSARY	23
APPENDIXES		
A	HANFORD SITE LOW-LEVEL TANK WASTE CHARACTERISTICS	A-1
B	TECHNICAL SELECTION CRITERIA	B-1

LIST OF TABLES

1	Low-Level Waste Simulant for Double-Shell Slurry Feed Waste Based on Analyses of Six Tanks Plus Dilutes Normalized to 6.0 M Na	9
2	Low-Level Waste Simulant for the Remaining Inventories (Less Double-Shell Slurry Feed) Based on Process Flowsheet Estimates Normalized to 6.0 M Na	10
3	Double-Shell Slurry Feed and Remaining Inventory Simulant Compositions on Calcined Solids Weight Basis and Volatiles	11
4	Concentration Ranges of Selected Elements in Double-Shell Slurry Feed Waste Based on Analyses of Six Tanks Plus Dilutes. Minimum and Maximum Concentrations have been Normalized to 6 M Na	13

EVALUATION OF MELTER SYSTEM TECHNOLOGIES FOR VITRIFICATION OF HIGH-SODIUM CONTENT LOW-LEVEL RADIOACTIVE LIQUID WASTES

STATEMENT OF WORK

1.0 INTRODUCTION

The Westinghouse Hanford Company (WHC) is conducting a two-phased effort to evaluate melter system technologies for vitrification of a liquid low-level radioactive waste (LLW) stream. The evaluation effort will include demonstration testing of selected glass melter technologies. This Statement of Work (SOW) is for Phases 1 and 2 of the planned testing and evaluation program.

The LLW will result from retrieval and pretreatment of approximately 230,000 m³ of defense nuclear waste stored in underground storage tanks at the U.S. Department of Energy (DOE) Hanford Site located in southeastern Washington State. The LLW stream will consist mostly of sodium nitrate and nitrite salts in alkaline liquid/slurry form. Handling, processing, and melter feeding of the LLW feed will be an important part of the LLW vitrification technology demonstrations. Only processes that are judged to be sufficiently developed for incorporation in plant design commencing in 1997 and brought on-line by 2005 will be considered. Capacity in the range of 100- to 200-metric tons/day glass output will be required to complete the LLW vitrification mission on schedule. Preliminary plans are to build a 100-metric tons/day LLW vitrification plant that can later be expanded to 200 metric tons/day.

2.0 STRATEGY FOR IMPLEMENTATION OF LLW MELTER TECHNOLOGY

2.1 TANK WASTE TREATMENT PLAN AND SCHEDULE

In the DOE planning case, the waste is retrieved from the underground tanks and separated into a large-volume liquid LLW stream from which significant radionuclide removal has occurred, and a smaller volume high-level waste (HLW) stream (sludge) in which most of the radioactivity will be concentrated. Both the resulting LLW and HLW streams will then be vitrified. This plan and a schedule for its implementation were recently agreed to by the DOE, the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology during renegotiation of the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1992), also known as the Tri-Party Agreement. The Tri-Party Agreement milestones established for LLW vitrification activities are listed below.

- Begin LLW melter testing with simulants (September 1994).

- Complete melter feasibility and system operability tests, select reference melter(s), and establish reference LLW glass formulation that meets complete systems requirements (June 1996).
- Submit conceptual design and initiate definitive design of the LLW vitrification facility (November 1996).
- Initiate construction of the LLW vitrification facility (December 1997).
- Complete construction of the LLW vitrification facility (December 2003).
- Initiate hot operations of the LLW vitrification facility (June 2005).
- Complete vitrification of Hanford Site low-level tank waste (December 2028).

2.2 TESTING AND EVALUATION OF VITRIFICATION SYSTEM TECHNOLOGIES

A multiphase technology evaluation and testing program is planned. Multiple melter system technologies will be selected for Phase-1 testing. These orders will be extended at WHC's option after Phase-1 testing to include Phase-2 testing. It is anticipated that a reference melter system technology and a first-alternative technology will be selected following Phase-2 testing.

For this testing and evaluation program, a melter system technology is defined to include the melter, melter feed preparation and melter feeding system, and offgas and waste treatment equipment considered to be unique to the melter and feed systems. All LLW simulants used in this program will be nonradioactive.

2.2.1 Phase-1 Testing

Phase 1 will be a "proof of principle" test to demonstrate that a melter system technology can process a simulated highly alkaline, high nitrate/nitrite content LLW feed and produce a glass product of consistent quality. A LLW simulant formulated to simulate a LLW type scheduled for early vitrification will be used. Data to be generated and reported will include descriptive chronology of events, general operating behavior including upsets and operating problems, quantity of feed processed and processing rates, mass and energy balances, offgas characteristics, melt characteristics (phase separation), and product glass composition consistency and uniformity.

2.2.2 Phase-2 Testing (Optional)

The objectives of Phase-2 testing are to ensure that the melter system technologies are adequately evaluated to provide a technical basis for selection of preferred reference and first-alternative LLW vitrification technologies. Modifications to equipment and procedures will be made for

Phase-2 testing based on lessons learned during Phase-1 testing. These modifications will be developed jointly (by the Seller and WHC) before or during Phase-2 test plan preparation and approved by WHC.

Two or more LLW simulant formulations may be run during Phase 2 providing extended testing time and testing the effects of compositional variability. One of the Phase-2 LLW simulants will be a nominal composition representing LLW scheduled for later vitrification. Other Phase-2 LLW simulants may contain selected minor components omitted from the initial simulants, and it is likely they will contain enhanced concentrations of LLW components such as phosphate, sulphate, fluoride, and chloride that may phase separate in the melter (or volatilize or degrade glass quality).

2.2.3 Selection for Phase-2 Testing

Westinghouse Hanford Company may, at its option, extend demonstration testing to include Phase-2 testing. Criteria to be applied in the evaluation and selection of technologies that will be continued to Phase-2 testing are summarized below. The following provides summary guidance on anticipated down-selection criteria. Reasons for terminating testing of a particular technology at the end of Phase 1 could include the following:

1. Failure of "proof of principle." A significant technical issue that surfaces during Phase-1 testing that is judged to constitute a failure of proof of principle or indicate the technology is not feasible
2. Two or more technologies selected for Phase-1 testing are similar with the exception of one or more special features, and Phase-1 testing results clearly demonstrate the superiority of such special features associated with a particular melter system technology
3. Results from supporting studies indicate that a particular technology is not a realistic or competitive option for implementation for the LLW vitrification mission. Studies to be conducted will include: LLW performance requirements (may influence glass formulation and product configuration), a facilities options study, effects of a vitrification technology on balance of plant, shielding, and/or remote operations requirements, and melter disposal.

3.0 OBJECTIVES

The primary objective of this melter systems technology demonstration testing and evaluation program is to identify the best overall melter system technology available for vitrification of projected Hanford Site low-level tank waste streams on the schedule described in Section 2.1. Specific objectives for Phases 1 and 2 testing were described in Sections 2.2.1 and 2.2.2.

The following types of data will be collected and evaluated to meet specific objectives, establish a basis for selecting a reference vitrification technology, and provide preliminary data to support LLW vitrification plant conceptual design.

- Processing throughput and efficiency of operation. Feed rates and critical temperatures will be monitored to determine throughput and effectiveness of process control.
- Demonstration of a practical and reliable feed system capable of consistent mixing and delivery of LLW simulant and glass former feed materials to the melter, and providing control of product glass composition.
- Ability to produce a durable, consistent, homogeneous glass with a target composition (product quality).
- Data to demonstrate the readiness of the process to be scaled up and implemented in a 100-metric tons/day LLW vitrification plant with flexibility to expand plant capacity to 200 metric tons/day.
- Mass balance data across the melter for potentially volatile components such as Cs, Na, B, Mo, SO_x , F, I, and Cl to determine partitioning of these components between the glass, condensed deposits, offgas entrained particulates, and scrub solutions. Mass balance data also are needed for elements of radiological interest, including Cs, Sr, I, and Tc (Mo will stand in for Tc).
- Offgas measurements for NO_x and SO_x concentrations, flow rates, and quantities and composition of entrained particulates.
- Determination of requirements for feed processing, secondary waste, and offgas treatment systems.
- Observation and sampling of any apparent melt phase separation and assessment of the PO_4 , SO_4 , F, and Cl concentration limits that can be processed. These data will identify melter systems with the greatest flexibility to process feeds with these components, and provide data on concentration limits for these components that can be realistically processed by vitrification.
- Ability to idle the melter for extended periods, or shut down and restart, and the consequences of idling (including waste component volatility) and/or shutdown and restart cycles (Phase 2). (Depending on melter type, observation of batch dissolution and sampling of any observed melt phase separation may occur during the process halt.)
- Obtain information on the melter system technology to support WHC engineering studies, technology evaluation, and life-cycle cost analysis.
- Evaluate life expectancy, reliability, and maintenance requirements for melter system major components.

Other observations, measurements, or samples may be taken for specific melter technologies. For example, WHC may want to measure wear on specific parts or components such as electrodes, refractories, and/or feed injectors.

The life expectancy, reliability, and maintainability of the melter systems will be evaluated based on vendor records and industrial/commercial experience (where available). A methodology for projecting life expectancy, reliability, and maintainability will need to be developed where new or novel equipment concepts are being used that do not have a history of industrial/commercial use.

4.0 WORK SCOPE

4.1 PHASE 1

Following Phase-1 award, the Seller will perform the following work scope tasks.

1. Prepare a project-specific quality assurance plan (QAP) for approval by WHC in accordance with guidance provided in Section 12.0 of this SOW.
2. Prepare a detailed test plan for approval by WHC in accordance with guidance provided in Section 7.0 of this SOW.
3. Conduct a glass-melting demonstration in the Seller's designated test/pilot facilities using simulated LLW materials provided by WHC and glass formers provided by the Seller in accordance with the approved test plan. Test duration shall be of sufficient duration to achieve the test objectives stated in this SOW, and at a minimum, shall be of sufficient duration to process at least three times the melter system glass inventory. In no event shall test duration be less than 24 hours continuous processing time.
4. Perform pre-test and post-test inspection of the equipment. To the extent possible, inspection should identify solids buildup, deposits, plugging, corrosion, erosion, refractory wear, electrode wear (if applicable), and equipment damage. The Seller is to describe in the test plan the extent of the inspection considered to be feasible. Westinghouse Hanford Company shall participate in equipment inspections.
5. Provide samples collected according to a WHC-approved sampling plan (to be developed in the test plan) to WHC and/or WHC-designated laboratories for analysis and archival. Feed, product glass, offgas scrub solution, and offgas sampling shall be done approximately every 4 hours after reaching steady-state operation. (Analyses of feed, product glass, separated melt phases, and scrub solution samples will be separately contracted by WHC. Offgas analyses will be provided by the Seller.)

6. Prepare a preliminary (quick look) test report that summarizes test conditions, test chronology, sample identifications, test monitoring data (such as temperatures, feed rates, etc.), and key observations. The purpose of the preliminary test summary report is to provide information necessary to allow WHC to begin evaluation of test results before the draft (full) test report is available.
7. Prepare a (full) test report documenting test conditions, test chronology, sample identifications, and all Seller-generated data in accordance with guidance provided in Section 10.0 of this SOW.
8. Provide technical information to support WHC engineering studies, technology evaluation, and life-cycle analyses. Typical information needed would include requirements for utilities (types and quantities) and support systems, size and configuration of full-scale system, maintenance requirements, operational history of in-service systems, expected life of materials (refractories, electrodes, etc.), and performance characteristics and cost information applicable to technology evaluation and life-cycle analysis. Such information may be requested at any time and shall be provided, as available, when requested. A summary of this information shall be provided in a report.
9. Prepare a report summarizing life expectancy and reliability of the full-scale melter system based on maintenance records and other pertinent data that are available. Life-expectancy data for major systems components and consumable parts, types of failures, frequency of failure, and suspected causes of failures shall be included. Westinghouse Hanford Company will assess the reliability and maintainability of the melter system design in a nuclear facility environment based on considerations to include passivity or freedom of moving parts, repairable failure modes, and non-repairable failure modes.
10. Develop, with WHC, a Phase-2 testing definition as a basis for a Seller option bid. Process and equipment modifications proposed for Phase-2 testing and estimated costs will be included.

4.2 PHASE 2

Following Phase-2 award, the Seller will perform the following work scope tasks.

1. Prepare a Phase-2 test plan for WHC approval. Process and equipment modifications will be described as part of the test plan.
2. Implement approved process and equipment modifications.
3. Perform testing in accordance with the approved test plan. For proposal cost estimation, assume that three simulant formulations will be run in Phase-2. Test duration with each simulant formulation shall be of sufficient duration to achieve the test objectives stated in this SOW, and at a minimum, shall be of

sufficient duration to process at least three times the melter system glass inventory. In no event shall test duration be less than 24 hours continuous processing time. A process halt or shutdown/restart cycle will be demonstrated between testing with two of the simulant formulations.

4. Perform pre-test and post-test inspection of the equipment. To the extent possible, inspection should identify solids buildup, deposits, plugging, corrosion, erosion, refractory wear, electrode wear (if applicable), and equipment damage. The Seller is to describe in the test plan the extent of the inspection considered to be feasible. Westinghouse Hanford Company shall participate in equipment inspections.
5. Provide samples collected according to an approved sampling plan (to be developed in the test plan) to WHC and/or WHC-designated laboratories for analysis and archival.
6. Prepare a preliminary (quick look) test summary report similar to that prepared for Phase 1.
7. Prepare a (full) test report documenting test conditions, test chronology, sample identifications, and all Seller-generated data in accordance with guidance provided in Section 10.0 of this SOW.
8. Provide additional technical information to support WHC engineering studies and technology evaluation (continued from Phase 1) and update report summarizing this information.
9. Update the melter systems life expectancy and reliability report prepared for Phase 1 to incorporate new data relevant to life expectancy and reliability.

5.0 LLW AND SIMULANT CHARACTERISTICS

5.1 LLW STREAM ORIGIN AND CHARACTERISTICS

Hanford Site tank waste was generated by several different chemical processing facilities and is stored in large underground tanks. The older single-shell tanks (SST) hold mostly precipitated sludges and saltcake. The newer double-shell tanks (DST) hold liquid wastes.

In the reference tank waste retrieval and pretreatment process, the sludges (low solubility) and saltcake (high solubility) wastes will be washed, producing a relatively large volume liquid waste stream and a smaller volume of washed solids that contains most of the radioactive waste components. Most of the radioactive cesium in the liquid waste stream will be removed by ion exchange to produce the liquid LLW stream to be sent to the LLW vitrification facility. The cesium removed from the liquid LLW stream will be combined with the washed solids HLW fraction. The primary constituents of the LLW stream are sodium nitrate, sodium nitrite, sodium hydroxide, and sodium aluminate.

Waste from DSTs will be retrieved for separation before the waste in SSTs. Because the waste generation history of the DSTs and SSTs is not identical, the LLW that will be obtained from the DSTs will differ from the LLW obtained from SSTs. Although wastes will be blended to the extent practical to minimize variability of the waste constituents, it is anticipated that at least two LLW types will need to be vitrified. These LLW types are identified as double-shell slurry feed (DSSF) and a larger quantity of remaining inventory LLW derived primarily from the SSTs. Projected average blended compositions (normalized to 5 M Na) and quantities of these two waste types are given in Table A-1 of the Appendix.

The nominal LLW stream discharged from the waste separation process will likely be 4 to 6 M Na concentration and contain a small quantity of undissolved solids (less than 1%). This feed could be concentrated and fed to a melter at 10 to 15 M Na, depending on the melter and feed systems selected, to decrease the quantity of water fed to the melter. Such a concentration of the LLW stream will cause crystallization of some salts, resulting in a slurry that is 10 to 30 vol% undissolved solids depending on the degree of concentration and feed temperature.

5.2 LLW TEST SIMULANTS

A DSSF simulant composition based on actual DST characterization data is chosen for Phase-1 testing. The DSSF simulant composition and compounds needed to prepare the simulant are given in Table 1. A preliminary composition and associated compounds needed to achieve the composition are given in Table 2 for the remaining inventory of non-DSSF DST and SST LLW simulant. The remaining inventory simulant will be one of two or more simulants run during Phase-2 testing. Calcined solids compositions (assuming no halide or metal oxide volatility) and the relative quantities of volatile components for these two LLW simulants are given in Table 3.

The Phase-1 DSSF simulant composition is based on a weighted average of analyses from six DSTs plus analyses of samples of dilute DST wastes intended for evaporator/crystallizer operations. Detailed analyses, including radionuclides, for the six DSSF tanks and dilutes are provided in Table A-2 of the Appendix. Many of the minor elements or species (mostly those contributing less than 0.02 wt%) analyzed in these tanks have not been included in developing the Phase-1 DSSF simulant. Elements and species chosen to be included in the simulant are the DSSF major constituents plus those that may be potentially volatile during vitrification (Cs, I, Cl, and Mo), and those that may be present at concentrations exceeding their solubility in silicate glasses (PO_4 , SO_4 , Cl, and F). Strontium is included because ^{90}Sr will be the highest-activity radionuclide present in the LLW. Concentrations of Cs, Sr, I, and Mo have been spiked to 0.01 M concentration to provide sufficient amounts of these elements to allow a mass balance to be determined across the melter.

Additional LLW simulants expected to be run during Phase-2 testing will likely include minor components omitted from the two simulants described in Tables 1-3 and/or contain more extreme concentrations of components such as PO_4 , SO_4 , NO_3 , F, Cl, OH, and Cr. Maximum and minimum concentrations for these components measured in DSSF tanks (see Table A-2 [excerpted from

Table 1. Low-Level Waste Simulant for Double-Shell Slurry Feed Waste Based on Analyses of Six Tanks Plus Dilutes Normalized to 6.0 M Na.

Component	Target concentration M	Compound	Formula weight	Moles/L required
Al^{+3}	0.61	$Al(NO_3)_3 \cdot 9H_2O$	375.14	0.61
Ca^{+2}	0.00063	$Ca(NO_3)_2 \cdot 4H_2O$	236.16	0.00063
Cr^{+3}	0.0052	$Cr(NO_3)_3 \cdot 9H_2O$	400.17	0.0052
Fe^{+3}	0.00046	$Fe(NO_3)_3 \cdot 9H_2O$	404.01	0.00046
K^+	0.30	KOH	56.10	0.30
Mg^{+2}	0.00062	$Mg(NO_3)_2 \cdot 6H_2O$	256.41	0.00062
Mn^{+2}	0.00025	$Mn(NO_3)_2$	178.94	0.00025
Mo^{+6} (a)	0.010	$Na_2MoO_4 \cdot H_2O$	241.95	0.010
Na^+	6.0	--	--	--
Sr^{+2} (a)	0.010	$SrCl_2$	158.52	0.010
Cs^+ (a)	0.010	$CsNO_3$	194.91	0.010
PO_4^{-3}	0.026	$NaH_2PO_4 \cdot H_2O$	138.00	0.026
IO_3^- (a)	0.010	$NaIO_3$	197.89	0.010
CO_3^{-2}	0.16	Na_2CO_3	106.00	0.16
Cl^-	0.096	$NaCl$	58.45	0.076
F^-	0.15	NaF	42.00	0.15
SO_4^{-2}	0.026	Na_2SO_4	142.06	0.026
NO_3^-	1.9	--	--	--
NO_2^-	1.0	$NaNO_2$	69.00	1.0
OH^- (b)	2.3	$NaOH$	40.00	4.0
TOC	0.81 (9.7 g/L)	$Na_4EDTA, (C_{10})$	416.20	0.081

(a)Cs, Sr, I, and Mo are spiked to 0.01 M to provide sufficient amounts of these elements to allow a mass balance to be determined across the melter.

(b)To neutralize acidic hydrolyzable metal salts of Al, Ca, Cr, Fe, Mg, Mn, and Sr, an excess of 1.4 moles of NaOH are included.

TOC = Total organic carbon

Table 2. Low-Level Waste Simulant for the Remaining Inventories
(Less Double-Shell Slurry Feed) Based on Process Flowsheet
Estimates Normalized to 6.0 M Na.

Component	Target concentration M	Compound	Formula weight	Moles/L required
Al^{+3}	0.16	$Al(NO_3)_3 \cdot 9H_2O$	375.14	0.16
Ca^{+2}	0.00040	$Ca(NO_3)_2 \cdot 4H_2O$	236.16	0.00040
Cr^{+3}	0.0042	$Cr(NO_3)_3 \cdot 9H_2O$	400.17	0.0042
Fe^{+3}	0.00024	$Fe(NO_3)_3 \cdot 9H_2O$	404.01	0.00024
K^+	0.0058	KOH	56.10	0.0058
Mg^{+2}	1.1 E-06	$Mg(NO_3)_2 \cdot 6H_2O$	256.41	1.1E-06
Mn^{+2}	0.0010	$Mn(NO_3)_2$	178.94	0.0010
Mo^{+6} (a)	0.010	$Na_2MoO_4 \cdot H_2O$	241.95	0.010
Na^+	6.0	--	--	--
Sr^{+2} (a)	0.010	$Sr(NO_3)_2$	149.63	0.010
Cs^+ (a)	0.010	$CsNO_3$	194.91	0.010
PO_4^{-3}	0.11	$NaH_2PO_4 \cdot H_2O$	138.00	0.11
IO_3^- (a)	0.010	$NaIO_3$	197.89	0.010
CO_3^{-2}	0.050	Na_2CO_3	106.00	0.050
Cl^-	0.0092	$NaCl$	58.45	0.0092
F^-	0.13	NaF	42.00	0.13
SO_4^{-2}	0.038	Na_2SO_4	142.06	0.038
NO_3^-	3.6	$NaNO_3$	85.00	3.0
NO_2^-	0.26	$NaNO_2$	69.00	0.26
OH^- (b)	1.4	$NaOH$	40.00	2.2
TOC	0.11 (1.3 g/L)	$Na_4EDTA, (C_{10})$	416.20	0.011

^(a)Cs, Sr, I, and Mo are spiked to 0.01 M to provide sufficient amounts of these elements to allow a mass balance to be determined across the melter.

^(b)To neutralize acidic hydrolyzable metal salts of Al, Ca, Cr, Fe, Mg, Mn, and Sr, an excess of 0.8 moles of NaOH are included.

TOC = Total organic carbon

Table 3. Double-Shell Slurry Feed and Remaining Inventory Simulant Compositions on Calcined Solids Weight Basis and Volatiles.

Low-level waste simulant composition calcined solids basis (wt%)		
Component	Double-shell slurry feed	Remaining inventory
Na ₂ O	72.67	85.36
K ₂ O	5.77	0.13
Al ₂ O ₃	12.70	3.84
CaO	0.01	0.01
Cr ₂ O ₃	0.16	0.15
Cs ₂ O	0.58	0.66
Fe ₂ O ₃	0.01	0.01
MgO	0.01	0.00
MnO ₂	0.01	0.04
MoO ₃	0.59	0.68
SrO	0.42	0.49
P ₂ O ₅	0.75	3.68
SO ₃	0.85	1.43
NaCl	2.29	0.25
NaF	2.57	2.57
NaI	0.61	0.71
Total solids as g/L @ 6.0 M Na ⁺	245.05	212.49
Volatiles as g/100g calcined solids		
H ₂ O (estimated)	330	380
NO ₃ ⁻	48.07	105.04
NO ₂ ⁻	18.77	5.63
OH ⁻	15.96	11.20
CO ₃ ⁻	3.92	1.41
Organic carbon	3.96	0.61

WHC-SD-WM-TI-528, *Grout Treatment Facility Waste Feed Projections* (Hendrickson et al. 1993)] in the Appendix) are compared in Table 4 to the average values chosen for these components in the Phase-1 DSSF simulant. Running higher concentrations for these expected problem components in simulants meets two objectives. First, running simulants with higher concentrations of these components will identify melter system technologies that provide the most flexibility for processing these feed components. Second, the tests may identify limits for these components that can realistically be processed by vitrification and provide a basis for feed specification limits for these components.

5.3 SIMULANT CHARACTERISTICS AND PREPARATION FOR TESTING

The two simulants described in Tables 1-3 are based on a preliminary assumed Na concentration of 6.0 M. Depending on the melter system technology, there may be an incentive to further concentrate the LLW (possibly to 10-15 M) before feeding it to the melter to reduce demands on the melter offgas system and maximize the capacity and energy efficiency of the melter. However, there is a concern that solids precipitating from highly concentrated pre-mixed simulants may be difficult to redissolve or suspend in a consistent slurry at the time of testing. Westinghouse Hanford Company will determine the optimum concentration and form for which a more concentrated simulant may be delivered. Two options for the LLW simulant preparation under consideration are as follows.

1. A WHC-contracted supplier prepares the simulant at 6 M Na concentration, or the highest practical concentration, and then ships the pre-mixed simulant to the Seller's test facility. Heating and agitation will likely be required to dissolve precipitated salts if the simulant is to be fed as a liquid. The ability to supply a single-part simulant greater than 6 M Na concentration, that may be fed as a slurry, is to be determined.
2. A more concentrated simulant may require preparation by the Seller. For example, a concentrated simulant may be delivered in two parts: an acid part containing dissolved $\text{Al}(\text{NO}_3)_3$ and acid soluble components; and a highly alkaline part containing dissolved sodium salts, which are mixed by the user. Some heat would be released and significant precipitation of solids would occur when the parts are mixed.

The Sellers should indicate to WHC their preferences, within the bounds of the above described options, as to how the LLW simulants should be supplied. Further details on simulant specifications, properties, and preparation procedures will be provided to Sellers when this information becomes available. Seller test facilities will need to have adequate tanks (agitated and/or heated) to stage prepared LLW simulant materials for melter feeding.

Table 4. Concentration Ranges of Selected Elements in Double-Shell Slurry Feed Waste Based on Analyses of Six Tanks Plus Dilutes. Minimum and Maximum Concentrations have been Normalized to 6 M Na.

Component	DSSF simulant M	Minimum measured DSSF concentration M	Maximum measured DSSF concentration M
Al	0.61	0.15	0.87
Cr	0.005	0.0017	0.016
Na	6.0	6.0	6.0
PO ₄	0.026	0.003	0.25
Cl	0.096	0.07	0.12
F	0.13	0.0	1.2
SO ₄	0.026	0.006	0.09
OH	2.3	0.7	4.4
NO ₃	1.9	1.0	2.5

DSSF = Double-shell slurry feed

6.0 GLASS FORMULATION

The glass composition to be produced during testing will be defined in the test plan to be prepared by the Seller and approved by WHC. Westinghouse Hanford Company will provide limited glass formulation support, including laboratory crucible test melts for composition durability verification, as needed. Soda-lime-silica and alumino-borosilicate compositions are candidate glass compositions for Hanford Site LLW feeds. Typical composition ranges are 15-25 wt% Na₂O, 0-12 wt% CaO, 5-12 wt% Al₂O₃, 0-12 wt% B₂O₃, and 1-5 wt% other LLW components and the balance (50-70 wt%) SiO₂. Other composition variations and components may be proposed to optimize glass formulation for the specific vitrification system.

It is desirable that all or most of the Na₂O in the glass composition be derived from the LLW simulant to demonstrate ability to optimize waste loading. Target waste loading (the portion of the glass composition derived from the LLW simulant) should be about 25 wt% for Phase-1 testing. The remainder of the composition will be derived from glass former materials to be supplied by the Seller.

*Necessary laboratory crucible testing and related glass formulation support will be provided at no cost to the Seller by Pacific Northwest Laboratory through WHC.

Durability and performance requirements for Hanford Site LLW glasses have not yet been established. Therefore, flexibility in melting temperature and the ability to process a range of glass compositions will be a factor in melter system technology selection. Preliminary performance assessment work suggests a need for highly durable glass compositions. However, optimization of glass compositions to meet specific durability and waste loading requirements is not a primary objective for this SOW. Proposed glass formulations should be reasonably durable with a Na normalized leach rate of 1 g/m²/day or less measured by the Product Consistency Test method (Jantzen 1992) at 90 °C. This is the approximate durability of the Savannah River Environmental Assessment glass that is used as a minimum durability benchmark for HLW glass waste acceptance.

7.0 TEST PLAN

A detailed test plan will be prepared by the Seller and approved by WHC before each testing phase. The test plan will define test objectives, equipment configuration, process conditions, glass compositions, glass former materials, test duration, processing rates, measurements and samples to be taken, and any special procedures to be used. Test plans shall contain the following information, as a minimum.

Test Objectives, Strategy, and Scope. Test objectives and the strategy for meeting those objectives consistent with the requirements of this SOW should be described along with the scope of the testing to be conducted.

Process and Equipment Description. A detailed description of the vitrification process and pilot-/test-scale equipment used for testing shall be provided. Equipment descriptions shall include figures and drawings, as required, to provide a clear description of operating principles and design features. Equipment described should include:

- The test melter, including refractory and electrode types (if used), processing temperatures, projected processing rate (tons/day glass), glass residence times, the basis for melter operation, and the basis for scaleup of test results to a 100-metric tons/day plant. Test melter characteristics such as energy supply, glass surface area, melter size, etc., also should be stated.
- Equipment for receiving, batching, and preparing the simulated feed and glass forming chemicals.
- Feed system for metering, mixing, and delivering the waste simulant and glass former materials to the melter. Figures showing melter

*The Product Consistency Test is under review by the American Society for Testing Materials (ASTM) committee C26.13 for acceptance as an ASTM standard test.

feed systems component designs, including design features for feed injector cooling and design features to provide materials containment, shall be included.

- Equipment for handling and treating offgas and secondary waste streams.
- Data acquisition and sampling capabilities.
- Verification that the proposed test facility possesses the required local, state, and federal permits required for performing the demonstration tests and managing/disposing of unused feed materials, secondary wastes such as offgas condensates, tank flushes, and other test residues, or that necessary waivers or permits can be obtained. Any exceptions or restrictions on feed composition or test parameters related to permitting shall be identified.

Test Preparations. Equipment and facility modifications and new equipment required for this testing shall be described. Laboratory or scoping tests to be performed by the Seller before actual testing with the LLW simulants shall be identified. Materials remaining in the melter, feed, and offgas systems from previous testing are to be removed or subject to WHC approval, characterized before initiation of testing. Procedures for removal or flushing of these materials also shall be described. Any special feed preparation procedures also shall be described.

Feed and Glass Compositions. Sources, compositions, and characteristics (i.e., sieve or particle size, mineral or phase identification, purity, etc.) of glass former materials shall be provided. Target glass compositions and waste loadings shall be developed in accordance with guidance provided in Section 6.0 of this SOW. Composition for the supplied LLW simulants, and additions to or changes in these compositions expected as a result of feed processing, shall be described.

Run Conditions and Parameters. Items covered shall include: (1) test schedule and run segment durations; (2) target feed and processing rates; and (3) critical target operating temperatures. Test duration with each simulant formulation shall be of sufficient duration to achieve the test objectives stated in this SOW, and at a minimum, shall be of sufficient duration to process at least three times the melter system glass inventory. In no event shall test duration be less than 24 hours continuous processing time.

Observations, Measurements, and Samples. Observations, instrumentation, measurements, and samples to be taken and frequency of data collection shall be described in accordance with guidance provided in Section 9.0 of this SOW. Descriptions of the system instrumentation should include descriptions of instrument functions and instrument type. Identification of process measurements to be taken, methods of measurement and data logging, and measurement frequency shall be included. A sampling schedule(s) that identifies all sampling and states the means of sample collection, sampling frequency, and sample size shall be included. A flow diagram showing sample and data collection points shall be provided. Logistics for delivery of samples to WHC and/or WHC-contracted laboratories for analyses shall be described (includes feed, product glass, melt phase and offgas scrub solution

samples). Analyses and data reduction to be performed by the Seller using in-house analytical facilities, or by Seller-contracted laboratories, shall be described (includes offgas analyses). Sample identification and data traceability methods, as well as data formats, also shall be described.

Disposition of Product Glass and Other Test Residues. Planned disposition of product glass, unused feed materials, and other wastes and test residues shall be indicated. The Seller is responsible for disposition of unused feed materials, product glass, and other waste and test residues in accordance with applicable federal and state regulations.

8.0 TESTING

Testing will be conducted in accordance with the approved test plan in Seller-designated facilities. The requirements for test duration and sub-test segments will depend on the vitrification system. Test segment duration with each simulant formulation shall be of sufficient duration to achieve the test objectives stated in this SOW, and at a minimum, shall be of sufficient duration to process at least three times the melter system glass inventory. In no event shall test duration be less than 24 hours continuous processing time. Steady-state processing conditions will need to be reached with each LLW simulant composition to obtain accurate mass balance data across the melter for potentially volatile species, and to evaluate process control effectiveness and product glass consistency.

Test preparation and actual testing will be observed by WHC representatives, which may include personnel from WHC, Pacific Northwest Laboratory, the DOE, and consultants. Designated observers may inspect equipment and document equipment conditions and/or witness inspection performed by the Seller before and after testing as required to determine specific equipment performance.

9.0 DATA, SAMPLES, AND ANALYSES

The test plan will identify data and samples to be taken to satisfy the test plan objectives. Measurements and data collected shall be made using calibrated equipment. Instrument calibrations or user calibration procedures shall be traceable to national standards (e.g., the National Institute of Standards and Technology or the American Society for Testing and Materials). At a minimum, the following data and samples shall be collected:

- Feed rates (LLW simulant and glass formers) and glass production rates
- LLW simulant temperature in make-up/storage tank and near the injection point to the melter or other applicable feed system point
- Average glass/furnace temperature

- Melter/furnace gas or plenum space temperature
- Melter offgas temperature, pressure, and flow rate
- Offgas treatment equipment (scrubbers, filters, etc.) operating pressures, flow rates, and temperatures
- Offgas monitoring for NO_x and SO_x concentrations at the melter exit
- Inter-refractory, electrode, and discharge zone temperatures if relevant
- Individual simulant and glass former feed materials (archival samples provided to WHC)
- Periodic samples of processed or blended feed materials (sample frequency to be determined, analyses by WHC)
- Periodic samples of product glass (approximately every 4 hours at steady-state operation, analyses by WHC)
- Samples of any phase-separated melt materials observed in the melter or secondary glass refining chambers (analyses by WHC)
- Periodic samples of condensates or scrub solution samples from offgas treatment equipment (analyses by WHC)
- Collection of offgas entrained particles upstream and downstream of the initial quench scrubber or first stage cooling/cleaning device. Sampling of offgas shall be conducted by a qualified air quality laboratory using EPA methods in conjunction with protocols for analyses described in SW 846. Particulates shall be analyzed by a qualified analytical laboratory with analyses to include Na, K, Cs, Si, Ca, B, Cr, and Mo (analyses provided by Seller).

Most sample analyses will be performed by qualified laboratories whose services will be contracted directly by WHC or a designated DOE contractor. Samples will be shipped to WHC or directly to the contracted laboratory with duplicate archival samples shipped to WHC. Certain analyses, such as onsite offgas stream characterization, may use qualified laboratories contracted by the Seller.

Westinghouse Hanford Company shall have access to primary data, notebooks, software, and records as needed to verify data traceability and data quality.

10.0 REPORTING

Four deliverable technical reports are required for each test phase:
(1) a preliminary test summary report, (2) a draft and final full test report,
(3) a draft report on life expectancy and reliability of the melter system

technology, and (4) a report summarizing information required to support WHC engineering studies and technology evaluation. Other documentation identified to be prepared by the Seller are the QAP at the start of Phase 1 and test plans for both Phases 1 and 2 testing.

The preliminary test report will provide much of the same information to be included in the (full) test report but in an abbreviated format, including a summary of test conditions, test chronology, sample identifications, test monitoring data (such as temperatures, feed rates, etc.), and key observations. The purpose of the preliminary test summary report is to provide information necessary for WHC to begin evaluation of test results before the draft full test report is available.

The Seller shall provide a draft (full) test report to WHC within 45 days of test completion. A final report shall be provided within 15 days after receiving review comments on the draft report. The report will include the following minimum information: (1) a descriptive chronology of events and operating behavior during the test; (2) quantity of feed processed and glass produced versus time; (3) energy consumption data; (4) identification, description, and sampling time for all samples collected for analysis or archival; (5) description of operating behavior including upsets, failures, operating problems, and unexpected behavior; and (6) data for measured run parameters including temperatures, pressures, offgas stream flow rates (instantaneous and average), and offgas stream compositions (including entrained solids quantities and compositions). The data shall, at a minimum, cover the melter, melter feed preparation and feeding systems, and available offgas quenching and treatment systems. The test report also should address a basis to scale test results to a 100-metric tons/day capacity melter system.

Following Phase-1 testing, the Seller shall prepare a draft report summarizing information required to support WHC engineering studies and evaluation of the melter system technology. As a minimum, this report should cover items identified in Section 4.1 under work scope item 8, and any other technical information requested and provided on an ongoing level of effort basis. This report will be reviewed and revisions will be made to address additional identified information needs to the extent feasible. This report will be updated following Phase-2 testing to include revised information and additional identified information needs.

Following Phase-1 testing, the Seller shall also prepare a report summarizing the life expectancy and reliability of the full-scale melter system using maintenance records and other pertinent data that are available. As a minimum, this report should cover items identified in Section 4.1 under work scope item 9. A methodology for projecting life expectancy and reliability will need to be developed where new or novel equipment concepts are being used that do not have a history of industrial/commercial use. This report will be updated following Phase-2 testing to address effects on life expectancy and reliability implied by the test results for processing projected Hanford Site LLW feed materials.

11.0 SAFETY AND ENVIRONMENTAL

The Seller is responsible for ensuring that all work is conducted in a safe and environmentally acceptable manner.

11.1 SAFETY

Liquid/slurry LLW simulant materials to be supplied for testing are highly caustic and hazardous to personnel safety if improperly handled. The Seller is responsible for observing all applicable laboratory and industrial safety measures when preparing and handling these materials. Testing shall be performed following Seller-established safety practices. Any significant or unusual hazards or safety problems identified during this work, or any special safety issues related to the tested technologies, shall be documented in the test report.

11.2 ENVIRONMENTAL

Significant NO_x and lesser SO_x emissions may result from vitrification or thermal treatment of LLW simulant materials due to their nitrate/nitrite and sulfate content. Because of high caustic and nitrate content, and the potential to include regulated components (such as Cr, Cd, Ba, and Pb), wastes generated from handling and processing the LLW simulant materials may be classified as regulated materials. The Seller shall ensure that the pilot/test facility possesses the required local, state, and federal permits or waivers required for performing the tests described by this SOW. The Seller is responsible for managing or disposing of unused feed materials and any secondary wastes such as offgas condensates, tank flushes, sediments, or other test residues.

12.0 QUALITY ASSURANCE

The Seller shall submit a project-specific QAP for Phases 1 and 2 of this SOW within 30 days of award for WHC approval. This QAP shall describe how the Seller will conduct and control activities affecting the quality of the work with particular emphasis on activities that affect the quality and traceability of data to be obtained. The QAP should address the following:

- Organization
- Test control
- Software control
- Control of measuring and test equipment
- Identification and control of items
- Control of purchased items and services
- Handling, storage, and shipping
- Records control.

These activities are chosen from ASME NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities*, including supplements (ASME 1989), which is recommended as a guide for QAP preparation if the Seller does not currently have a QAP in place. The purpose in requiring a QAP is to document that the Seller will have control over the work that is judged to be consistent with good laboratory standards and practices.

In addition, the Sellers will submit technical procedures that are required to conduct the work scope of this SOW and others procedures defining implementation of their QAPs as requested by WHC.

The Seller will ensure that subcontractors performing work on behalf of the Seller meet the requirements of the approved QAP. The Seller will be responsible for review and approval of subcontractor QAPs. Westinghouse Hanford Company will have the right of access to the test facility and subcontractor facilities for the purpose of inspection, surveillance, and/or audits as appropriate. Westinghouse Hanford Company may elect to accompany the Seller on selected inspections, surveillances, and/or audits of subcontractors.

13.0 ORGANIZATIONAL RESPONSIBILITIES

Westinghouse Hanford Company is responsible for the following activities:

1. Reviewing and approving test plans and providing limited technical support (e.g., glass formulation assistance) during test plan preparation
2. Providing sufficient quantities of LLW simulant for testing purposes and providing simulant property data and instructions for simulant preparation and handling
3. Analyzing test samples such as feed materials, product glass, melt phase separation, and offgas scrub solution samples consistent with an approved sampling and analysis plan
4. Observing testing activities
5. Evaluating test results.

The Seller is responsible for the following activities:

1. Preparing a project-specific QAP for WHC approval
2. Preparing detailed test plans for WHC approval
3. Procuring glass former materials to be used
4. Scheduling testing activities in a timely manner consistent with the WHC overall schedule for LLW vitrification technology testing and evaluation

5. Providing facilities, equipment, and materials (other than LLW simulants) required for testing
6. Conducting tests in accordance with the approved test plans
7. Collecting samples as specified in the approved sampling and analysis plan (developed in the test plans) and shipping samples to WHC and WHC-specified laboratories within 7 days of test completion
8. Collecting data to monitor test conditions as specified in the test plans
9. Providing a qualified air-quality laboratory to sample and analyze offgas using approved EPA methods
10. Providing preliminary (quick look) test summary reports
11. Providing draft (full) test reports and final test reports incorporating WHC review comments
12. Disposing of glass produced, unused LLW simulants and glass former feed materials, and other test residues
13. Providing technical information on proposed melter and support systems as required to support WHC engineering studies and technology evaluation. This information will be summarized in a report following Phase-1 testing that will be updated during Phase-2 testing.
14. Preparing a report summarizing life expectancy and reliability of the melter and melter support systems following Phase-1 testing that will be updated during Phase-2
15. Developing, with WHC, a Phase-2 testing definition option proposal.

14.0 SCHEDULE

The following dates are anticipated for initiation and completion of testing phases:

- September 1994--Initiate Phase-1 testing
- December 1994--Complete Phase-1 testing (tentative)
- April 1995--Initiate Phase-2 testing (tentative)
- September 1995--Complete Phase-2 testing (tentative).

The following schedule applies to the completion of identified Phase-1 deliverables.

- Provide a project-specific QAP for WHC approval within 30 days of Phase-1 award.

- Submit a draft test plan for WHC review within 30 days of Phase-1 award and provide a final draft for WHC approval within 15 days of receipt of review comments. The review and comment cycle is expected to require 21 days.
- Start of Phase-1 testing is anticipated to be within 90 days of award. All Phase-1 testing will be conducted during the September through December 1994 period.
- Provide preliminary (quick look) test summary report to WHC within 15 days of test completion.
- Provide a draft report summarizing technical information to support WHC engineering studies and technology evaluation within 30 days of completion of Phase-1 testing and a final draft within 15 days of receipt of WHC review comments. The review and comment cycle is expected to require 21 days.
- Submit report on life expectancy and reliability of the melter and melter support systems within 30 days of completion of Phase-1 testing.
- Submit a draft (full) test report to WHC for review within 45 days of test completion and a final draft within 15 days after receipt of review comments. The review and comment cycle is expected to require 21 days.

The following schedule applies to the completion of identified Phase-2 deliverables.

- Submit a draft test plan for WHC review within 15 days of Phase-2 award and provide a final draft for WHC approval within 15 days of receipt of review comments. The review and comment cycle is expected to require 21 days.
- Start of Phase-2 testing is anticipated to be within 90 days of award. Phase-2 testing is expected to be conducted during the April through September 1995 period.
- Provide preliminary test summary report to WHC within 15 days of test completion.
- Provide an update revision of the report summarizing technical information provided to support WHC engineering studies and technology evaluation within 21 days of completion of Phase-2 testing.
- Provide an update revision of the report on life expectancy and reliability of the melter and melter support systems within 21 days of completion of Phase-2 testing.

- Submit a draft (full) test report to WHC for review within 45 days of test completion and a final draft within 15 days after receipt of review comments. The review and comment cycle is expected to require 21 days.

15.0 REFERENCES

- ASME, 1989, *Quality Assurance Program Requirements for Nuclear Facilities*, ASME NQA-1-1989, American Society of Mechanical Engineers, New York, New York.
- Ecology, EPA, and DOE, 1992, *Hanford Federal Facility Agreement and Consent Order*, 2 vols., Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.
- Hendrickson, D. W., and J. M. Conner, 1993, *Grout Treatment Facility Waste Feed Projections*, WHC-SD-WM-TI-528, Westinghouse Hanford Company, Richland, Washington.
- Jantzen, C. M., 1992, *Nuclear Waste Product Consistency Test Method Version 5.0*, WSRC-TR-90-539, Westinghouse Savannah River Company, Aiken, South Carolina.

16.0 GLOSSARY

ABBREVIATIONS AND ACRONYMS

DOE	U.S. Department of Energy
DSSF	double-shell slurry feed
DST	double-shell tank
EPA	U.S. Environmental Protection Agency
HLW	high-level waste
LLW	low-level waste
QAP	quality assurance plan
SOW	Statement of Work
SPG	specific gravity
SST	single-shell tank
TIC	total inorganic carbon
TOC	total organic carbon
WHC	Westinghouse Hanford Company

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WHC-SD-WM-RD-044
Revision 0

APPENDIX A

HANFORD SITE LOW-LEVEL TANK WASTE CHARACTERISTICS

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WHC-SD-WM-RD-044
Revision 0

Table A-1. Nominal Low-Level Waste Streams.

Component	Double-shell slurry feed (mol/L)	Remaining inventory (mol/L)	Solids (wt%)
Ag ⁺	7.3 E-06	5.0 E-07	3.4 E-03
Al ³⁺	--	--	2.2
Al(OH) ₄ ⁻	5.6 E-01	1.6 E-01	--
As ⁵⁺	1.9 E-04	3.4 E-06	5.4 E-03
B ³⁺	--	1.3 E-06	0.02
Ba ²⁺	3.2 E-06	1.3 E-07	0.02
Be ²⁺	2.0 E-03	1.4 E-07	7.6 E-06
Bi ³⁺	2.1 E-04	5.2 E-04	1.6
Ce ²⁺	5.7 E-04	3.3 E-04	1.3
Cd ²⁺	5.7 E-06	2.9 E-06	0.07
Ce ³⁺	--	2.9 E-06	1.9
Co ³⁺	--	1.5 E-06	6.3 E-03
Cr ³⁺	--	--	0.27
Cr(OH) ₄ ⁻	4.7 E-03	3.5 E-03	--
Cu ²⁺	1.1 E-04	2.9 E-07	6.3 E-03
Fe ³⁺	4.2 E-04	2.0 E-04	6.0
Hg ²⁺	7.1 E-06	7.4 E-06	7.3 E-05
K ⁺	2.8 E-01	4.8 E-03	0.14
La ³⁺	--	4.0 E-06	0.32
Li ⁺	--	7.5 E-06	2.8 E-04
Mg ²⁺	5.7 E-04	9.2 E-07	0.04
Mo ⁶⁺	2.8 E-04	8.8 E-06	0.04
Na ⁺	5.0 E+00	5.0 E+00	5.8
Ni ³⁺	4.0 E-04	4.3 E-07	0.06
Pb ⁴⁺	5.0 E-04	3.0 E-07	0.24
Rb ⁺	--	1.2 E-06	2.1 E-06
Re ⁷⁺	--	4.2 E-06	3.2 E-04
Rh ³⁺	--	2.0 E-07	3.5 E-03
Ru ³⁺	7.9 E-06	4.4 E-07	4.3 E-03
Sb ⁵⁺	1.5 E-03	7.8 E-07	0.01
Se ⁶⁺	2.3 E-04	1.2 E-06	0.02
Si ⁴⁺	2.0 E-03	3.2 E-04	0.38
Sm ³⁺	--	3.5 E-09	2.6 E-04
Sr ²⁺	--	7.0 E-06	0.30
Te ⁶⁺	--	6.8 E-06	2.0 E-03
Th ⁴⁺	--	2.4 E-06	0.22
Ti ⁴⁺	5.8 E-06	2.3 E-07	3.6 E-03
Ti ³⁺	--	2.5 E-06	0.04
UO ₂ ²⁺	2.2 E-06	5.2 E-04	12.0
V ⁵⁺	3.5 E-04	3.2 E-07	3.2 E-04
W ⁶⁺	1.3 E-03	--	--
Zn ²⁺	8.8 E-04	1.2 E-06	0.01
Cl ⁻	8.7 E-02	7.7 E-03	0.02
CO ₃ ²⁻	1.5 E-01	4.2 E-02	1.4
F ⁻	1.4 E-01	1.0 E-01	0.47
Fe(CN) ₆ ³⁻	--	--	--
I ⁻	--	2.0 E-06	2.4 E-06
NO ₂ ⁻	9.4 E-01	2.1 E-01	0.54
NO ₃ ⁻	1.3 E+00	2.9 E+00	8.4
OH ⁻	2.1 E+00	1.1 E+00	13.5
PO ₄ ³⁻	2.4 E-02	9.0 E-02	3.8
SO ₄ ²⁻	2.4 E-02	3.2 E-02	0.33
Cancrinite	--	--	22.3
MnO ₂	2.3 E-04	8.1 E-04	3.2
Ni ₂ Fe(CN) ₆	--	--	4.1
P ₂ O ₅ ·24WO ₂ ·44H ₂ O	--	--	0.17
Organic carbon (g/L)	8.8 E+00	1.0 E+00	3.2
ZrO ₂ ·2H ₂ O	1.7 E-04	2.5 E-04	7.9
Polyelectrolyte	--	1.2 E-03	0.52
Total kilograms	--	--	8.00 E+04
Total volume (L)	7.7 E+07	6.0 E+06	--

*Cancrinite = 2NaAlSiO₄·0.52NaNO₃·0.68 H₂O

WHC-SD-WM-RD-044
Revision 0

Table A-2. Double-Shell Slurry Feed Family Waste Summary. (sheet 1 of 3)

DSSF family wastes			Decayed to		10/01/93		
Units: Molarity; uCi/L for radionuclides; others as noted							[NOT Decayed]
Waste	Tank	Tank	Tank	Tank	Tank	Tank	Dilute wastes
Component	106-AN	101-AW	106-AP	104-AN	106-AN	103-AN	
Ag	3.37 E-06	3.06 E-04	2.00 E-04	--	--	1.46 E-04	1.64 E-05
Al	3.44 E-01	1.03 E+00	1.60 E-01	1.39 E+00	1.74 E+00	2.13 E+00	4.76 E-02
As	9.61 E-07	1.33 E-07	6.66 E-06	--	--	2.14 E-03	6.65 E-06
B	--	--	--	--	--	--	--
Ba	6.06 E-06	6.80 E-05	4.36 E-05	--	--	1.17 E-04	6.13 E-06
Be	--	--	--	--	--	1.76 E-03	--
Bi	6.94 E-04	5.79 E-04	3.70 E-04	--	--	2.30 E-04	5.91 E-05
Ca	2.25 E-03	6.26 E-04	1.06 E-03	--	--	2.16 E-03	2.73 E-05
Cd	4.41 E-04	1.06 E-05	6.92 E-06	--	--	1.42 E-04	3.93 E-06
Ce	--	--	--	--	--	--	--
Cr	1.06 E-02	3.09 E-03	3.32 E-03	1.30 E-02	1.30 E-02	1.63 E-02	2.19 E-04
Cu	5.90 E-06	3.81 E-04	2.42 E-04	--	--	1.89 E-04	3.89 E-05
Fe	1.24 E-04	7.66 E-04	2.00 E-04	2.00 E-04	2.00 E-04	1.26 E-03	3.04 E-04
Hg	2.49 E-07	7.82 E-07	4.99 E-07	--	--	7.96 E-05	4.11 E-08
K	2.76 E-02	1.07 E+00	6.67 E-01	1.83 E-01	1.67 E-01	3.89 E-01	1.11 E-01
La	--	--	--	--	--	--	--
Li	--	--	--	--	--	--	--
Mg	1.14 E-04	2.16 E-03	4.95 E-04	--	--	1.16 E-03	2.73 E-04
Mn	1.01 E-03	4.76 E-04	3.06 E-04	--	--	5.24 E-04	3.13 E-05
Mo	6.94 E-04	6.00 E-04	3.66 E-04	--	--	9.17 E-04	6.12 E-05
Na	3.93 E+00	1.00 E+01	6.35 E+00	1.20 E+01	1.20 E+01	1.46 E+01	7.71 E-01
Nd	--	--	--	--	--	--	--
Ni	--	--	2.15 E-03	--	--	4.09 E-04	1.75 E-04
P	1.97 E-01	--	1.43 E-02	--	--	--	2.26 E-03
Pb	2.22 E-03	1.46 E-03	9.33 E-04	--	--	3.47 E-04	7.75 E-05
Pd	--	--	--	--	--	--	--
Sb	--	--	--	--	--	1.31 E-03	--
Se	1.70 E-06	4.20 E-07	2.73 E-07	--	--	2.63 E-03	7.33 E-08
Si	--	4.36 E-03	3.53 E-03	--	--	9.66 E-03	4.40 E-04
Sn	--	--	--	--	--	--	--
Ta	7.18 E-07	--	--	--	--	--	1.66 E-05
Ti	7.33 E-05	9.66 E-05	6.36 E-05	--	--	3.34 E-04	1.01 E-05

WHC-SD-WM-RD-044
Revision 0

Table A-2. Double-Shell Slurry Feed Family Waste Summary. (sheet 2 of 3)

DSSF family wastes				Decayed to		10/01/83			
Units: Molarity; uCi/L for radionuclides; others as noted								(NOT Decayed)	
Waste	Tank	Tank	Tank	Tank	Tank	Tank	Dilute wastes		
Component	106-AN	101-AW	105-AP	104-AN	106-AN	103-AN			
U g/L	1.08 E-05	9.39 E-04	6.06 E-04	--	--	5.18 E-04	7.29 E-03		
V	--	--	--	--	--	3.14 E-04	--		
W	--	--	--	--	--	1.13 E-03	--		
Zn	1.44 E-04	4.84 E-03	1.16 E-03	--	--	7.34 E-04	3.39 E-04		
Zr	3.05 E-04	5.54 E-04	3.59 E-04	--	--	2.63 E-04	5.65 E-05		
CN ⁻	2.31 E-04	1.03 E-03	6.65 E-04	--	--	1.29 E-03	6.19 E-05		
S ⁻²	--	--	--	--	--	--	--		
NH ₄ ⁺	7.22 E-03	1.45 E-02	2.34 E-03	--	--	--	4.20 E-03		
NH ₃	--	--	--	6.89 E-03	2.00 E-02	--	--		
CO ₃ ⁻²	3.27 E-01	2.05 E-01	2.53 E-01	4.72 E-01	3.63 E-01	1.49 E-01	2.06 E-02		
Cl ⁻	6.94 E-02	1.46 E-01	7.28 E-02	2.12 E-01	2.40 E-01	2.71 E-01	1.41 E-02		
F ⁻	3.24 E-03	4.02 E-03	1.30 E-01	--	--	3.87 E-02	1.56 E-01		
SO ₄ ⁻²	2.24 E-02	1.07 E-02	2.48 E-02	6.82 E-02	6.82 E-02	1.67 E-02	1.14 E-02		
NO ₃ ⁻	1.09 E+00	3.46 E+00	2.66 E+00	3.10 E+00	3.12 E+00	2.54 E+00	1.83 E-01		
NO ₂ ⁻	6.44 E-01	2.19 E+00	1.09 E+00	1.92 E+00	2.61 E+00	2.99 E+00	7.83 E-02		
PO ₄ ⁻³	1.94 E-01	2.22 E-02	1.62 E-02	2.94 E-02	2.00 E-02	9.77 E-03	2.36 E-03		
OH ⁻	4.74 E-01	5.07 E+00	4.63 E+00	4.08 E+00	3.64 E+00	5.74 E+00	4.09 E-01		
TOC g/L	3.26 E+00	2.46 E+00	3.92 E+00	5.53 E+01	4.66 E+01	6.13 E-01	4.27 E-01		
TIC g/L	--	2.46 E+00	--	--	--	--	9.85 E-01		
SPG	1.23	1.56	1.347377	1.499809	1.503333	1.6	1.03 E+00		
Total Solids	--	--	--	--	--	--	--		
pH	--	--	--	13.5	13.5	--	--		
3H	2.68 E+00	5.90 E+00	7.40 E+00	--	--	2.44 E+00	4.49 E+00		
C ¹⁴	3.35 E-01	3.70 E-01	2.36 E-01	--	--	2.00 E+00	2.20 E-02		
Mn ⁵⁴	--	--	--	--	--	--	--		
Mn ⁵⁵	--	--	--	--	--	--	--		
Co ⁶⁰	5.10 E+00	1.94 E+01	1.04 E+01	--	--	1.20 E+01	6.40 E+00		
Ni ⁶³	--	--	--	--	--	--	--		
Sr ⁷⁹	2.40 E-01	4.80 E-01	3.06 E-01	--	--	4.30 E+01	3.27 E-02		
Sr ⁹⁰	2.01 E+03	1.01 E+03	1.90 E+02	9.84 E+03	3.23 E+03	1.05 E+04	1.37 E+03		
Nb ⁹⁴	2.30 E+01	6.82 E+01	4.35 E+01	--	--	7.10 E+00	7.27 E+00		
Nb ⁹⁵	--	--	--	--	--	--	8.67 E+00		

WHC-SD-WM-RD-044
Revision 0

Table A-2. Double-Shell Slurry Feed Family Waste Summary. (sheet 3 of 3)

DSSF family wastes		Decayed to	10/01/93				
Units: Molarity; uCi/L for radionuclides; others as noted							(NOT Decayed)
Waste	Tank	Tank	Tank	Tank	Tank	Tank	Dilute wastes
Component	106-AN	101-AW	106-AP	104-AN	105-AN	103-AN	
To ⁹⁹	6.92 E+01	1.52 E+02	1.79 E+01	--	--	1.70 E+02	7.86 E+00
Ru ¹⁰³	--	--	--	--	--	--	2.10 E+01
RuRh ¹⁰⁶	6.78 E+01	4.18 E+02	9.90 E+01	--	--	1.73 E+01	3.56 E+02
Sn ¹¹³	--	--	--	--	--	--	2.89 E+01
I ¹²⁹	7.50 E-02	3.03 E-01	4.18 E-02	--	--	5.20 E-01	3.28 E-02
Cs ¹³⁴	5.33 E+00	5.20 E+02	5.25 E+02	7.20 E+01	7.20 E+01	5.75 E+00	1.35 E+02
Cs ¹³⁷	1.85 E+05	4.83 E+05	2.56 E+05	7.56 E+05	5.04 E+05	6.13 E+05	2.22 E+04
CePr ¹⁴⁴	--	--	--	--	--	--	1.59 E+02
Eu ¹⁵⁴	--	--	--	--	--	--	4.07 E+01
Eu ¹⁵⁵	--	--	--	--	--	--	4.63 E+01
Ra ²²⁶	--	--	--	--	--	--	2.15 E+02
U ²³⁴	--	--	--	--	--	5.30 E-02	4.17 E-03
U ²³⁵	--	--	--	--	--	1.10 E-03	2.72 E-04
²³⁸ U	--	--	--	--	--	1.40 E-02	9.59 E-04
Np ²³⁷	2.11 E+00	2.16 E+00	1.39 E+00	--	--	2.00 E-02	3.10 E-04
Pu ²³⁸	1.93 E-02	--	3.67 E-02	--	--	9.14 E-01	1.00 E-01
Pu ^{239/240}	3.78 E-02	1.14 E+00	4.23 E-02	1.04 E+01	1.04 E+01	1.90 E+00	1.44 E-01
Am ²⁴¹	6.02 E-01	1.20 E+00	1.33 E+00	1.12 E+04	1.12 E+04	2.27 E+00	1.03 E-01
Cm ²⁴²	--	--	--	--	--	--	--
Cm ²⁴³	4.23 E-02	4.94 E-02	3.07 E-02	--	--	--	--
Cm ²⁴⁴	--	--	--	--	--	3.00 E-01	6.60 E-03
Volume (L)	3.67 E+06	3.82 E+06	3.14 E+06	3.02 E+06	4.27 E+06	3.55 E+06	3.16 E+07

DSSF = Double-shell slurry feed
SPG = Specific gravity
TIC = Total inorganic carbon
TOC = Total organic carbon

WHC-SD-WM-RD-044
Revision 0

APPENDIX B

TECHNICAL SELECTION CRITERIA

WHC-SD-WM-RD-044
Revision 0

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**EVALUATION OF MELTER SYSTEM TECHNOLOGIES FOR VITRIFICATION
OF HIGH-SODIUM CONTENT LOW-LEVEL RADIOACTIVE LIQUID WASTES**

STATEMENT OF WORK

TECHNICAL SELECTION CRITERIA

Proposals will be evaluated and technologies selected by a Source Evaluation Board (SEB) with technical support from non-voting external technical advisory panels. Multiple vitrification technologies will be selected for Phase 1 feasibility testing. Only processes which are judged sufficiently developed to be incorporated in plant detailed design commencing in 1997 and brought on line by 2005 will be considered.

Technologies will be grouped into three categories according to the primary method used for heating the glass in the melter. The Offeror is to specify in which category his proposal should be evaluated. These categories are:

- 1) Joule Heated - The glass is heated by passing electric current through the glass between electrodes.
- 2) Combustion - The glass is heated by the combustion of fossil fuels.
- 3) Other - The glass is heated by other means, including arc, plasma and induction heating.

Proposals will be individually evaluated based on the criteria identified below. Each of the criteria have been assigned numerical weights with the Offeror's response to these criteria evaluated and point scored. The top rated proposal from at least two categories will be selected for Phase 1 testing. Additional proposals may be selected, depending on availability of funding, based on best overall ratings.

The relative importance of these evaluation factors is as follows: Criterion A, Technical Merits of Technology, is weighted half of the total; Subfactors A.1 and A.2 are of equal importance; A.3 is slightly less than A.1 or A.2. Subfactor A.4 is slightly higher than Subfactors A.5 through A.9 which are of equal value. Subfactors A.10 and A.11 are listed in descending importance. Criterion B, Pilot/Test Facilities and Capabilities, is slightly less than one fourth of the total. Subfactors B.1 and B.2 are of equal importance; B.3 and B.4 are of equal weight and are roughly half of B.1 and B.2. B.5 is slightly less. Criterion C, Seller Qualifications, is weighted slightly less than Criterion B with Subfactors C.1 and C.2 of equal weight and slightly more than C.3 and C.4 being of equal weight. Criterion D, Schedule, is weighted approximately half of Criterion B and Criterion E, Cost, is weighted half of Criterion D. The criteria are listed in descending order of importance.

A. Technical Merits of Proposed Technologies

- A.1 Maturity of the technology. Development status, including past demonstration and/or industrial applications. Do features of technology carry a high degree of technical risk?
- A.2 Ability of the melter feed system and melter to reliably process projected Hanford LLW liquid/slurry feed streams containing NaOH, NaNO₃, NaNO₂ and NaAlO₂ as major components; PO₄, SO₄, Cl and F; and minor components (including Cr, Cu and Ni).
- A.3 Flexibility to process a range of glass compositions with melting temperatures in the 1100°C to 1450°C range.
- A.4 Process control approach and the ability to produce a consistent glass product with a controlled composition.
- A.5 Design features related to operation and remote maintenance, such as the ability to drain the melter if required, ability to replace parts, and the potential for performing these operations remotely. Operational simplicity of the technology, compactness of design, consideration of passive design features and the amount of moving or consumable parts.
- A.6 Suitability of the melter system for operation and maintenance in a radiologically controlled environment. Ability to maintain confinement of radioactive materials. Potential for radionuclide source buildup. Achievement of personnel exposure "as low as reasonably achievable" (ALARA) goals.
- A.7 Requirements placed on the balance of plant and support systems (e.g. facility size, maintenance systems, safety mitigation systems, offgas and secondary waste treatment systems) by the proposed vitrification technology and process flowsheet.
- A.8 Expected operating lives for melter and radioactive contaminated support equipment and ease of disposal. Minimization of size and quantity of contaminated equipment and materials requiring disposal.
- A.9 Qualitative consideration of design features and requirements (not fully considered under other criteria) that significantly affect life cycle cost, such as, replacement frequency for major equipment and consumable parts, energy and utilities requirements, and requirements for expensive glass former materials or feed additives.
- A.10 Demonstrated technical basis to scale the vitrification process to 100 metric tons/day glass production capacity.
- A.11 Capability to sample product glass and capability to recycle out of specification glass.

B. Pilot/Test Facilities and Capabilities

An assessment will be made regarding the capabilities of proposed test/pilot facilities (including proposed modifications and equipment to be acquired) to be used for conducting the workscope described in the statement of work (SOW). Specific considerations will include:

- B.1 Scale of pilot/test system. Preferred scale for testing is expected to be 0.5 - 10 tons/day glass capacity depending on the melter system technology. A basis must exist for scaling results from testing to a 100 metric tons/day glass plant.
- B.2 Ability to handle, prepare and feed alkaline liquid/slurry LLW simulants containing NaOH, NaNO_3 , NaNO_2 and NaAlO_2 as major components and PO_4 , SO_4 , Cl and F as minor components.
- B.3 Off-gas handling capabilities and ability to process LLW simulants in compliance with applicable NO_x and SO_x emission requirements (or obtain waivers).
- B.4 Sampling, instrumentation and test monitoring capabilities.
- B.5 Ability to handle feed materials that may contain regulated components such as Ba, Cd, Cr and Pb and treat and/or dispose product glass, unused materials and test residues.

C. Seller Qualifications

- C.1 Understanding of technical requirements for successful operation of a vitrification facility for Hanford low-level tank wastes.
- C.2 Prior experience conducting vitrification demonstration testing and successful operating units in service.
- C.3 Qualifications of key technical staff and of subcontracted organizations, laboratories and consultants.
- C.4 Quality Assurance Program (QAP) to provide control over work judged to be consistent with good laboratory standards and practices. (see SOW section 12.0)

D. Schedule

The buyer is soliciting technologies for which testing can begin in September 1994 but plans to test technologies in sequence. A highest rating on schedule will be assigned to sellers that can start testing before September 30, 1994. All sellers must be ready to start testing by December 1, 1994.

E. Cost

Cost will be considered and rated relative to the technical merits and value represented by the proposal.

- Estimated cost for conducting workscope as per the SOW. Itemize in accordance with Attachment 4.

NOTE: Projected cost of implementing the technology to complete the LLW vitrification mission is rated under Technical Merits of Proposed Technologies (A.9).

DATE

FILMED

7/01/94

END