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1. EDT No 611405

2. To: (Receiving Organization) TWRS LLW Program		3. From: (Originating Organization) Waste Product Technology		4. Related EDT No.: 156899	
5. Proj./Prog./Dept./Div.: TWRS LLW Program		6. Cog. Engr.: W. C. Eaton (509) 376-9541		7. Purchase Order No.: MMI-SVV-384216 USBM	
8. Originator Remarks: United States Bureau of Mines melter test plan for issuance.				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: May 25, 1995	
15. DATA TRANSMITTED					
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator
1	WHC-SD-WM-VI-021	55	0	Test Plan: Phase 1 Demonstration of 3-Phase Electric Arc Melting Furnace Technology for Vitrifying High-Sodium Content Low-Level Radioactive Liquid Wastes	Q
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 2. Release 3. Information 4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)		1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged	
(G)	(H)	17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)			
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Document Number: WHC-SD-WM-VI-021, Rev. 0

Document Title: TEST PLAN: PHASE 1 DEMONSTRATION OF 3-PHASE ELECTRIC ARC MELTING FURNACE TECHNOLOGY FOR VITRIFYING HIGH-SODIUM CONTENT LOW-LEVEL RADIOACTIVE LIQUID WASTES

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SUPPORTING DOCUMENT		1. Total Pages 57
2. Title Test Plan: Phase 1 Demonstration of 3-Phase Electric Arc Melting Furnace Technology for Vitrifying High-Sodium Content Low-Level Radioactive Liquid Wastes	3. Number WHC-SD-WM-VI-021	4. Rev No. 0
5. Key Words Vendor. Radioactive. LLW. Waste. Vitrification. Glass. Melter. Testing. Hanford. Sodium.	6. Author Name: W. C. Eaton, ed. Signature Organization/Charge Code 74610/D42AN	
7. Abstract This document provides a test plan for the conduct of electric arc vitrification testing by a vendor in support of the Hanford Tank Waste Remediation System (TWRS) Low-Level Waste (LLW) Vitrification Program. The vendor providing this test plan and conducting the work detailed within it [one of seven selected for glass melter testing under Purchase Order MMI-SVV-384216] is the U.S. Bureau of Mines, Department of the Interior, Albany Research Center, Albany, Oregon. The U. S. Bureau of Mines author for this document is Laurence L. Oden. This test plan is for Phase I activities described in the above Purchase Order. Test conduct includes feed preparation activities and melting of glass with Hanford LLW Double-Shell Slurry Feed waste simulant in a 3-phase electric arc (carbon electrode) furnace.		
		8. RELEASE STAMP OFFICIAL RELEASE BY WHC DATE MAY 31 1995 35 Station 21

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TEST PLAN

**PHASE 1 DEMONSTRATION OF 3-PHASE ELECTRIC ARC MELTING FURNACE
TECHNOLOGY FOR VITRIFYING HIGH-SODIUM CONTENT LOW-LEVEL
RADIOACTIVE LIQUID WASTES, REV. 1**

**Prepared by the U.S. Bureau of Mines, Department of the Interior, Albany Research Center,
Albany, Oregon**

Technical Category: Other melting technology.

Date submitted: January 12, 1995

TEST PLAN

**PHASE 1 DEMONSTRATION OF 3-PHASE ELECTRIC ARC MELTING FURNACE
TECHNOLOGY FOR VITRIFYING HIGH-SODIUM CONTENT LOW-LEVEL
RADIOACTIVE LIQUID WASTES**

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ACRONYMS

AC	Alternating current
ALRC	Albany Research Center
APCS	Air pollution control system
ASME	American Society of Mechanical Engineers
CFB	Circulation fluidized bed
CFR	Code of Federal Regulations
HEPA	High energy particulate air
ID	Inside diameter
INEL	Idaho National Engineering Laboratory
LLW	Low level radioactive waste
MMT	Multiple metals train
PNL	Pacific Northwest Laboratory
QA	Quality assurance
QC	Quality control
RDF	Refuse derived fuel
RWMC	Radiation Waste Management Complex
SCE	Southern California Edison Corporation
TCLP	Toxicity characteristic leaching procedure
TRU	Transuranic
USBM	U.S. Bureau of Mines
WHC	Westinghouse Hanford Company
WTE	Waste to energy

PHASE 1 DEMONSTRATION OF 3-PHASE ELECTRIC ARC MELTING FURNACE TECHNOLOGY FOR VITRIFYING HIGH-SODIUM CONTENT LOW-LEVEL RADIOACTIVE LIQUID WASTES

(1) INTRODUCTION

The thermal waste treatment facility at the Albany Research Center in Albany, Oregon was constructed in 1990 in cooperation with The American Society of Mechanical Engineers (ASME) and has been successfully applied since that time to vitrify a number of waste materials on a scale of 1000 to 2000 lb/h. Materials treated in 1991 and 1992 in cooperation with the ASME comprised over 54,000 lb of residues from five municipal waste combustors including combined dry grate residue and fly ash from three state-of-the-art mass burning waste-to-energy (WTE) plants, combined ash from a multiple-hearth waste water treatment sludge combustor, and fly ash from a WTE plant that burned refuse-derived-fuel (RDF). The resulting slags, metals, and mattes were benign on the basis of the TCLP test. Fly ash resulting from the test failed the TCLP test owing to enrichment in lead and zinc, which may qualify it for smelter feed. The following year, over 40,000 lb of materials were vitrified in cooperation with the Idaho National Engineering Laboratory (INEL). These materials simulated incinerated residues from 5 categories of radioactive and mixed wastes and soils from the Radiation Waste Management Complex (RWMC) at the INEL. Heavy metals and the TRU surrogate (Ce) in the waste mixtures were immobilized within predominantly vitreous product slags, which readily passed the TCLP test. Current cooperative research efforts in addition to the present project with Westinghouse Hanford Company (WHC) involve Southern California Edison Co. (SCE) and the INEL. SCE, a privately owned utility in Rosemead, CA, desires to vitrify materials simulating combustion residues from a circulating fluidized bed (CFB) utility boiler burning RDF and other hazardous wastes generated by the utility in the course of day-to-day operation including asbestos, contaminated soils, metal hydroxide sludges generated by cleaning boiler tubes, and contaminated concrete. The INEL wastes simulate as-retrieved radioactive and mixed wastes from the RWMC and, therefore, contain significant proportions of water, combustibles, nitrates, chlorides, and sulfur-bearing compounds. One waste category (Series 745 nitrate salts from the Rocky Flats plant) contains significant concentrations of alkali nitrate salts, similar to the high-sodium low level liquid wastes from the Hanford site.

The existing air pollution control system (APCS) was designed to treat the gases and recover particulates from offgas produced by melting combustion residues, soils, and similar low-gas producing materials. As such, the system was inadequate for some of the SCE wastes and for the as-retrieved INEL buried wastes. The APCS currently is undergoing a significant upgrade to provide for complete oxidation of combustible gases, destruction of chlorinated hydrocarbons and NO_x , collection of entrained particulate and condensed fumes during furnace operation, acid gas removal, rapid analysis of exhaust gases, and final polishing of exhaust gases by means of high-energy-particulate-air (HEPA) and activated carbon filters. It is anticipated that advantages will accrue to all cooperators by virtue of the diversity of wastes scheduled for vitrification and the sharing of capital expenses resulting from designing and constructing an APCS with the flexibility to manage large volumes of gases containing entrained particulates, condensible inorganic and carbonaceous fumes, and acid gases.

1.1. Objectives:

- (1) Prepare pelletized dry furnace feed by two methods, designated A and B, for the ALRC arc melter and which also is appropriate to other dry-feed melting technologies using 10 M LLW simulant and readily available industrial minerals.
- (2) Denitrify the furnace feed prior to melting by reducing nitrates and nitrites to nitrogen in order to minimize the production of the oxides of nitrogen within the melting furnace.
- (3) Demonstrate the technical and practical feasibility of 3-phase electric arc furnace melting technology for vitrifying simulated Hanford Site low-level tank waste (LLW simulant) in a continuous 24-hour test with constant processing conditions including feeding and tapping of glass. Approximately 20 h will be allocated to melting Method B material, and the final 4 h of the 24-h test will be allocated to Method A material. Feed rates for both materials will be in the range 500 to 1500 lb/h (225 to 675 kg/h).
- (4) Demonstrate that the 3-phase electric arc furnace can be operated in a practical and acceptable manner to minimize reduction of metal oxides, recognizing that total avoidance of reduction reactions in the vicinity of the electrodes is not possible. Said reduction reactions are manifest by a metallic furnace product (drop out of iron and other transition metals) and by metallic vapors (predominantly alkali metals), fine metallic particulates, and fine particles of oxides, chlorides, sulfates, sulfides, and other compounds formed by secondary reactions in the furnace offgas.
- (5) Demonstrate the inherent reliability, versatility, and maintainability of the 3-phase electric arc melting furnace including the ability to stop, idle for extended periods, and restart.
- (6) Demonstrate the capability of the 3-phase electric arc melting furnace to vitrify feed materials containing NaOH, NaNO₃, NaNO₂, and NaAlO₂ as significant constituents, PO₄⁻³, SO₄⁻², Cl, and F as minor constituents, and regulated components including Ba, Cd, Cr, and Pb.
- (7) Demonstrate the capability of the electric arc melting furnace to produce a durable, consistent, and homogeneous glass containing minimum 25 pct waste loading.
- (8) Demonstrate the capability of the electric arc melting furnace to process the LLW simulant in compliance with applicable NO_x and SO_x requirements.
- (9) Determine the distribution of LLW components among glass, fume solids, and offgas products.

(10) Conduct measurements of offgas flow rates and composition including acid gases and quantities and composition of entrained particulates. A qualified air quality control laboratory using accepted EPA methods and protocols will be contracted to collect samples during furnace operation to analyze furnace exhaust gases for CO, CO₂, N₂, H₂, O₂, SO_x, and NO_x as minimum requirements, with speciation of NO_x and Cl, F, PO₄⁻, B, NH₃, and CH₄ desired. Particulate matter will be further analyzed with the protocols of SW 846 for all feed components to assess entrainment.

In addition, offgas composition will be monitored semi-continuously by on-line gas chromatography to determine the concentrations of He tracer, O₂, N₂, CO, CO₂, NO_x and SO₂. Solids recovered from the cyclone and baghouse and solution from the acid gas scrubber in the APCS will be sampled at fixed time intervals for analysis to determine mass balance over the electric furnace.

(11) Collect and compile experimental electrical and process data that can be scaled to the requisite 100 metric tons/day LLW vitrification plant to support engineering studies, technology evaluation, life-cycle cost analysis, and to evaluate life expectancy, reliability, and maintenance requirements.

1.2. Summary of Pretest Research:

The objectives of pretest research were to prepare furnace feed with 25 pct waste loading from readily available low-cost industrial minerals and 10 M LLW simulant to provide product glass designated as acceptable by WHC; to decompose nitrates and nitrites in the furnace feed prior to melting; to minimize NO_x formation both during denitrification and during melting by the appropriate choice of reductants; and to determine melting temperature and fluidity of the selected glass composition.

1.2.1. Investigation of furnace feed materials:

Preparation of furnace feed currently is being investigated by two general methods designated A and B:

Method A. Prepare furnace feed in two steps consisting of: 1. Agglomerating glass-forming materials with suitable binders to form pellets having physical strength to withstand normal handling and capacity to absorb LLW simulant containing a suitable reductant, or alternatively to prepare pellets comprising glass-forming materials and reductant(s) with capacity to absorb LLW simulant, and 2. Absorbing LLW simulant or simulant containing a suitable reductant into the pellets. Loaded pellets after drying and heating to reduce nitrates and nitrites constitute denitrified furnace feed. Method A is preferred for application to actual LLW in that the exposure, effort, and expense of processing radioactive materials are significantly decreased. The method becomes more cost effective with scale. Pellet production is a well known industrial process, which by virtue of its continuous character, is not expensive. In industrial practice heat for drying and induration, if needed, would be derived from inexpensive fossil fuels utilizing automated handling and heating facilities.

Method B. Prepare furnace feed in a single operation by mixing all dry materials including glass formers, dry binders, and reductants; pelletizing the dry materials with LLW simulant and additional water if needed; drying the loaded pellets; and then heating to induce decomposition of nitrates and nitrites to provide denitrified furnace feed. This latter method is more cost effective for preparing relatively small quantities of furnace feed in a batch process and is the preferred method for this test.

Melting of furnace feed prepared by both method is scheduled for the demonstration test with approximately 20 h allocated to feed prepared by Method B and approximately 4 h to feed prepared by method A.

Method A: Preparation of pelletized, dry, denitrified furnace feed material was investigated using in-house and contractor-supplied 10 M LLW simulant with the objective to prepare inexpensive hardy pellets with adequate absorption capacity. The glass composition designated LD6-5510 (from Kim 5/16/94) was selected for investigation. Numerous different mixtures of industrial minerals were investigated to meet the compositional requirement for product glass. Glass formers included Bayer alumina, diatomite (impure fossil-derived silica), high-purity -200 mesh silica sand, Micro-Cel (expanded calcium silicate), limestone, slaked lime, boric acid, and Colmanite (calcium borate); binders included southern bentonite, Portland cement, sodium silicate, and methyl cellulose; reductants included ethylene glycol, propylene glycol, sucrose, corn starch, various paraffin (mineral) oils, urea, and various activated carbons.

Bayer alumina is the preferred source of alumina owing to its low cost and high purity. Boric acid was found to be a potent binder and is much preferred to Colmanite, which also is more expensive. Portland cement was found to be completely ineffective as a binder contrary to expectations. Micro-Cel is the preferred calcia source in Method A pellets where it provides additional green strength. Southern bentonite was included to provide improved green strength at minimal cost. Diatomite and silica sand were balanced to provide adequate but not excessive absorption capacity. Sodium silicate was not an effective binder, contrary to expectations. The composition selected for production is described in table 1.1, which lists the components, the composition of pellets after heating to vaporize volatile constituents, and the composition of product glass.

The reductant or combination of reductants was selected to provide effective decomposition of nitrates and nitrites at the lowest possible temperature. Sucrose, corn starch, urea, and activated carbon are effective reductants, but individually each has a shortcoming. Sugar as the sole reductant provided the lowest reduction initiation temperature, but was not acceptable owing to a tendency for gas evolution to rupture the pellets during reaction. Reaction was incomplete with starch resulting in excessive unreacted carbon remaining in the furnace feed. Urea resulted in ammonia in the reaction gases. Carbon was effective, but required initiation temperatures in excess of 300 C. An activated carbon obtained from NUCON International, NUCON NUSORB LN 100-325, was selected for usage in combination with sugar, wherein sugar initiates the reaction at temperatures in the range 150 to 200 C and carbon completes the reaction without excessive gas evolution. Optimization of the ratio of reductant to LLW simulant based upon equations 1, 2, 3, and 4, which may not accurately describe the reactions but provide a basis for experimentation, was investigated over the range 75 to 150

Table 1.1.- Composition of Industrial Minerals, 10 M LLW Simulant, and Resultant Pellets and Product Glass for Method A Furnace
 Feed Waste loading: 25 pct Saved as Table 1_1

Component	Bayer alumina	Boric acid	Southern Bentonite	Diatomite	Micro Cell	Glass makers sand	Pellet As prepared	10 M LLW simulant	Glass after melting	
Pct	5.677	11.021	3.646	50.364	18.875	10.417				
Component	Analysis						Pct	Pct of sol'n	Pct of solids	Pct
Ag2O						Ag2O	0.000	0.000	0.000	0.000
Al2O3	99.700		15.700	3.893	1.568	0.060 Al2O3	8.495	3.544	12.595	10.146
B2O3		56.200				B2O3	6.194	0.000	0.000	5.101
BaO						BaO	0.000	0.000	0.000	0.000
CaO			4.370	0.658	30.223	CaO	6.195	0.003	0.010	5.105
CdO						CdO	0.000	0.000	0.000	0.000
CeO2						CeO2	0.000	0.000	0.000	0.000
Cr2O3						Cr2O3	0.000	0.045	0.159	0.040
Cs2O						Cs2O	0.000	0.162	0.575	0.144
CuO						CuO	0.000	0.000	0.000	0.000
FeO						FeO	0.000	0.000	0.000	0.000
Fe2O3				2.030	1.273	0.010 Fe2O3	1.264	0.003	0.010	1.043
HgO						HgO	0.000	0.000	0.000	0.000
K2O			0.640	0.349	0.281	K2O	0.252	1.610	5.722	1.638
MgO				0.464	0.779	MgO	0.381	0.003	0.010	0.316
MnO2						MnO2	0.000	0.003	0.010	0.002
MoO3						MoO3	0.000	0.165	0.585	0.146
Cl						Cl	0.000	0.388	1.378	0.344
F						F	0.000	0.324	1.153	0.288
I						I	0.000	0.144	0.512	0.128
Na2O	0.300		0.280	3.734	0.310	Na2O	1.966	21.181	75.278	20.439
NiO						NiO	0.000	0.000	0.000	0.000
P2O5				0.041	0.066	P2O5	0.033	0.209	0.744	0.213
PbO				0.0005		PbO	0.000	0.000	0.000	0.000
SO3				0.045	0.122	SO3	0.046	0.237	0.843	0.248
SeO2						SeO2	0.000	0.000	0.000	0.000
SiO2			51.000	86.210	49.415	99.910 SiO2	65.013	0.000	0.000	53.547
SrO						SrO	0.000	0.117	0.417	0.104
TiO2						TiO2	0.000	0.000	0.000	0.000
ZnO						ZnO	0.000	0.000	0.000	0.000
ZrO2						ZrO2	0.000	0.000	0.000	0.000
Other*	-0.000	0.000	8.210	0.851	2.610	0.000 Other	1.221	0.000	0.000	1.005
Subtotal	100.000	56.200	80.200	98.275	86.647	99.980 Subtotal	91.060	28.14	100.00	100.000
CO3-				0.005	3.103	CO3-	0.588	1.103		
H2O		43.800	19.800	1.720	10.250	0.020 H2O	8.352	46.348		
NO3-						NO3-	0.000	13.526		
NO2-						NO2-	0.000	5.281		
OH-						OH-	0.000	4.491		
Org C						Org C	0.000	1.114		
						Subtotal		71.863		
Total	100.000	100.00	100.00	100.00	100.00	100.00	100.00	100.00		
* Other comprises unanalyzed components of the industrial minerals.										

* Other comprises unanalyzed components of the industrial minerals.

pct of stoichiometry. The combination of 25 pct of stoichiometric sugar and 50 pct of stoichiometric carbon was found to provide acceptable residual nitrogen (0.25 to 0.35 pct) and carbon (2.5 to 3.0 pct) in the furnace feed. Stoichiometric requirements, based upon the following equations, to reduce nitrate and nitrite with sucrose and activated carbon, expressed as g/100g 10 M LLW, are 12.6072 and 5.3095, respectively.

Sucrose reductant:

Carbon reductant:

Pelletizing to produce experimental furnace feed by Method A was done on a conventional 36 in disc pelletizer using a fine mist of water to prepare pellets ranging in size from 1/8 in (3 mm) to 3/4 in (20 mm). A larger disc at ALRC will be used to pelletize the glass formers to prepare 4,000 lb of Method A furnace feed for the demonstration melting test. Incorporation of the reductants as powdered sugar and activated carbon within the pellets resulted in hard and durable pellets after drying at 85 to 100 C overnight. The composition selected for investigation does not require induration other than drying, which significantly decreases the cost of producing furnace feed by Method A.

LLW simulant was readily absorbed within a few seconds into the dry pellets in proportions exceeding the requirement for 25 pct waste loading thereby necessitating careful mixing of pellets and LLW. Drying was accomplished by heating to 85 C overnight. Figure 1.1 provides the process flow diagram for preparing furnace feed by Method A.

Decomposition of nitrates and nitrites in loaded Method A pellets was investigated by impaling dried pellets containing both LLW simulant and 100 pct of stoichiometric reductant (25 sucrose-75 carbon) weighing on the order of 1 g on Type J thermocouple beads and heating in a current of hot air. Figure 1.2 indicates air temperature and the temperature of the interior of the pellet during the heating cycle. The initiation temperature is poorly defined owing to conduction of heat into the pellet by the thermocouple wire and a torturous diffusion path through the pellet proper. Nevertheless, the data clearly indicate initiation beginning as low as 170 C. The reaction enthalpy carried the temperature to about 600 C.

Experimentation to determine NO_x generation during heating to induce reaction between reductants and nitrates/nitrites in Method A pellets was not conclusive owing to inadequate scrubber capacity to collect gases soluble in dilute caustic solution. However, definitive tests were conducted for loaded pellets prepared by Method B using series absorbers to capture caustic-soluble gases. Chemical reactions to reduce nitrates and nitrites are expected to be identical in pellets prepared by both Methods A and B.

Figure 1.1.-Preparation of Furnace Feed by Method A

Figure 1.2.- Reaction of Method A Furnace Feed

Reacted pellets of the LD6-5510 composition also were analyzed by X-ray diffraction, which identified $\text{SiO}_2 \cdot x\text{H}_2\text{O}$, which is hydrated silica or Opal, as the primary phase (>40 pct of the sample), sodium aluminum silicate nitrite hydrate, $\text{Na}_8(\text{Al}_6\text{Si}_6\text{O}_{24})(\text{NO}_2)_2 \cdot 3\text{H}_2\text{O}$, as a minor phase (5 to 30 pct of the sample), traces of identified compounds, and amorphous material. Of interest is the formation of a stable nitrite phase, which explains the residual nitrogen.

Approximately 5 lb of unreacted Method A pellets was prepared using the general scheme described above for analysis by PNL. That material was shipped by Federal Express in mid December.

Method B: Furnace feed providing product glass of the LD6-5510 composition was prepared by pelletizing mixtures of glass formers, binders, and reductants with 10 M LLW simulant. Numerous glass former minerals, binders, and reductants were investigated in the laboratory, with the objective to decrease the cost of raw materials and to minimize residual nitrogen and carbon in the reacted pellets. Finely divided limestone is a satisfactory source of calcia replacing expensive Micro-Cel. Reductant additions in the range 75 to 150 pct of stoichiometric requirements (based upon equations 1 through 4) were investigated, and the results indicated satisfactory reduction at the 75 pct level with sucrose and activated carbon at 25 and 50 pct of stoichiometric requirements, respectively. The combination of sucrose and carbon reductants and 10 M LLW simulant produced strong and durable pellets after drying at 85 to 100 C. Table 1.3 lists the glass formers to be used for Method B and the calculated composition of the resultant glass. The process for Method B, as outlined on figure 1.3, relies upon pellet formation by mixing the dry ingredients including glass formers and reductants in a Hobart mixer, adding the LLW simulant with continued mixing, and finally adding water until pellet formation is complete. The proportion of liquid in the mixture is very critical to the formation of satisfactory pellets.

Various pelletizing techniques were investigated including a 3-liter Hobart mixer, impeller-type mixer, and a simulated ring pelletizer. Given the resources, a ring apparatus is the pelletizer of choice, but it must be preceded by a competent mixer. An efficient mixer, such as the double ribbon mixer, which provides the best of mixing actions, produces pellets in a single operation without the added expense of a pelletizer. A 50 cu ft unit was purchased for delivery before December 31, 1994.

Decomposition of pellets containing 75 pct of stoichiometric reductant was investigated, and figure 1.4 indicates the air temperature and the temperature of the interior of a single pellet weighing about 1 g during thermal decomposition in air. The graph indicates initiation of the reduction reaction at about 180 C; but note that the reaction enthalpy only increased the temperature of the pellet to about 550 C.

Table 1.3.- Composition of Industrial Minerals, 10 M LLW Simulant, and Product Glass for Method B Furnace Feed
Waste loading: 25 pct

Date prepared: 12-16-94

Saved as Table 1_3

Component	Bayer alumina	Boric acid	Ag lime	Diatomite	Glass makers sand	10 M LLW solution	Glass after melting	
Pct	6.160	10.670	10.280	52.890	20.000			
Component	Analysis					Pct of sol'n	Pct of solids	Pct
Ag2O					Ag2O	0.000	0.000	0.000
Al2O3	99.700			3.893	0.060 Al2O3	3.544	12.595	10.000
B2O3		56.200			B2O3	0.000	0.000	5.003
BaO					BaO	0.000	0.000	0.000
CaO			54.908	0.658	CaO	0.003	0.010	5.002
CdO					CdO	0.000	0.000	0.000
CeO2					CeO2	0.000	0.000	0.000
Cr2O3					Cr2O3	0.045	0.159	0.040
Cs2O					Cs2O	0.162	0.575	0.144
CuO					CuO	0.000	0.000	0.000
FeO					FeO	0.000	0.000	0.000
Fe2O3				2.030	0.010 Fe2O3	0.003	0.010	0.900
HgO					HgO	0.000	0.000	0.000
K2O				0.349	K2O	1.610	5.722	1.585
MgO			0.480	0.464	MgO	0.003	0.010	0.248
MnO2					MnO2	0.003	0.010	0.002
MoO3					MoO3	0.165	0.585	0.146
Cl					Cl	0.388	1.378	0.344
F					F	0.324	1.153	0.288
I					I	0.144	0.512	0.128
Na2O	0.300			3.734	Na2O	21.181	75.278	20.483
NiO					NiO	0.000	0.000	0.000
P2O5				0.041	P2O5	0.209	0.744	0.204
PbO				0.0005	PbO	0.000	0.000	0.000
SO3				0.045	SO3	0.237	0.843	0.231
SeO2					SeO2	0.000	0.000	0.000
SiO2				86.210	99.910 SiO2	0.000	0.000	54.712
SrO					SrO	0.117	0.417	0.104
TiO2					TiO2	0.000	0.000	0.000
ZnO					ZnO	0.000	0.000	0.000
ZrO2					ZrO2	0.000	0.000	0.000
Other*	-0.000	0.000	0.700	0.851	0.000 Other	0.000	0.000	0.436
Subtotal	100.000	56.200	56.088	98.275	99.980 Subtotal	28.14	100.00	100.000
CO3-				0.005	CO3-	1.103		
H2O		43.800	43.912	1.720	0.020 H2O	46.348		
NO3-					NO3-	13.526		
NO2-					NO2-	5.281		
OH-					OH-	4.491		
Org C					Org C	1.114		
						71.863		
Total	100.000	100.00	100.00	100.00	100.00	100.00		
*Other comprises unanalyzed components of the industrial minerals								

*Other comprises unanalyzed components of the industrial minerals.

Figure 1.3.- Preparation of Furnace Feed by Method B

Figure 1.4.- Reaction of Method B Furnace Feed

The extent of nitrate/nitrite reduction, residual nitrogen in the reacted pellets, and caustic-soluble gases liberated during reaction of Method B pellets containing 75 and 100 pct of stoichiometric reductant were determined by heating about 5 g of loaded pellets in air and passing the resulting gases through series absorption columns each containing 50 ml of 50 mM NaOH. The glass apparatus was rinsed with deionized water after usage, and the rinse solutions were added to the absorber solutions for analysis by ion chromatograph for nitrate and nitrite. The data obtained, as listed in table 1.4, indicate that about 10 pct of the nitrogen in the loaded pellets remained in the reacted pellets for both compositions. The small decrease in residual nitrogen does not justify the higher level of reductant in the loaded pellets. Less residual carbon in the reacted pellets translates to better melting practice, an additional reason to use the minimum reductant. Residual carbon includes unreacted sucrose and activated carbon, carbonates in the glass formers, and carbon in the 10 M LLW simulant. About 5 pct of the nitrogen in the loaded pellets was captured in the absorbers, leaving about 85 pct of the nitrogen unaccounted for and assumed to have been liberated as the element or an oxide (NO or N₂O) not readily absorbed in caustic solution.

Table 1.4.- Chemical Analysis of Loaded and Reacted Pellets and Caustic-Soluble Gases for Method B Furnace Feed

Sample LD6-5510-1490: (25 sucrose + 50 carbon)*			Absorber solution		
	Loaded pellets	Reacted pellets	200 ml		
Weight	5.0037	4.1722	NO ₃ ⁻	NO ₂ ⁻	Sum
Nitrogen (as N)					
Conc, pct	3.08	0.257	114 mg/l	50 mg/l	
Wt, mg	154.1	10.7	5.15	3.04	8.19
pct of total	100	6.96	3.34	1.98	5.32
Carbon					
Conc, pct	4.04	2.50	NA	NA	
Wt, mg	202.1	104.3	NA	NA	
pct of total	100	51.6	NA	NA	
Sample LD6-5510-1475: (25 sucrose + 75 carbon)*			Absorber solution		
	Loaded pellets	Reacted pellets	200 ml		
Weight	5.0002	4.1809	NO ₃ ⁻	NO ₂ ⁻	Sum
Nitrogen (as N)					
Conc, pct	3.06	0.226	95 mg/l	43 mg/l	
Wt, mg	153.0	9.4	4.29	2.62	6.91
pct of total	100	6.18	2.80	1.71	4.51
Carbon					
Conc, pct	5.02	3.31	NA	NA	
Wt, mg	251.0	138.4	NA	NA	
pct of total	100	55.1	NA	NA	

* Refers to pct of stoichiometric requirement as per equations 1 through 4.

1.2.2. Melting tests of LD6-5510 glass composition:

A furnace feed mixture simulating the composition of LD6-5510 (from Kim) was prepared from sodium borate, diatomite, Micro Cell, southern bentonite, and sodium carbonate. The mixture was pelletized, dried at 100 C, and melted in a 50-lb steel capacity single-phase electric arc furnace using 3 in diameter graphite electrodes (W-size) and power density ranging from 25 to 32 kW/ft² of hearth area. The method of choke feeding was used, which requires that the molten pool be covered with a layer of unmelted feed material throughout the melt (cold top). In this test the cold top ranged from 4 to 10 in deep. Fluidity of the molten glass was adequate at 1,370 C for very successful tapping of the furnace. Fume generation was minimal, and the furnace refractory (chromium aluminum spinel bonded alumina) was not visible attacked in 45 min by the molten glass, which indicates that refractory attack may not be significant during the larger-scale demonstration melting test. Product glass is being analyzed to determine the chemical composition and to verify its amorphous form.

A second melting test of about 40 lb of material in the W-size furnace was conducted with furnace feed prepared by Method A. The test, a prototype for the demonstration test melt, was successfully accomplished using choke feeding and a cold top of about 12 in. Gas and dust generation were minimal, and the resultant glass was tapped from the furnace at about 1,450 C following 20 min of superheat after the cold top had melted. It was clear after the test that superheat is not needed. Product glass has been submitted for chemical analysis.

A third melting test in the W-size furnace was conducted during the week of December 19 for loaded pellets of Method B feed that had not been heated to induce reaction between reductants and nitrates/nitrites. No problems were encountered during melting, and a fluid glass was produced that was readily tapped from the furnace at temperatures less than 1,400 C. Scrubbing of the offgas from the test was planned, but poor performance by the baghouse and failure of the scrubber rendered the data useless. Metallic aluminum applied by the method of twin-wire arc spraying was shown to effectively retard oxidation of the graphite electrodes.

(2) DESCRIPTION OF MELTER SYSTEM

The melter system is comprised of three primary components: feed system; 3-phase electric arc melting furnace and 800 kV.A power supply, and air pollution control system (APCS). Ancillary to the melter system is a facility for feed preparation that includes 18, 36, and 48 in diameter disc pelletizers, various drying ovens and furnace, 50 cu ft double ribbon mixer, and a 50 ft conveyor to deliver wet feed pellets to the 24 ft long by 42 in wide steel belt dryer with temperature capability to about 350 C.

2.1. Feed System:

The feed system shown schematically in figure 2.1 is serviced by motorized barrel lift and/or overhead crane. Materials to be melted can be transferred directly into the 60 ft³ (1.7 m³) receiving bin or mixed with additives in a 2-barrel capacity hopper, which then is transferred by overhead crane to the receiving bin. Twin tapered, counter-rotating, 12-in (30.48 cm) diameter screws in the base of the bin discharge material to a bucket elevator, which lifts the material 17 ft (5.2 m) to a 10 ft³ (0.28 m³) metering bin. The height of material in the metering bin is controlled by sonic level indicator with high and low set points. Calibrated twin counter-rotating 6-in (15.24 cm) diameter screws in the base of the metering bin deliver material through a rotary air lock into a 6-in-diameter splitter screw, which feeds two 6-in-diameter delivery screws. Each delivery screw discharges into the furnace through a pneumatically activated diverter gate, which changes position at 6 s intervals to divide and route the feed to two separate ports in the furnace roof. Feed is thereby uniformly admitted into the furnace through four ports in the roof. The ports are arranged in a square array surrounding the electrode triangle.

Water-cooled feed tubes extend through the feed ports in the roof to within 18 in (0.46 m) of the surface of the molten pool to minimize dust generation within the furnace. These tubes are double-walled carbon steel structures 48 in (122 cm) long, by 8.625 in (21.91 cm) OD, by 5.5 in (13.97 cm) ID. The annular water jacket is divided by spacers to form 6 water passages each of which is supplied by a nominal 1/4 in (6.35 mm) copper tube that extends to within 1/2 in (12.7 mm) of the bottom of the passage. Cooling water is supplied to the feed tubes in the range 20 to 25 gal/min (1.21 to 1.51 l/s).

The height of material in the furnace under one of the charge ports is determined automatically by a level sensor or manually by lowering a weight suspended on a stainless steel cable in the manner of a plumb bob. The feed system, rated to deliver up to 2,200 lb/h (1 mt/h) of minus 1/2-in (12.7 mm) screened and semi-dried material with a bulk density of approximately 80 lb/ft³ (1.28 g/cm³), is operated manually or controlled automatically by a programmable controller.

Fugitive dust liberated by dumping of the hopper and/or barrels and during operation of the feed system is collected in a dedicated baghouse through a system of ducts connected to the receiving bin, bucket elevator, and metering bin. In practice, the quantity of fugitive dust is collected, weighed, and analyzed to permit a material balance.

The furnace is normally operated in sealed condition to avoid oxidation of graphite electrodes and combustible components in the feed materials. However, as is often the case, air is needed for combustion of carbon in the furnace feed. A controlled air injection system comprising blower, flow control valve, and mass flow transmitter is available to supply air to the furnace through the feed tubes.

Figure 2.1.- Schematic of Furnace and Feed System

Denitrified material in pelletized form, as prepared from LLW simulant, organic reductants, and glass formers by the schemes described as Methods A and B, will be fed directly into the furnace by the feed system, which is capable of delivering about 30 cu ft/h to the furnace. Based upon a bulk density of about 20 to 35 lb/cu ft for materials prepared by Methods A and B, feed rates ranging from 600 to 1050 lb/h are anticipated.

It is known from prior experience with changes in feed composition that the molten furnace product reaches steady state after four changes of hearth volume. The volume of the recently reconstructed hearth is about 5 cu ft, which will contain about 825 lb of molten glass with density about 165 lb/cu ft (2.6 g/cc). Therefore, a 4- to 5-h period devoted to melting about 4,000 lb of the test glass composition will precede the 24-h demonstration melting test. Uniform composition of the target glass will be assured by providing homogeneous feed at constant feed rate to the furnace and by maintaining constant electrode position, cold top depth, and power input to the furnace. The electric furnace is an excellent mixer for liquid melts with viscosities in the range to 100 Poise. Viscosity in the range 10 to 25 Poise is anticipated from prior W-size tests for the test glass composition.

The hearth of the melting furnace was recently rebuild with chromium aluminate-bonded alumina ramming refractory, and the APCS is being completely replaced prior to the demonstration melting tests. The entire melter system will have undergone shakedown melting tests with calcium silicate slag prior to the demonstration test. As such, all components of the melter will contain remnants of the prior feed. For that reason, a pretest melt of about 4 h is planned. At the completion of the pretest melt, the cyclone and baghouse will be emptied and the scrubber and cooler/condenser liquors will be sampled.

Wear and erosion of melter refractories will be calculated from a material balance over the furnace based upon chromium and aluminum. Chromium, a component of the hearth refractory, is a convenient tracer owing to low concentration in the furnace feed.

2.1.1. Preparation of furnace feed for demonstration melting test:

Melting at the anticipated rate of 1,000 lb/h for the 4-h pre-demonstration melt to bring the furnace to steady state, 20-h demonstration test with Method B feed, and 4-h demonstration test with Method A feed will require approximately 28,000 lb (12,700 kg) of dry denitrified furnace feed. No shakedown test in the 3-phase furnace is anticipated owing to the successful melts conducted in the W-size furnace. The mixtures of glass-former materials and product glass compositions for Method A and B feeds were listed previously in tables 1.1 and 1.2, respectively, and flow diagrams for preparing both furnace feed were provided by figures 1.1 and 1.3. The quantities of glass formers, reductants, and 10 M LLW needed are listed in table 2.1. All materials have been received.

Table 2.1.- Materials Needs for Furnace Feeds

Method A Feed (4,000 lb furnace feed)		
Components		
Glass formers	Pct of glass formers	Weight, lb
Bayer alumina	5.677	187
Boric acid	11.021	363
S bentonite	3.646	120
Diatomite	50.365	1659
Micro-Cel	18.875	622
-200 silica	10.417	343
Subtotal glass formers:	100.000	3295
(3295 lb of minerals provides 3000 lb of glass, which requires 1000 lb of LLW solids)		
Reductants		
Powdered sugar (25 pct of stoichiometric)		112
Activated carbon (50 pct of stoichiometric)		94
Subtotal reductants:		206
10 M LLW simulant		3554
Total wet weight:		7055
Total dry weight (about 43 pct wt loss)		4000

Method B Feed (24,000 lb furnace feed)		
Components		
Glass formers	Pct of glass formers	Weight, lb
Bayer alumina	6.160	1233
Boric acid	10.670	2136
Limestone	10.280	2058
Diatomite	52.890	10590
-200 silica	20.000	4004
Subtotal glass formers:	100.000	20023
(20,023 lb of minerals provides 18,000 lb of glass, which requires 6,000 lb of LLW solids)		
Reductants		
Powdered sugar		672
Activated carbon		566
Subtotal reductants:		1238
10 M LLW simulant		21322
Total wet weight:		41259
Total dry weight (about 42 pct wt loss)		24000

Furnace feed will be prepared by the following steps.

Method A Furnace Feed

1. Mix all dry materials as 500 lb batches including glass formers, binders, and reductants in double ribbon mixer (approximately 5 min)
2. Remove dry materials from mixer and store temporarily in 55 gal barrels.
3. Pelletize dry materials with water mist on 36 in disc.
4. Dry pellets on belt dryer with set point temperature 100 C.
5. Spray with or dip dry pellets into 10 M LLW simulant to achieve uniform distribution of LLW liquid on pellets.
6. Dry pellets in flowing air with radiant heat provided by infra red heating elements. Excessive temperature, as provided by incandescent heating elements and flames, must be avoided to prevent premature reduction of nitrates and nitrites in the pellets.
7. React dry pellets on a belt dryer designed to capture offgases as a necessary safety measure. Dryer temperature will be set at 250 C with the realization that reaction within individual pellets will occur at surface temperatures less than 200 C.
8. Store furnace feed in closed polyethylene sacks within 55 gal barrels.

Method B Furnace Feed

1. Mix all dry materials as 500 lb batches including glass formers, binders, and reductants in double ribbon mixer (approximately 5 min).
2. Continue mixing, and add 10 M LLW simulant through distribution pipe within the mixer to achieve uniform distribution of LLW simulant within dry materials (approximately 5 min).
3. Continue mixing, and add additional water to induce pellet formation (approximately 5 min). The quantity of water needed is a function of the effectiveness of the mixer and must be determined experimentally.
4. Remove pellets from mixer and distribute uniformly on heated belt conveyor. Allow 1 h for partial drying to occur so that pellets are free flowing.
5. Convey partially dried pellets to the belt dryer where drying is completed and reaction occurs to decompose nitrates and nitrites. Dryer temperature will be set at 250 C with the realization that reaction within individual pellets will occur at surface temperatures less than 200 C.
6. Store furnace feed in closed polyethylene sacks within 55 gal barrels.

2.2. Melter and Power Supply:

2.2.1. Three-Phase Electric Arc Melting Furnace:

The furnace, as shown previously in figure 2.1, is a sealed 3-phase electric arc furnace with three 4-in (10.2 cm) diameter graphite electrodes arranged in an equilateral triangle 11.25 in (28.6 cm) between electrode centers. The furnace proper is a refractory-lined carbon steel shell 65 in (1.65 m) high tapering from 56-in (142.2 cm) ID at the top to 60-in (152.4 cm) ID at the bottom. The roof and sidewalls of the furnace are water cooled and the bottom of the furnace shell is air cooled to minimize refractory erosion. The initial 18 in (46 cm) of the exhaust gas exit port also is water cooled. Metal is tapped from the furnace and the hearth is drained as needed by manually opening a 1-1/2-in (3.81 cm) diameter hole in the bottom center of the hearth. Glass is tapped continuously or upon demand from the furnace at rates up to 2,200 lb/h (1 mt/h) through a water-cooled copper tapping fixture, which is a welded, double-walled, structure 6 in (15.24 cm) diameter by 7.5 in (19 cm) long with 0.625 in (1.59 cm) diameter central hole. A graphite tapping fixture with central hole up to 4 in diameter (10.2 cm) is available if the water cooled fixture interferes with tapping of glass.

The bottom of the furnace shell is lined with 5 in (12.7 cm), two courses, of chromic oxide-alumina bonded 90 pct alumina super duty firebrick (Ruby). Five courses of Ruby key bricks shape the hearth and form the sidewall up to a steel shelf 28 in (71.1 cm) above the bottom, which is about 7 in (17.8 cm) above the glass tap hole. One in (2.54 cm) of dry phosphate-bonded silicon carbide ramming mix was placed between the steel bottom and the first course of Ruby bricks to improve heat transfer to the bottom. This ramming mix also was placed between the Ruby key bricks and the steel sidewall for the same reason. The upper sidewall is lined with 4.5 in (11.43 cm) of 70 pct alumina insulating arch firebrick. One in (2.54 cm) Fiberfrax batting was placed between the arch brick and sidewall for additional insulation. The finished inside diameter of the furnace is about 46 in (1.17 m). The hemispherical hearth with 5 ft³ capacity below the glass tap hole was finish formed with Ruby ramming mix.

The roof of the furnace is lined with 4 in (10.2 cm) of 85 pct alumina plastic refractory.

2.2.2. Power supply:

The furnace is powered by a 3-phase 800 KVA transformer and three 250 KVA single-phase transformers configured such that the primary circuit of each 250 KVA transformer is in parallel with one of the primary phases of the 3-phase transformer and the secondary circuit of each 250 KVA transformer is in series with the corresponding secondary phase of the 3-phase transformer.

Voltage regulation of 3 to 5 pct of the mean from open circuit to full load is provided by the power supply with 2,080 ampere maximum output current measured at the furnace. Power can be increased for a given transformer tap position by increasing the electrode positioning rheostats. A rheostat for each phase, working through the electrode positioning circuit for that phase, adjusts the electrode position to decrease the arc length, or even submerge the

electrode in the melt, thereby providing increased current. Power to the furnace is a function of the voltage (transformer tap), current (electrode position as determined by rheostat setting), and the resistivity of the slag. A rheostat controls each electrode thereby providing a means to balance the power. Table 2.2 lists the secondary open-circuit voltage measured at the furnace for each transformer tap setting.

Table 2.2. - Power Supply Characteristics

	Phase-to-phase voltage	Phase-to-ground voltage
Tap A	352	192
Tap B	304	168
Tap C	256	145
Tap D	239	134

2.2.3. Cooling water supply:

Water for component cooling is pumped to the melter system from a 1,500 gal (5.6 m³) cool water sump by a 15-hp centrifugal pump. The furnace shell is cooled by a curtain of water (50 gal/min (190 L/min)) that cascades down the wall from an annular distribution trough near the top of the shell. The flow rates in circuits servicing the air pollution control duct, feed tubes, and copper tapping fixture are indicated by flow meters. All cooling water is collected at the base of the furnace in a trough and returned by gravity to a 1,500 gal (5.6 m³) warm water sump. Water is pumped from the warm water sump to a cooling tower supplying up to 150 gal/min (566 L/min) of water at 75 F with 142 F maximum return temperature and 70 F wet bulb air temperature. Temperature and flow rate are measured in the input and return water lines to provide the cooling water contribution to the overall melter heat balance.

2.3. Air Pollution Control System:

The air pollution control system (APCS) is shown schematically in plan view on figure 2.2 and in elevation view on figure 2.3. The system is designed to meet the demands of current research efforts to vitrify materials containing significant proportions of water, combustibles, chlorides, sulfates, nitrates, and nitrites. Temperature, pressure, gas flow, and sampling locations are indicated on figures 2.1 and 2.3.

2.3.1 Refractory lined ductwork and thermal oxidizer:

Conditions within the furnace and the refractory lined ductwork leading to the thermal oxidizer will be maintained reducing to destroy NO_x prior to the thermal oxidizer and to minimize the tendency for accretions to form within the ducts. The viscosity of glasses and slags and hence the propensity for accretion formation, increases with the oxidation state of the transition elements. Trivalent iron tends to participate in and extend the silicate network,

Figure 2.2.- Plan View of Melter System

Figure 2.3.- Elevation View of Melter System with Sample Collection Points

whereas divalent iron tends to terminate the network.

Temperature within the ductwork will be maintained above the melting temperature of anticipated condensates and particulates by the combined input from two 800,000 Btu natural gas burners. All ducts slope to the thermal oxidizer, which is fitted with a removable refractory-lined catch basin, so that all molten materials can be collected at a single source. The thermal oxidizer, which is heated by a 3 MMBtu natural gas burner, will be operated in the oxidizing mode by injecting air below the venturi. The thermal oxidizer will oxidize CO and all residual hydrocarbons and will destroy all remaining carbon-chlorine bonds. Design temperatures are 870 C within the plenum of the furnace, achieved by limiting combustion air to the volume needed to oxidize carbon in the feed to CO, and 1,230 C in the refractory-lined ductwork and the thermal oxidizer. It is an unfortunate fact of life that thermal NO_x will form within the thermal oxidizer owing to the high temperatures. Nitrogen oxides thus formed will be absorbed in the acid gas scrubber following the baghouse.

2.3.2. Evaporative gas cooler, APCS valve, and wind box:

Close-coupled to the thermal oxidizer is a cooler designed to decrease the temperature of the offgas from 1,230 C to 260 C by means of evaporative cooling. This an automated unit that cools the exhaust gases to 260 C at the output by air atomization of water. The APCS valve following the cooler, as indicated in figure 2.3, regulates gas flow to provide negative 0.5 in water column in the furnace. Air collected by hoods over the glass and metal tap holes by the cooling air blower is regulated by the cooling air valve and then is injected into the windbox following the APCS valve to decrease the temperature to 150 C, which is the appropriate entry temperature for the baghouse.

2.3.3. Cyclone and baghouse:

The cyclone between the wind box and the baghouse functions to provide additional residence time to allow incandescent particles to cool and to remove large particles. The baghouse allows for changing of the bags from the clean air side of the tube sheet as a safety measure and to expedite changing of bags.

2.3.4. Scrubber and cooler/condenser:

Acidic species are removed from the exhaust gases in the caustic scrubber following the baghouse to allow collection of particulate and condensed fume solids without contamination by dry scrubber solids (chloride and sulfate/sulfite salts). Gases exit the scrubber saturated with water vapor at 67 C, which are unacceptable conditions for the induced draft blower. The cooler/condenser decreases the temperature to 32 C by circulating water from the cooling tower, but the gases exit the unit saturated with water vapor.

2.3.5. Gas reheater, induced draft blower, and filters:

Gentle reheat of the offgas to 38 C prior to the blower is necessary to prevent condensation in the blower and in the HEPA and activated carbon filters. Reheating prior to the blower also minimizes the visible steam plume from the stack.

2.4. Secondary Streams:

Five secondary streams are identified for collection, sampling, and analysis. Materials accumulated during the demonstration test will be collected according to the following schedule, weighed, and analyzed.

1. Base of the thermal oxidizer. The catch basin of the thermal oxidizer will be removed and cleaned before beginning and at the conclusion of the 24 h continuous demonstration test.
2. Cyclone. Accumulated solids will be sampled and emptied at two-hour intervals and additionally as specified in table 3.1 during the demonstration test by rotating the air lock valve at the base of the cyclone.
3. Baghouse. The baghouse will be emptied and the accumulated solids will be sampled at two-hour intervals and additionally as specified in table 3.1 during the demonstration test by rotating the air lock valve at the base of the baghouse.
4. Scrubber solution. The caustic scrubber solution will be sampled at two-hour intervals and additionally as specified in table 3.1 during the demonstration test. Knowledge of the composition and volume of the solution will allow calculation of acid gas components in the offgas.
5. Cooler/condenser solution. The cooler/condenser functions by recirculating water from the cooling tower over polyethylene packing through which gases flow countercurrent. During the demonstration test the cooling water will be sampled at two-hour intervals and additionally as specified in table 3.1 to ascertain changes in water chemistry. However, the cooling tower and associated warm water and cool water sumps contain about 3200 gal of water, and it is unlikely that appreciable changes in water chemistry will occur.

2.5. Flowsheet to be tested:

Preparation of feed materials by Methods A and B in separate operations prior to melting greatly simplifies conduction of the demonstration melting test. No chemical adjustments to change feed chemistry will be needed, liquids need not be handled, and less than 100 cfm of offgas is expected. Air to oxidize carbon in the feed to CO (26 cfm air if feed contains 2 pct C) will likely be provided by air entrained with the feed. The glass composition identified by Kim as LD6-5510 (5.0 B₂O₃, 20.0 Na₂O, 5.0 CaO, 10.0 Al₂O₃, and approximately 57 SiO₂) is planned for the demonstration test melt.

Impurities in the glass product will be those present in the natural minerals and materials from which the furnace feeds were prepared. Tables 1.1 and 1.3 list the concentration of unknown components in the glasses at about 1 pct.

2.5.1. Handling of feed material and products:

Feed material consisting of pre-reacted pellets will be weighed by crane scale as deposited in the receiving bin. Glass product in cast iron molds containing about 800 lb also will be weighed by crane scale. Lesser quantities, as obtained from the thermal oxidizer catch basin, cyclone, and baghouse will be weighed by calibrated floor scale or analytical balance. Samples for analysis will be entered on the appropriate log and stored in sealed plastic containers.

Samples of product glass will be collected as simple flat quasi-cylinders by cooling product glass on a 1/2 in thick steel plate.

(3) TEST MONITORING AND SAMPLING

Basic information required to evaluate the performance of the feed system, electric arc melting furnace, and the APCS are recorded electronically and/or manually throughout a melting campaign. Sampling of offgas will be done by Entropy Inc., a qualified air quality laboratory using EPA methods described in 40 CFR part 60 Appendix A. Particulate matter will be further analyzed with the protocols of SW 846 for all feed components to assess entrainment.

3.1. Electrical Parameters:

Electrical parameters for analyzing demand and consumption of the electric furnace are continuously monitored by a True RMS Power and Demand Analyzer Model 3950, which records rms voltage (V), rms current (A), apparent power (VA), active power (W), reactive power (var), power factor, and total energy (Kw.h). These data are integrated over 1 min interval, and the integral values are stored by the instrument. Four channels (V, A, Kw, and Kw.h) are transmitted to a data logger, which receives up to 38 additional inputs from sensors in the feed system, electric furnace, and APCS, applies a linear scaling factor to each input as needed, and transmits the calculated values to a personal computer at intervals of 1 min for display and storage. A hard copy is printed at 5-min intervals.

3.2. Continuous Monitoring Points:

Monitoring points in the furnace and the APCS are indicated on figure 2.3. The following data derived from both the furnace and the APCS will be recorded continuously during the vitrification demonstration test by the data acquisition system:

Temperature sensor and thermocouple type:	Monitoring point
Furnace exit after gas burner 1, Type R.	1.
Crossover duct exit after burner 2, Type R.	2.
Thermal oxidizer exit, Type R.	3.
Evaporative gas cooler exit, Type J.	4.
Cooling air supply duct, Type J.	5.
Wind box exit (cyclone entrance), Type J.	6.
Cyclone exit (baghouse entrance), Type J.	7.

Baghouse exit, Type J.	8.
Scrubber exit, Type J.	9.
Cooler/condenser exit, Type J.	10.
Reheater exit (ID blower entrance), Type J.	11.
ID blower exit (filter entrance), Type J.	12.
Filter exit (stack), Type J.	13.
Furnace upper plenum, Type K.	14.
Furnace shell bottom, Type J.	15.
Metal tap hole, Type R.	16.
Product glass, continuous indicating pyrometer.	17.
Primary combustion air, Type J.	18.
Secondary combustion air, Type J.	19.
Cooling water to furnace, Type J.	20.
Warm water return, Type J.	21.

Gas pressure transducer:	Monitoring point
Evaporative Gas Cooler exit.	4.
Cooling air.	5.
Wind box exit.	6.
Cyclone exit.	7.
Baghouse exit.	8.
Scrubber exit.	9.
Cooler/condenser exit.	10.
Reheat exit.	11.
ID blower exit.	12.
Filter exit or stack.	13.
Furnace upper plenum (air draft X-mitter).	14.
Primary combustion air.	18.
Secondary combustion air.	19.

Gas flow sensor and type:	Monitoring point
Atomization air for EGC, flow X-mitter.	air supply
Evaporative gas cooler exit, He tracer.	4.
Cooling air duct, S-type pitot with P X-ducer.	5.
Baghouse exit, He tracer.	8.
Baghouse exit, S-type pitot with P X-ducer.	8.
Stack, S-type pitot with P X-ducer.	13.
Primary combustion air, flow X-mitter.	18.
Secondary combustion air, S-type pitot with P X-ducer	19.

Water flow sensor and type:	Monitoring point
EGC water, flow X-mitter.	water supply
Cooling water to furnace, totalizing flow meter.	20.
Warm water return, totalizing flow meter.	21.

3.3. Additional Logs:

Manual logs will be kept to record the following:

1. Date, time, and weight of all materials entering the receiving bin of the feed system.
2. Depth of cold top at irregular intervals to verify continuous indicating sensor.
3. Feed rate at irregular intervals to verify continuous indicating sensor.
4. Furnace parameters: transformer tap, electrode voltage, electrode current, power, energy, and rheostat settings.
5. Date and time collected and the weight of product glass ingots and samples for analysis.
6. Date and time collected and the weight of all APCS products.
7. Date and time installed and the weight of each electrode segment.

3.4. Offgas Analysis:

Furnace exhaust gases will be analyzed by contractor for CO, CO₂, N₂, H₂, O₂, SO_x, and NO_x as minimum requirements, with speciation of NO_x, Cl, F, PO₄, B, NH₃, and CH₄ desired. An on-line dual-column gas chromatograph also will be available to determine concentrations of CO, CO₂, O₂, N₂, SO₂, NO_x, and He at 1-min intervals. He, the tracer gas, will be continuously injected at a measured rate into the plenum of the furnace to allow calculation of gas flow rate at any point downstream. The output of the chromatograph is displayed on a video monitor and also saved to disk.

3.5. Sampling Procedure:

Sample management tracking will be done as per WHC instructions and procedures, as stated in Attachment B. A description of samples and the frequency of sample collection are summarized in table 3.1.

Table 3.1.- Sampling Record

Type Additives	Description Starting materials	Number and Frequency 1 each material
A Feed	Dry pellets w/o LLW	2 (400 g each)
A Feed	Wet pellets w LLW	2 (400 g each)
A Feed	Dry pellets w LLW	2 (400 g each)
A Feed	Reacted pellets	8 (1 per 500 lb, each 400 g)
A Feed	Reacted pellets	1, (1 kg)
A Feed	Offgas from denitrification	1
B Feed	Wet pellets	2 (400 g each)
B Feed	Reacted pellets	48 (1 per 500 lb, each 400 g)
Offgas	Offgas/particulate	2 sets during demonstration test of B feed
Offgas	Offgas/particulate	1 set during demonstration test of A feed
Offgas	Offgas/particulate	1 set during hot idle
Offgas	Cyclone solids	1 during each offgas set
Offgas	Cyclone solids	Every 2 h, except as above
Offgas	Baghouse	1 during each offgas set
Offgas	Baghouse	Every 2 h, except as above
Offgas	Scrubber solution	1 during each offgas set
Offgas	Scrubber solution	Every 2 h, except as above
Offgas	Cooler/condenser	1 during each offgas set
Offgas	Cooler/condenser	Every 2 h, except as above
Offgas	Thermal oxidizer	1 at end
Glass	Collect on steel plate	1 at T = 0, B feed
Glass	Collect on steel plate	1 each offgas set and 3 others during B feed
Glass	Collect on steel rod	1 during hot idle with B feed
Glass	Collect on steel plate	1 after hot idle with B feed
Glass	Collect on steel plate	1 during A feed
Metal	Collect from metal tap	1 at end of test

3.6. Traceability:

All samples to be analyzed or archived will be assigned an identifying designation, entered on the appropriate log, and stored in clean labeled plastic containers.

Samples of feed and product glass collected at 4-h intervals will be provided to the WHC-designated analytical laboratory, and the others will be archived in clean labeled plastic containers.

All data shall be clearly traceable from a final report back through the analytical records and worksheets to the date of analysis, the individual who performed the analysis, and to the measuring and test equipment used to collect the data.

All analytical test conditions, specimen preparation information, and related data for conducting the analyses shall be documented as a part of the laboratory records, and shall be clearly traceable to the final report of analytical results.

3.7. Records Disposition:

The final disposition of project records (data files, logs, report formats, records storage and disposition) shall be determined by the WHC Project Manager and the subcontractor.

(4) DEMONSTRATION TEST SCHEDULE

4.1. Planned Chronology of Test Events:

4.1.1. Pretest conditions: The following conditions will be assured prior to beginning the demonstration test:

- (1) At least 28,000 lb of pelletized, denitrified, LD6-5510 feed material consisting of 4,000 lb of feed prepared by Method A and 24,000 lb prepared by Method B is available.
- (2) The feed system, furnace, power supply, APCS, and data acquisition systems are functioning, as determined by one or more shakedown tests during which the refractories in the furnace and the ductwork were cured by heating to 1,230 C.
- (3) The thermal oxidizer catch basin is clean and the cyclone and baghouse are clean.
- (4) The scrubber solution concentration is known and the solution has adequate capacity.
- (5) He tracer inlet valve and gas chromatograph are functioning.
- (6) All manual logs are available, and pertinent starting data are entered including electrode weight and length.
- (7) Applicable safety measures are extant.
- (8) Demonstration test procedures have been discussed and are understood by crew members.

4.1.2. Furnace and APCS preparation: Starting time for the demonstration test will be denoted $T = 0$.

1. T minus 24 h: Allow minimum 12 h to heat refractory-lined ductwork to operating temperature (1230 C). Control of temperature during heatup is manual, whereas control during subsequent operation is automatic. The evaporative gas cooling (EGC) system functions automatically at gas temperatures above 260 C. Final cooling of offgas is by programmed air injection. Both blowers (induced draft blower and cooling air blower) are controlled manually, but the flow rate in each system is controlled automatically by butterfly valves (APCS valve and cooling air valve). The baghouse, scrubber, cooler/condenser, and filters function continuously.

2. T minus 12 h: Start furnace and begin feeding equimolar lime-silica mixture at 500 lb/h (225 kg/h). Monitor APCS units to adjust to increasing offgas load. Maintain furnace pressure at negative 0.5 in WC. Continue feeding and melting lime-silica for 6 h to preheat furnace refractories. Calcium silicate is more effective than the test glass composition to preheat the furnace owing to its higher melting temperature (1,544 C). Begin He tracer injection into the furnace plenum, and verify operation of the chromatograph at the baghouse exit. Confirm veracity of thermocouples, pressure and velocity probes, and totalizing water and natural gas meters.

3. T minus 6 h: Begin feeding denitrified pellets of Method B Feed at 500 lb/h. Over 2 h period balance the feed rate, cold top depth, power input, and furnace pressure to melt 1,000 lb/h with continuous tapping of glass. Continue fine tuning of system while melting at 1,000 lb/h for 4 h to purge the furnace of residual calcium silicate. Obtain glass samples at one-half h intervals to document steady state melting conditions.
 4. T minus 15 min: Clean cyclone and baghouse, sample scrubber solution, and collect glass samples (2 kg in a conical steel mold and 2 kg on a cold steel plate).
- 4.1.3. Demonstrate steady state operation with Method B feed:
1. T = 0: Maintain steady state test conditions. Collect, identify, and package samples of glass, cyclone and baghouse solids, and scrubber solution at 2-h intervals.
- 4.1.4. Demonstrate ability to stop for an extended time and restart (1 h):
1. At T plus 8 h stop feed, allow cold top to melt, plug glass tap hole with iron bar, stop power with electrodes in place, and stop cooling water to furnace shell. Maintain cooling water in all other circuits.
 2. At T plus 8 h 20 min restart power supply on transformer tap D. If power starts readily, stop power to continue the stop test.
 3. At T plus 8 h 40 min restart power supply on transformer tap D. If power starts readily, stop power to continue the stop test.
 4. At T plus 9 h restart power supply on transformer tap D. If power supply is slow to start, increase tap to C, then B, and then A until current flow is established. Decrease transformer tap to C, restart water flow to the furnace sidewalls, and begin feeding to increase cold top to previous level. After 30 min, remove iron bar from slag tap hole to initiate continuous tapping. Establishment of continuous tapping completes the demonstration to stop for extended period and restart the furnace.
- 4.1.5. Demonstrate ability to idle for extended time (2 h):
1. At T plus 16 h stop feed, melt cold top, decrease power to minimum (transformer tap D with rheostats 0), and plug glass tap hole with iron bar.

2. At T plus 18 h increase power to previous value, and begin feeding at previous rate. After 30 min remove iron bar to initiate continuous tapping. Establishment of continuous tapping completes the demonstration to idle for an extended period.

4.1.6. Demonstrate steady state operation with Method A feed:

1. T = 20 h switch to Method A feed, and maintain steady state test conditions while feeding and melting 1000 lb/h. Collect, identify, and package samples of glass, cyclone and baghouse solids, and scrubber solution at 2-h intervals.

2. At T plus 24 h cease feeding and allow cold top to melt. Plug glass tap hole with iron bar. Open metal tap hole to drain furnace contents into preheated ladle. Sample glass as it exits the furnace using steel crucible and steel plate. Operate power supply as needed to maintain flow of material from the metal tap hole in order to completely drain the hearth. Sample molten stream near end of tap to capture metal if present. Completion of tapping stops the clock and ends the 24-h demonstration test. Remove ladle from the pit and transfer contents to cast iron molds.

3. Conduct scheduled shutdown procedure for APCS, and allow furnace to cool. Remove electrodes from cool furnace. Record weight, length, and appearance on the electrode log. Collect residues from cyclone and baghouse, and sample scrubber solution. Observe interior of furnace through inspection port in roof, and describe appearance of refractory.

4.2. Decision Points and Schedule for Conduction of Test and Completion of Reports:

Receive Phase I contract from WHC	Jun 20, 1994
Requisition materials and equipment	Jun 27, 1994
Begin preparation and alteration of site	Jun 27, 1994
Submit draft test plan to WHC	Sept 15, 1994
Receive test plan comments from WHC	Oct 28, 1994
Conduct small-scale melting tests	Sep 6, 1994
Submit final test plan to WHC	Dec 20, 1994
Receive approval for test plan from WHC	Dec 23, 1994
Receive all equipment and supplies	Jan 6, 1995
Prepare furnace feeds	Jan 13, 1995
Complete site preparation and assemble of equipment	Feb 10, 1995
Conduct shakedown vitrification tests of 3-phase furnace	Feb 15, 1995
<u>Decision: Conduct W-Size 24-h demonstration test</u>	Feb 17, 1995
Conduct vitrification demonstration test, W-Size or 3-phase furnace	Feb 24, 1995
Finish all test work	Mar 3, 1995
Submit preliminary (quick look) test summary report to WHC	Mar 18, 1995
Submit draft technical summary report to WHC	Mar 25, 1995
Submit melter reliability and life expectancy report to WHC	Mar 25, 1995
Submit draft (full) test report to WHC	Mar 25, 1995
Receive technical summary report comments from WHC	Mar 28, 1995
Submit final technical summary report to WHC	April 5, 1995
Receive (full) test report comments from WHC	April 5, 1995
Submit final (full) test report to WHC	April 7, 1995

(5) SAFETY AND ENVIRONMENTAL ISSUES

5.1. Safety:

All personnel attending the furnace will be required to wear protective clothing, respirators, gloves, boots, safety glasses, and hard hats. Face shields and reflective heat-resistant clothing will be required of the tapping crew. Additional common sense measures will be required including remaining out of harm's way when not actually conducting a task.

5.2 Environmental:

5.2.1. Air quality in the work place: Contamination of air within the building including the control room will be assured by the following preventative and control measures.

1. Emissions of gases and fumes into the building will be significantly decreased during furnace operation by withdrawing air through hoods over the tap holes for injection into the APCS (cooling air). The hood over the metal tap hole will be closed while tapping glass to maximize fume collection over the glass tap hole. Similarly, the hood over the glass tap hole will be closed while tapping of the metal side.
2. Air within the building housing the thermal waste treatment facility will be changed at intervals of 2 min by a combination of 3 blowers that remove air from ducts in the roof.
3. The control room will be pressurized with filtered air to preclude ingress of air from the furnace room.
4. Air within the building will be sampled by stationary air monitoring devices located above the glass (North) and metal (South) tap holes. A reference (R) monitor is installed in the control room. The monitors will be operated for 8 h during the demonstration test.

5.2.2. Air quality in the neighborhood: Contamination of air outside of the building will be well within State guide lines as assured by oxidation of CO and volatile hydrocarbons and destruction of chlorinated hydrocarbons in the thermal oxidizer, collection of particulate and condensed fume solids by baghouse, removal of acid gases by caustic scrubber, and final polishing of exhaust gases by activated carbon and HEPA filters on the stack.

5.2.3. Disposal of unused feed and test products: All feed will be melted to eliminate potential disposal problems. Product glass, cyclone solids, and baghouse solids will be disposed of in a municipal landfill if shown to be benign by analysis. All materials failing the TCLP test will be interred in a hazardous waste landfill. Scrubber and cooler/condenser solutions will be diluted and drained into the city sewer if shown to be benign by analysis. Solutions not acceptable to sewer disposal will be evaporated to dryness, and the solids will be placed in a hazardous waste landfill.

Attachment A:

Sample Management and Tracking Procedure

1.0 Purpose

The following sampling instructions are provided to standardize the sampling, labeling, and handling for the Melter System Technology Evaluation testing for all vendors involved in this project. This document provides a concise set of instructions relating to sample integrity issues involved with this effort. Though the use of the following instructions, positive chain of custody, sample identification, and sample tracking will be achieved.

2.0 Scope

The sampling instructions included in this document deal with sample integrity issues (e.g., control of samples, chain of custody, etc.) involved with obtaining samples to submit for analysis or archive. This document is not intended to provide methods for obtaining actual samples. These instructions are specifically written for vendor samplers for use in Phase I tests associated with the Melter System Technology Evaluation project.

3.0 Supplies

Supplies necessary to ensure good sample integrity and positive chain of custody for sampling are as follows:

- Labels
- Evidence Tape
- Chain of Custody Forms
- Locked Sample Storage Area (e.g., locked room or cabinet)
- Sample Log

4.0 Procedure

4.1 Sample Numbering

To facilitate data evaluation and sample identification by Westinghouse Hanford Company (WHC), a sample identification system has been developed. WHC requests that the vendors utilize this system for sample identification during Phase I testing. The system consists of seven separate identifiers and below, each of the fields and expected information are described (Figure A):

- First Character: Vendor Identification, consisting of the first letter in the vendor's name
- Second Character: Phase identifier (e.g., "1" for Phase I testing)
- Third Character: Sample type. The vendor is free to supplement this with additional sample types specific to each individual process. WHC has identified seven different types of samples:
 - S = LLW Simulant
 - A = Additives
 - F = Feed, Mixed
 - I = Intermediate (e.g., samples between feed and glass product)
 - G = Glass
 - O = Offgas
 - W = Waste
- Fourth Character: Sample point number. Used to designate multiple sample points for a specific sample type, and should relate to a sampling diagram in the test plan

- Fifth through Seventh Characters: Serial sample number. Corresponds to the time samples are taken (e.g., assuming a four hour sampling schedule, 10:00 on the first day of testing, all samples taken have an -001 extension, 14:00 on the first day of testing, all samples taken have an -002 extension, 10:00 on the second day of testing, all samples have an -007 extension, etc.)
- Eighth Character: Laboratory identifier. Used to designate sample destination (Figure A)
- Ninth Character: Snapshot set identifier. This is used to designate samplings where samples are taken from all applicable sample and data points (this is to facilitate easy data identification for mass balance, this will usually correlate with offgas measurements)

4.2 Sample Labeling

Sample labels can be supplied by WHC or generated by the vendor. There are five fields of information required for sample labeling:

- Sample Number: Described in section 4.1
- Sample Date: Date sample taken
- Time Sampled: Time sample taken (24 hour clock)
- Sampler Initials: Initials of sample collector. This will also be the individual who initiates the Chain of Custody form
- Laboratory: Destination for the sample:
 - Quanterra
 - Pacific Northwest Laboratory
 - Westinghouse Hanford Company - 222-S Laboratory
 - Geotechnical Engineering Laboratory - Westinghouse Hanford Company
 - Corning
 - USGS

4.3 Chain of Custody

Chain of Custody (COC) for samples is initiated by the sample collector at the time of sampling. At the end of the shift, the COC should be placed in the same locked storage area as the samples. Boxes on the Chain of Custody form not mentioned in this section will be completed by WHC representatives. There are ten areas of concern for vendor samplers (example forms attached):

- Collector: Name of person collecting sample. This person initiates the Chain of Custody form
- Sample Type: The type of sample collected (e.g., simulant, additive, feed, etc.)
- Possible Hazards: Any potential hazards associated with the samples
- Sample Number: The number generated for the sample (section 4.1)
- Sample Point: Point in the process where the sample was taken
- Date Sampled: Date sample was taken
- Time: Time sample was taken
- Relinquished By: Sample is signed over by the collector to another custodian as needed. (e.g., this will also apply to the custodian, shipper, and transporter).
- Received By: Person receiving custody of the sample (e.g., custodian, shipper, transporter, laboratory)
 - Note: Custody must be relinquished and received each time the sample changes hands (e.g. from the collector to the shipper, sample must be relinquished just prior to shipment even though the transporter may not actually sign the form, and finally from the transporter to the lab custodian)

- **Special Instructions/Remarks:** Complete this section if there are any special instructions for the laboratory

4.4 Sample Log

A sample log is required for summary sampling information and sample tracking. There are eight fields of information required for the sample log (Figure B):

- Sample Number
- Sample Date
- Sample Time
- Sampler Initials
- Sample Type: Type of sample (sample types listed above in section 4.1)
- Sample Point: Location in the process where the sample was taken
- Sample Destination: Location the sample will be shipped to for analysis / archive (section 4.2)
- Shipment Date: Date samples sent for analysis / archive

4.5 Sequential Steps

The following steps should be followed by the vendor to ensure positive chain of custody and sample tracking:

1. Obtain sample
2. Generate sample number (section 4.1)
3. Label sample (section 4.2)
4. Apply tamper resistant evidence tape supplied by WHC and complete initials and date section on tape
5. Complete Chain of Custody form (section 4.3)
6. Complete sample log information (section 4.4)
7. Store sample in a locked area with the Chain of Custody form until shipment

Melter Project: Sample Numbering Scheme

USBM

M	1	F	1	-	0	0	1	Q	1
Vendor Identification	Phase Identifier	Sample Type	Sample Point Number	Hyphen	Serial	Sample	Number	Lab ID	Snapshot Set ID
<i>USBM</i>	<i>Phase 1</i>	<i>Feed Sample</i>	<i>Sample Point 1</i>		<i>Sample</i>	<i>Number</i>	<i>1</i>	<i>Quanterra</i>	<i>1 = 1st Mass Balance Set</i>

Vendor
M = USBM

Sample Type
 F = Feed Additive
 A PW= A Pellets Wet
 APD=A Pellets Dry
 APLW=A Pellets w/LLW
 APR=A Pellets Reacted
 BPW=B Pellets w/LLW
 BPR=B Pellets Reacted
 G1 = Glass
 MT2=Metal Tap
 T3=Thermal Oxidizer Base
 C4=Cyclone
 B5=Baghouse
 S6=Scrubber Solution

Lab ID	Sample Set ID
C = Corning	1 = 1 st Mass Balance Set
G = Archive (GEL)	2 = 2 nd Mass Balance Set
P = PNL	
Q = Quanterra	Blank = Individual Pts.
U = USGS	
W = 222-S	

Figure A

Q1 Rev. 12/01/94				CHAIN OF CUSTODY / SAMPLE ANALYSIS REQUEST										SAF NUMBER: 94-448 / 94-449 Page _____ of _____		
Collector:				Company Contact: Will Eaton				VENDOR: USBM				Data Turnaround Priority Normal				
Project: Melter System Technology Evaluation: Phase 1				Telephone No. (509) 376-9541				Protocol:								
Sample Point:				Sample Type:				Shipped To: QUANTERRA				Date Required:				
Possible Hazards:																
SAMPLE IDENTIFICATION				Container Type	Plastic										Plastic	
				Weight	300 grams										1000 ml	
				# of Containers	1										3	
				Sample Analysis	Unfiltered Metals: Al, B, Ca, Cr, Fe, K, Mg, Mn, Mo, Na, Ni, Si, Sr, Zr 6010	FAA Metal: Cs	Lab Specific	Anions: F, Cl, SO4 NO2, NO3, PO4	EPA 300.0	Iodide	EPA 345.1	TOC	EPA 415.1	TIC	EPA 415.1	pH 9040
Sample Number	Sample Point	Date Sampled	Time													
SPECIAL INSTRUCTIONS / REMARKS:														SAMPLE TYPE S= Simulant G= Glass A= Additives O= Offgas F= Feed, Mixed W= Waste I= Intermediate		

Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time

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CHAIN OF CUSTODY / SAMPLE ANALYSIS REQUEST										SAF NUMBER: 94-411										
										Page _____ of _____										
Collector:		Company Contact: Will Eaton		VENDOR: USBM		Data Turnaround		Priority		Normal										
Project: Melter System Technology Evaluation: Phase 1		Telephone No. (509) 376-9541		Protocol:				Date Required:												
Sample Point:		Sample Type:		Shipped To: QUANTERRA																
Possible Hazards:																				
SAMPLE IDENTIFICATION				Container Type	Plastic															
				Weight	1000 ml															
				# of Containers	3															
				Sample Analysis	Unfiltered Metals: Al, B, Ca, Cr, Fe, K, Mg, Mn, Mo, Na, Ni, Si, Sr, Zr	6010	FAA Metals: Cs	Lab Specific	Anions: F, Cl, SO4	EPA 300.0	Iodide	EPA 345.1	TOC	EPA 415.1	TIC	EPA 415.1	pH	9040	Visual Color	Lab Specific
Sample Number	Sample Point	Date Sampled	Time																	
SPECIAL INSTRUCTIONS / REMARKS:																				
SAMPLE TYPE S= Simulant G= Glass A= Additives O= Offgas F= Feed, Mixed W= Waste I= Intermediate																				
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time									
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time									
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time									
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time									

PI CHAIN OF CUSTODY / SAMPLE ANALYSIS REQUEST														SAF NUMBER: 94-448																	
Page _____ of _____																															
Collector:				Company Contact: Will Eaton				VENDOR: USBM				Data Turnaround Priority Normal																			
Project: Melter System Technology Evaluation: Phase I				Telephone No. (509) 376-9541				Protocol:																							
Sample Point:				Sample Type:				Shipped To: PNL				Date Required:																			
Possible Hazards:																															
SAMPLE IDENTIFICATION				Container Type	Plastic								Plastic																		
				Weight	100 grams								100 grams																		
				# of Containers	1								1																		
				Sample Analysis	Specific Gravity	Evaporable Water	Chemical Analysis Al, B, Ba, Ca, Cs, Cr, F, Fe, K, Mg, Mn, Mo Na, Ni, P, Si, Sr, Ti, Zr	Anions: F, Cl, SO4 I, NO2, NO3, PO4	TOC	TIC	Volume Percent Settled Solids	SEM-EDX	XRD	Optical Microscopy	Chemical Analysis Al, B, Ba, Ca, Cs, Cr, F, Fe, K, Mg, Mn, Mo Na, Ni, P, Si, Sr, Ti, Zr	Fe (II) Total Fe	Product Consistency Test (PCT)	Method A													
Sample Number		Sample Point		Date Sampled		Time																									
SPECIAL INSTRUCTIONS / REMARKS:														SAMPLE TYPE S= Simulant G= Glass A= Additives O= Offgas F= Feed, Mixed W= Waste I= Intermediate																	
Relinquished By				Date/Time				Received By				Date/Time				Relinquished By				Date/Time				Received By				Date/Time			
Relinquished By				Date/Time				Received By				Date/Time				Relinquished By				Date/Time				Received By				Date/Time			
Relinquished By				Date/Time				Received By				Date/Time				Relinquished By				Date/Time				Received By				Date/Time			
Relinquished By				Date/Time				Received By				Date/Time				Relinquished By				Date/Time				Received By				Date/Time			

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P2 Rev. 12/01/94				CHAIN OF CUSTODY / SAMPLE ANALYSIS REQUEST												SAF NUMBER: 94-448 / 94-449 Page _____ of _____			
Collector:				Company Contact: Will Eaton				VENDOR: USBM				Data Turnaround							
Project: Melter System Technology Evaluation: Phase 1				Telephone No. (509) 376-9541				Protocol:				Priority Normal							
Sample Point:				Sample Type:				Shipped To: PNL				Date Required:							
Possible Hazards:																			
SAMPLE IDENTIFICATION				Container Type		Plastic										Plastic			
				Weight		100 grams										1000 ml			
				# of Containers		1										1			
				Sample Analysis		<div style="display: flex; flex-wrap: wrap; padding: 2px;"> <div style="width: 33%;">Unfiltered Metals:</div> <div style="width: 33%;">Al, B, Ca, Cr, Cs,</div> <div style="width: 33%;">Fe, K, Mg, Mn,</div> <div style="width: 33%;">Mo, Na, Ni, Si, Sr,</div> <div style="width: 33%;">Zr</div> <div style="width: 33%;">6010</div> <div style="width: 33%;">Anions: F, Cl, SO4</div> <div style="width: 33%;">I, NO2, NO3, PO4</div> <div style="width: 33%;">Lab Specific</div> <div style="width: 33%;">TOC</div> <div style="width: 33%;">Lab Specific</div> <div style="width: 33%;">TIC</div> <div style="width: 33%;">Lab Specific</div> <div style="width: 33%;">pH</div> <div style="width: 33%;">Lab Specific</div> <div style="width: 33%;">Visual Color</div> <div style="width: 33%;">Lab Specific</div> <div style="width: 33%;">Total Phosphorus</div> <div style="width: 33%;">Lab Specific</div> <div style="width: 33%;">Density</div> <div style="width: 33%;">Lab Specific</div> <div style="width: 33%;">Alkalinity</div> <div style="width: 33%;">Lab Specific</div> </div>													
Sample Number	Sample Point	Date Sampled	Time																
SPECIAL INSTRUCTIONS / REMARKS:																SAMPLE TYPE S= Simulant G= Glass A= Additives O= Offgas F= Feed, Mixed W= Waste I= Intermediate			

Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time

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P3 Rev. 11/28/94				CHAIN OF CUSTODY / SAMPLE ANALYSIS REQUEST												SAI NUMBER: 94-411 Page _____ of _____					
Collector:				Company Contact: Will Eaton				VENDOR: USBM				Data Turnaround									
Project: Melter System Technology Evaluation: Phase I				Telephone No. (509) 376-9541				Protocol:				Priority Normal									
Sample Point:				Sample Type:				Shipped To: PNL				Date Required:									
Possible Hazards:																					
SAMPLE IDENTIFICATION				Container Type		Plastic															
				Weight		1000 ml															
				# of Containers		1															
				Sample Analysis		<div style="display: flex; justify-content: space-between; font-size: 0.8em;"> <div> Unfiltered Metals: Al, B, Ca, Cr, Cs, Fe, K, Mg, Mn, Mo, Na, Ni, Si, Sr, Zr </div> <div>6010</div> <div> Anions: F, Cl, SO4 I, NO2, NO3, PO4 </div> <div>Lab Specific</div> <div>TOC</div> <div>Lab Specific</div> <div>TIC</div> <div>Lab Specific</div> <div>pH</div> <div>Lab Specific</div> <div>Visual Color</div> <div>Lab Specific</div> <div>Total Phosphorus</div> <div>Lab Specific</div> <div>Density</div> <div>Lab Specific</div> <div>Alkalinity</div> <div>Lab Specific</div> <div></div> <div></div> </div>															
Sample Number		Sample Point		Date Sampled		Time															
SPECIAL INSTRUCTIONS / REMARKS:																		SAMPLE TYPE S= Simulant G= Glass A= Additives O= Offgas F= Feed, Mixed W= Waste I= Intermediate			

Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time

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CHAIN OF CUSTODY / SAMPLE ANALYSIS REQUEST				SAF NUMBER: 94-448 / 94-449		
				Page _____ of _____		
Collector:	Company Contact: Will Eaton		VENDOR: USDM		Data Turnaround	
Project: Melter System Technology Evaluation: Phase 1	Telephone No. (509) 376-9541		Protocol:		Priority Normal	
Sample Point:	Sample Type:		Shipped To:		Date Required:	
Possible Hazards:		222-S LABORATORY				
SAMPLE IDENTIFICATION		Container Type	Plastic		Plastic	
		Volume/Weight	250 grams		1000 ml	
		# of Containers	1		1	
		Sample Analysis	Specific Gravity	Lab Specific	Volume Percent Settled Solids	Lab Specific
			Volume Percent Centrifuged Solids	Lab Specific	OH-	Lab Specific
Sample Number	Sample Point	Date Sampled	Time			
SPECIAL INSTRUCTIONS / REMARKS:						
SAMPLE TYPE S= Simulant G= Glass A= Additives O= Offgas F= Feed, Mixed W= Waste I= Intermediate						
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	

CI CHAIN OF CUSTODY / SAMPLE ANALYSIS REQUEST														SAF NUMBER: 94-408																	
														Page _____ of _____																	
Collector:				Company Contact: Will Eaton				VENDOR: USBM				Data Turnaround Priority Normal																			
Project: Melter System Technology Evaluation: Phase I				Telephone No. (509) 376-9541				Protocol:																							
Sample Point:				Sample Type:				Shipped To: CORNING LABORATORY				Date Required:																			
Possible Hazards:																															
SAMPLE IDENTIFICATION				Container Type	Plastic								Plastic																		
				Weight	100 grams								100 grams																		
				# of Containers	1								1																		
				Sample Analysis	Specific Gravity	Evaporable Water	Chemical Analysis Al, B, Ba, Ca, Cs, Cr, F, Fe, K, Mg, Mn, Mo, Na, Ni, P, Si, Sr, Ti, Zr	Antions: F, Cl, SO4 I, NO2, NO3, PO4	TOC	TIC	Volume Percent Settled Solids	SEM-EDX	XRD	Optical Microscopy	Chemical Analysis Al, B, Ba, Ca, Cs, Cr, F, Fe, K, Mg, Mn, Mo, Na, Ni, P, Si, Sr, Ti, Zr	Fe (II) Total Fe	Product Consistency Test (PCT)	Method A													
				Sample Number	Sample Point	Date Sampled	Time																								
SPECIAL INSTRUCTIONS / REMARKS:														SAMPLE TYPE																	
														S= Simulant G= Glass A= Additives O= Offgas F= Feed, Mixed W= Waste I= Intermediate																	
Relinquished By				Date/Time				Received By				Date/Time				Relinquished By				Date/Time				Received By				Date/Time			
Relinquished By				Date/Time				Received By				Date/Time				Relinquished By				Date/Time				Received By				Date/Time			
Relinquished By				Date/Time				Received By				Date/Time				Relinquished By				Date/Time				Received By				Date/Time			
Relinquished By				Date/Time				Received By				Date/Time				Relinquished By				Date/Time				Received By				Date/Time			

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CHAIN OF CUSTODY / SAMPLE ANALYSIS REQUEST										SAF NUMBER: 94-408	
										Page _____ of _____	
Collector:		Company Contact: Will Eaton		VENDOR: USBM		Data Turnaround					
Project: Melter System Technology Evaluation: Phase I		Telephone No. (509) 376-9541		Protocol:		Priority		Normal			
Sample Point:		Sample Type:		Shipped To:		Date Required:					
Possible Hazards:				USGS LABORATORY							
SAMPLE IDENTIFICATION				Container Type	Plastic			Plastic			
				Weight	100 grams			100 grams			
				# of Containers	1			1			
				Sample Analysis	Specific Gravity						
					Evaporable Water						
					Chemical Analysis Al, B, Ba, Ca, Cs, Cr, F, Fe, K, Mg, Mn, Mo Na, Ni, P, Si, Sr, Ti, Zr						
					Anions: F, Cl, SO4 I, NO2, NO3, PO4						
					TOC						
					TIC						
					Volume Percent Settled Solids						
					SEM-EDX						
					XRD						
					Optical Microscopy						
					Chemical Analysis Al, B, Ba, Ca, Cs, Cr, F, Fe, K, Mg, Mn, Mo Na, Ni, P, Si, Sr, Ti, Zr						
					Fe (II) Total Fe						
					Product Consistency Test (PCT)						
					Method A						
SPECIAL INSTRUCTIONS / REMARKS:											
SAMPLE TYPE S= Simulant G= Glass A= Additives O= Offgas F= Feed, Mixed W= Waste I= Intermediate											
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time

GI CHAIN OF CUSTODY / SAMPLE ANALYSIS REQUEST										SAF NUMBER: 94-408	
										Page _____ of _____	
Collector:			Company Contact: Will Eaton			VENDOR: USBM			Data Turnaround		
Project: Melter System Technology Evaluation: Phase 1			Telephone No. (509) 376-9541			Protocol:			Priority Normal		
Sample Point:			Sample Type:			Shipped To: GEOTECHNICAL ENGINEERING LABORATORY			Date Required:		
Possible Hazards:											
SAMPLE IDENTIFICATION				Container Type	Plastic		Plastic		Plastic		
				Volume/Weight	100 grams		250 ml		1000 ml		
				# of Containers	1		1		1		
				Sample Analysis	ARCHIVE SAMPLES		ARCHIVE SAMPLES		ARCHIVE SAMPLES		
Sample Number	Sample Point	Date Sampled	Time	Cabinet	Shelf	Cabinet	Shelf	Cabinet	Shelf	Date Received by WIIC	
SPECIAL INSTRUCTIONS / REMARKS:										SAMPLE TYPE S= Simulant G= Glass A= Additives O= Offgas F= Feed, Mixed W= Waste I= Intermediate	
Relinquished By		Date/Time		Received By		Date/Time		Relinquished By		Date/Time	
Relinquished By		Date/Time		Received By		Date/Time		Relinquished By		Date/Time	
Relinquished By		Date/Time		Received By		Date/Time		Relinquished By		Date/Time	
Relinquished By		Date/Time		Received By		Date/Time		Relinquished By		Date/Time	

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XI CHAIN OF CUSTODY / SAMPLE ANALYSIS REQUEST										SAF NUMBER: _____					
Page _____ of _____															
Collector:			Company Contact: Will Eaton			VENDOR: USBM			Data Turnaround Priority Normal						
Project: Melter System Technology Evaluation: Phase 1			Telephone No. (509) 376-9541			Protocol:									
Sample Point:			Sample Type:			Shipped To:			Date Required:						
Possible Hazards:															
SAMPLE IDENTIFICATION				Container Type	Plastic			Plastic			Plastic				
				Weight/ Volume	100 grams			250 grams			1000 ml				
				# of Containers	1			1			1				
				Sample Analysis											
Sample Number	Sample Point	Date Sampled	Time												
SPECIAL INSTRUCTIONS / REMARKS:										SAMPLE TYPE S= Simulant G= Glass A= Additives O= Offgas F= Feed, Mixed W= Waste I= Intermediate					
Relinquished By		Date/Time		Received By		Date/Time		Relinquished By		Date/Time		Received By		Date/Time	
Relinquished By		Date/Time		Received By		Date/Time		Relinquished By		Date/Time		Received By		Date/Time	
Relinquished By		Date/Time		Received By		Date/Time		Relinquished By		Date/Time		Received By		Date/Time	
Relinquished By		Date/Time		Received By		Date/Time		Relinquished By		Date/Time		Received By		Date/Time	