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WSRC Am/Cm Stabilization Program - Cylindrical Induction Melter Studies

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1.0 Introduction

1.1 Summary

1.1.1 Kilogram quantities of Americium and Curium isotopes (Am/Cm) have been produced at the U.S. Department of Energy (DOE), Savannah River Site (SRS), Aiken, South Carolina. These highly radioactive isotopes have both government and commercial value and are currently stored as a nitric acid solution at the Savannah River Site. The material represents the largest source term in the F canyon at SRS. It is proposed that the Am/Cm material be vitrified to stabilize the material for long term, recoverable storage. This paper reviews the progress made during the process development phase of this program using the Cylindrical Induction Melter.

1.2 Am/Cm History

1.2.1 Approximately 11,000 liters (3,600 gallons) of nitric acid solution containing 10 Kg of Americium-243 isotopes and 3 Kg of Curium-244 isotopes are currently stored at SRS. These isotopes were recovered during Plutonium-242 production campaigns in the mid- and late-1970's, and are maintained behind heavy shielded walls as about 7 Kw/Hr total nuclear activity is emitted from the Americium (~1,800 Curies) and Curium (~210,000 Curies). The continued storage of these isotopes is an item of primary concern to the DOE. Currently, there are no existing SRS facilities that can be used to stabilize this material for safe interim storage and transportation to the heavy isotopes program at the Oak Ridge National Laboratory (ORNL). An analysis of several alternatives resulted in the recommendation to stabilize the Am/Cm solution in a high-lanthanide glass. The Multi-Purpose Processing Facility (MPPF) in the F-Canyon will be used for the vitrification process. Pretreatment operations will be performed in existing canyon vessels to separate actinides and lanthanides from other impurities (primarily iron, aluminum, and sodium) prior to the vitrification operation [Marra, 1998].

1.3 Am/Cm Resistance Heated Melter Development

1.3.1 Experimental work for the project began in 1995 by SRTC. Surrogate (non-radioactive) feed solutions were used. The technology selected for the Am/Cm vitrification was derived from the glass marble-melt fiberization process used in commercial industry. The small platinum/rhodium alloy bushing melters were investigated. These bushing melters are heated by the resistance incurred while passing large electrical currents through the Pt/Rh alloy outer walls and internal screens via the end terminal connections. After two years of development work with various bushing melter designs, it was determined that the technical risks associated with a bushing melter were unacceptable. Therefore, work began on development of a Pt/Rh alloy cylindrical induction melter (CIM). The CIM allowed for more precise temperature control throughout the melter is more structurally sound at the high temperatures required for vitrification of this particular feed, and is better suited to the MPPF environment. The process flowsheet was also changed from a continuous feed to a batch process. The proposed baseline flowsheet includes precipitation of the actinide materials with oxalic acid and then washing the precipitate to lower the nitric acid concentration. The subsequent oxalate precipitate along with glass formers is then added to the melter vessel. The resultant mixture is then dried and heated to approximately 1400°C to produce a molten glass product. The glass is then poured through a drain tube into a stainless steel cylinder.

1.3.2 Bushing Melter No.1

1.3.2.1 Am/Cm Bushing Melter 1 was initially designed to vitrify glass into which the nitric acid solution of Americium and Curium would be added. Melter 1 was an 80% Pt/20% Rh vessel insulated with castable refractory and powered by a 35 KVA low voltage, high current transformer. The 6-inch long drain tube was welded directly to the bottom drain opening of the melter vessel. The drain tube heater assembly was mounted to the lower melter frame such that the drain tube extended within the annulus of the drain tube heater. The initial drain tube heater assembly consisted of a 6 inch long 80% Pt/ 20% Rh alloy tube of 0.030-inch wall thickness concentric with an insulated heater coil.

1.3.2.2 The heating element was an 80% Pt/20% Rh wire, 0.060-inch thickness, wound around a ceramic tube and potted in castable refractory material.

1.3.2.3 Bushing Melter 1 contained seven type R thermocouples for temperature monitoring purposes, all of which measured the outside surface temperature of the Pt/Rh vessel. Two of these thermocouples provided input to the melter power controller, which regulated power input to the Pt/Rh vessel to maintain the desired vessel (and glass) temperatures. The drain tube heater assembly contained four additional type R thermocouples. Two measured the temperature of the Pt/Rh drain tube and two measured the insulated heater coil wire. A manually operated powerstat was used to control the power input to the drain tube heater coil.

1.3.2.4 The Bushing Melter 1 design proved inadequate due to its inability to keep the molten glass pool's exposed surface hot enough to allow for continuous feeding of the glass frit and nitric acid surrogate solution while avoiding overheating the lower glass pool.

1.3.3 Bushing Melter No. 2A

1.3.3.1 The second generation Bushing Melter 2A was designed and fabricated to include dual power input with additional heating screens. The redesign of the heating screens promoted the use of convection currents to bring the hotter glass from the lower area of the melt pool to the exposed cold cap at the top of the melt pool. This dual zone power input allowed for flexible heating of the upper cold cap area of the glass pool vs. the lower molten glass pool area.

1.3.3.2 The Bushing Melter 2A differed from the original Bushing Melter 1; it incorporated a reduced vapor space above the glass melt surface as a result of a shorter off-gas plenum, addition of an off-gas film cooler within the plenum, and PC monitoring/control of the process.

1.3.3.3 The vessel was a 90% Platinum/10% Rhodium alloy rectangular vessel of 25.4 cm wide by 7 cm thick by 28 cm tall. Two sets of Pt/Rh screens were located just below the melt line to aid in melting the feed. The Melter 2A operated at 1350°C to 1500°C. The glass was gravity fed from the bottom of the melter through an 80% Pt/20% Rh alloy heated drain tube, 6 in. long by 0.2 in. inside diameter, of 0.030-in. wall thickness. Applying cooling air to the upper and lower portions of the drain tube stopped the glass stream.

1.3.3.4 Although glass pool temperature control was improved by utilizing the dual zone power application, severe foaming of the glass batch was encountered when the nitric acid surrogate solution was fed to the melter which contained a glass pool of 50SrABS Hybrid glass. The foaming, coupled with extreme amounts of lead volatilization from the glass which resulted in the plugging of the off-gas film cooler, resulted in abandoning the bushing melter design concept.

1.3.4 Drain Tube Test Stand (DTTS)

1.3.4.1 The original Am/Cm Bushing Melter 1 was redesigned to allow for off-line testing of various drain tube heater configurations without interfering with the Bushing 2A development activities. The Melter 1 vessel was replaced with a 2.5-in. diameter by 11 in. tall by 0.060-in. wall thickness cylindrical vessel insulated with refractory brick and powered by the original 35 KVA transformer. The DTTS vessel was constructed of 90% Platinum/10 % Rhodium alloy. A 6-inch long Pt/Rh drain tube was attached to the bottom of the melter vessel, which was initially heated by a Pt/Rh resistance wire heater assembly.

1.3.4.2 The DTTS has been used to support the Am/Cm Vitrification Development project in many ways. The DTTS was originally used primarily in the development and testing of various drain tube heater designs. Most recently, the DTTS has been used in determining the operating characteristics of various glass batch compositions prior to their introduction to the CIM system.

2.0 Cylindrical Induction Melter System (CIM)

2.1 The CIM consists of seven major subsystems: Melter, Off-Gas, Chilled Water, Power Supplies, Surrogate Precipitation and Feed, and Instrumentation and Controls. The CIM has progressed through three designs. The original concept was a 3-inch melter for research purposes heated by two induction coils, one on the melter itself and one on the drain tube. A third zone was added at the conical section to allow greater control of the vertical temperature profile. After successful test runs with this configuration, a five-inch diameter melter was designed and constructed using the three-heat zone concept. The larger size was needed to duplicate production quantities. The five-inch system is currently in use and this design will be used for the final production system.

2.2 Melter Design

2.2.1 The melter vessel is constructed of an 80% platinum/20% rhodium alloy for corrosion and temperature resistance. The rhodium alloy enhances the high temperature strength capabilities of the vessel. It is cylindrically shaped, and heats by induction as a result of exposure to Electro-magnetic fields generated by the heat station. The vessel is 14" high overall, consisting of a 13" tall by 3" diameter cylinder, with the bottom 1" tapered to produce a conical transition to the 6" long by 0.20" I.D. drain tube welded to the bottom. The vessel wall thickness is 0.080", and the drain tube wall thickness is 0.030". Four R-type thermocouples are welded to the vessel wall while four spring-loaded R-type thermocouples are located along the length of the drain tube.

2.2.2 The vessel is surrounded by a Zircar insulating cylinder slipped between the vessel outer diameter and the water-cooled copper coils through which electric current is passed which produces the Electro-magnetic field. The conical bottom of the vessel and the drain tube are surrounded with insulation. The insulation is located between the induction coil and the vessel. The insulation serves to keep the vessel hot and limit heat gain to the copper induction coil.

2.2.3 Pour is initiated by heating the drain tube with the induction coil. To terminate the pour, cooling air is directed upon the drain tube to cool and stop the flow. The cooling air is supplied to the drain tube through four air jets. The air jets are located at two elevations on the drain tube - two near the top and two near the bottom. Cooling air for stopping glass flow through the drain tube is at flow rates up to 180 SCFH per pair.

2.2.4 Thermal growth in the vertical direction is significant. Since the current CIM does not incorporate a plenum bolted to the top of the assembly, the melter is not constrained at the top. As the vessel heats, it is simply allowed to expand out the top of the assembly. Radial growth is accommodated by the Zircar insulation fitted around the vessel.

2.2.5 The drain tube subassembly is designed such that up to four thermocouples can monitor temperature at any given time. The thermocouples are spring-loaded against the drain tube itself. To minimize the bending load on the drain tube, two thermocouples are located at the same elevation and oppose each other. This cancels out the side-loads imposed by the thermocouple springs on the drain tube. This load, while not critical at normal room temperature becomes significant at operating temperatures as the pt-Rh alloy softens. Each thermocouple and cooling jet can be adjusted independently to allow for flexing of the drain tube that occurs during the first heat cycle.

2.2.6 All metallic components around the induction field are aluminum and brass. These materials do not interact with the magnetic induction field as effectively as ferrous metals; and therefore, do not self-heat. Other non-metallic heat-resistant components are used to support the bottom of the melter when in very close proximity to the induction coil.

2.3 Melter Power Supply

2.3.1 There are three power supplies for the CIM; one for the top section, one for the conical section, and one for the drain tube. The top section is powered by an Ameritherm Model XP-20 Solid State Induction Heating Station and Power Supply. This unit supplies 20kW maximum power through the heating station to the vessel heating coils, operating at an RF Voltage of 1050 VRMS and a frequency between 50 and 450 kHz. The power supply auto-tunes at start-up to an appropriate frequency for the induction coil design. Both the power supply and heating station are water cooled from a closed-loop chilled water source. Approximately 6 gal/min water flow at 40 - 60 psi and 68° - 95°C are required to maintain the power supply and heat station at their proper operating temperatures. Internal sensors are present to detect low water flow and shut down the supply.

2.3.2 There are two 5 kW units operating at a RF voltage of 350 VRMS and a frequency between 50 and 450 kHz. The supplies auto-tune at start-up to an appropriate frequency for the induction coil design. One supply is for the conical section and the other is for the drain tube. Both power supplies and heating stations are water cooled from a closed-loop chilled water source. Approximately 1 gal/min water flow at 40-60 psi and 68-95°C is required to maintain power supply and heat station at their proper operating temperatures.

2.4 Off Gas System

2.4.1 Elimination of Lanthanide particulate emissions is the primary concern in treatment of the melter off-gas. The emissions before treatment were estimated to be extremely low, less than 0.003 weight-percent; however, as a good practice in preparation for eventual use in a nuclear process, a HEPA-type filter was included in the treatment system. A hood-type off-gas capture arrangement is used in order to eliminate problems encountered in previous designs associated with a sealed melter and plenum space. This hood arrangement dictated the off-gas air volumes and velocities required to capture melter emissions (80 scfm at the hood face).

2.4.2 An additional design consideration is to keep water from entering the HEPA filter housing. This job is traditionally accomplished by heating the air before entry into the HEPA to raise the temperature above the dew point. Because simplicity and adaptability are of prime concern, another approach is needed. First, a standard gas/liquid centrifugal separator (Wright-Austin Type T, 2-inch, Stainless Steel Separator) is installed between the hood and the HEPA housing. The separator removes gross moisture content and any condensation that may form in the piping run between the hood and the separator (approximately 8 feet). Second, 25% additional dry air is added to the off-gas flow after the separator in order to lower the dew point and prevent further condensation. The final consideration was to provide a suitable motive force for the required off-gas volume. An air driven jet compressor (Schutte & Koerting Type 420 with 2-inch connection) was selected since it provided the simple and robust solution required for remote operation.

2.4.3 Current operational experience with this off-gas system demonstrates the effectiveness of the design. Potential problems such as line pluggage, equipment failures, or loss of control have not been experienced. Off-gas system particulate sampling from a location between the hood and the moisture separator indicates that the initial analysis was correct, and that emissions are below the level where filtering would be required. However, as a conservative measure the filtered off-gas system was selected as the baseline design for the production facility.

2.5 Control System

2.5.1 Overview

2.5.1.1 The melter control system monitors six major systems: Melter, Off-Gas, Chilled Water, Power Supplies, Surrogate Precipitation and Feed. Each system must be monitored for performance to assure the safe operation of the system. The Melter and Surrogate Precipitation and Feed systems provide the information needed to assure consistent product quality. Alarms and power interlocks are provided which receive input from the four vessel surface-welded thermocouples; the optical pyrometer and the cooling water flow and temperature.

2.5.2 Instrumentation

2.5.2.1 Primary temperature control is provided by an optical pyrometer sensing the infrared energy emitted by the outer Pt/Rh vessel wall. The pyrometer used is a Mikron model M68 fiber Optic sensor. The fiber optic device allows the electronics to be placed fifteen feet away from the sensor head. This provides excellent Radio Frequency (RFI) noise resistance in the high fields encountered around the CIM vessel. Four type R thermocouples installed on the melter are monitored to protect the melter from over-temperature conditions. The melter temperature is monitored for analysis purposes at the feed tip using 2 type R thermocouples and in the melt pool using 2 more type R thermocouples. All of the thermocouple signals are filtered for RFI interference using an Acromag Model 250T thermocouple to 4-20 mA modules. Shielding and filtering for RFI was a major challenge in the design of the instrumentation system.

2.5.2.2 The chilled water system supplies cooling water to the power supplies. Temperature and flow to each unit are monitored for protection of these systems. The off-gas system is monitored with industrial pressure and flow instrumentation to assure proper operation. In addition, a port is available for connecting to a gas chromatograph for off-gas analyses. Power output from the three power supplies are monitored and recorded to help the operator make control decisions and to build an operational baseline for future process parameters. The Surrogate Precipitation and Feed system is a manually operated, batch system with visual level, temperature indicators to guide the operator.

2.5.3 Human Machine Interface and Control System

2.5.3.1 FactoryLink ECS, a software package, provides operator interface to the process. A Modicon 984 PLC provides control functions. Two interface modules are used: Modbus for communication with the PLC and an ASYNC or General Purpose Interface which provides RS232 communications to the power stations and the weight scale. FactoryLink also supports Power Visual Basic. The power of this utility is its ability to use all FactoryLink tag attributes without declaration or dimensioning. Code can be attached to graphical objects to provide for; data storage to disk, data collection from disk or over the network, graphics manipulation, input error checking, and other data management tasks.

2.5.4 Data Acquisition System

2.5.4.1 The data acquisition system for this application was developed in LabViewTM, it communicates with the ModiconTM 984 Programmable Logic Controller (PLC) over an RS232C communication line using the MODBUS RTU protocol. This system allows any PLC register to be monitored and recorded at any multiple of five seconds. The system is designed with two user selectable configurations, the first for research where every register in the point list is recorded every five seconds and the second for production where points are recorded much less frequently. In this application, about 50 points are monitored. Data files are written as tab delimited text and new files are generated every hour. The system is field configurable allowing changes to the point list, point name, scaling, and collection frequency to be made by the operator. Current trending is available for up to four points simultaneously and is updated in real time every five seconds. The figure below shows the user interface for the data acquisition system.

2.5.5 Procedures and Operator Training

2.5.5.1 In preparation for the operation of the Am/Cm Pilot Facilities, safety and administrative activities were completed. Procedures were written to cover items such as overall operation of the experimental equipment and process and emergency response. Technical personnel and operators were trained in the use of these procedures. Process Hazards Reviews, Job Hazards Analyses and additional safety reviews were performed prior to the startup of each melter. Individual Runs Plans were written and implemented during each experimental run.

3.0 Oxalic Pretreatment Process Description

3.1 Operation of the pilot facility is performed with a surrogate feed solution representing the expected composition of the feed after F-Canyon pretreatment. The first surrogate feed was based on 1993 sample results of the F-canyon Am-Cm solution and used erbium as a substitute for both americium and curium. Results of a 1998 sample have been obtained and the surrogate feed revised to incorporate the new sample results. Both surrogate compositions have been tested with no observed processing differences. The baseline glass forming composition (25SrABS) and the two surrogate feed compositions are shown in Table 1. #Er2O3 substituted for Am2O3 and Cm2O3 on weight percent basis. [dagger]Dy, Ho, Lu, Tb, Tm and Yb are present in the radioactive feed stream in very small amounts but not included in the surrogate feed. Lanthanides were normalized to account for the removal of these constituents [Fellinger, 1998].

Table 1. Surrogate feed and 25SrABS glass former compositions

3.2 An oxalic acid precipitation of the nitric acid feed stream will be the only "in-cell" pretreatment step before the feed material is introduced to the melter vessel. The precipitation pretreatment flowsheet is shown in Figure 1. The pretreatment includes a precipitation with the addition of 8 weight percent oxalic acid. The precipitated oxalates (primarily rare earth oxalates) are settled and the free liquid decanted. The precipitated oxalates are washed with 0.1 molar oxalic acid, and again allowed to settle before the

wash solution is decanted. A 1.0-liter surrogate precipitation yields approximately 160 grams of oxalate solids. The washed oxalate precipitate is then re-suspended and drained into the melter vessel on top of the 25SrABS glass formers. The precipitator is then rinsed with de-ionized water to remove residual solids. The volume of each feed chemical and reaction product is shown in Table 2 for both the 3" CIM and 5" CIM systems [Fellinger, 1998].

3.2.1 Precipitator Tank - The precipitator is a 25 liter 304 stainless steel cylindrical tank surrounded by a 1" annular water jacket. The tank has a 60-degree conical bottom and an inside diameter of 10 inches. The mixer is a Servodyne laboratory mixer with digital speed control and readout. The mixer is fitted with two 3" radial flow turbine agitator blades. The bottom blade is located at the solid-liquid interface when the solids in the tank are allowed to settle and the upper blade is 7" above the lower blade. A high level probe and temperature are the only instruments on the tank. The drain valve is a 1" pipe with a full-bore ball valve.

3.2.2 Surrogate Feed System - The surrogate feed is made-up in a 52-liter carboy, which also serves as the pilot facility feed tank. The surrogate is pumped from the feed carboy into a batch tank. The batch tank has an overflow line set to overflow when the tank contains the required amount of surrogate. The batch tank is gravity drained to the precipitator.

3.2.3 Oxalic Acid Feed System - The 8-weight percent oxalic acid and 0.1M oxalic acid are also made-up in carboys, which also serve as the pilot facility tank. The 8-weight percent acid is maintained at the same temperature as the precipitator tank with a water bath. The 8-weight percent oxalic acid is metered to the precipitator with a peristalic metering pump. The 0.1M oxalic acid is pumped to the precipitator using the same line. The 0.1M serves as a line flush in addition to washing the oxalate solids in the precipitator. The oxalic acid is added to the precipitator as a subsurface feed to avoid splattering during the precipitation process.

3.2.4 Precipitator Rinse System - The precipitator rinse is metered into the precipitator with a peristalic-metering pump. Initially, a spray ring was used to distribute the rinse along the vessel walls, but high flowrate requirements led to the development of a "slinger ring" mounted on the agitator shaft. The slinger ring is a 4" diameter radial flow turbine agitator blade with a solid bottom plate. The rinse water is dropped onto the plate and centrifugal force slings the rinse water onto the tank walls.

3.2.5 Decant System - The decant tank is a 25 or 52 liter carboy. An airjet is used to pull a 25 to 30 INWC vacuum on the decant tank to start the decant process. Once the decant is started, the air jet is stopped and the solution allowed to siphon into the decant tank. The dip leg for the decant transfer is set to leave 2500 ml of solution in the precipitator after decanting for a 6.9 liter precipitation.

Figure 2. Precipitator Vessel

4.0 Glass Chemistry

4.1 Glass Former

4.1.1 Composition - The nominal 25SrABS frit composition (see Table 3) was selected based on a balance between the feed loading, melting characteristics of the frit, and interactions between the frit and the oxalate precipitate). Although the specifications for size and size distribution are not defined at this time, the 25SrABS frit was obtained from a vendor to support testing in the Drain Tube Test Stand (DTTS) and the Cylindrical Induction-Heated Melter (CIM) and can be manufactured to the specifications during operations testing. The compositional specifications submitted to the vendor are shown in Table 3.

4.1.2 Particle Size - The particle size and shape of the 25SrABS glass former is being addressed in the DTTS and the CIM using three different mesh sizes. The particle size of the frit may be crucial due to a volume expansion and/or high temperature bubble formation that has been observed in laboratory-scale tests and confirmed in both the DTTS and CIM. The volume expansion is most prevalent when the particle size of the 25SrABS frit is relatively small (e.g., < 100 mesh). When coarse 25SrABS cullet is used, the effects of the volume expansion are minimized, if not eliminated.

4.2 Product Description

4.2.1 Nominal Composition - Table 4 shows the nominal compositions (in wt%) of the 25SrABS glass former, the nominal baseline glass composition (AmCm-1a) based on a 47 wt% loading and the most recent material balance calculations and the AmCm-1 surrogate composition. The compositional specifications (or tolerances) that will be allowed in the MPPF have not yet been determined. This is being addressed in a 20% composition variability study to be performed during future CIM runs. The AmCm-1a surrogate glass is very similar in composition to that estimated as the baseline. There are some minor differences in the relative percentage of the lanthanide oxides. This stems from the fact that the oxides of Tb, Dy, Ho, Er, Tm, Yb, and Lu appear to be at or below detection limits of the analytical equipment. Assuming that these oxide components are not present in the incoming actinide-bearing stream, one can distribute their contribution (2.66 wt%) over the remaining lanthanide oxides (i.e., increase the other seven Ln2O3 concentrations by 0.38 wt%). Again, previous work has suggested that the total Ln2O3 concentration is critical, not the distribution. This "redistribution" technique keeps the total Ln2O3 content equivalent to that of the nominal baseline glass (AmCm-1a).

Oxide	**Actinide Bearing Feed Material (Tank 17.3E)**	**25SrABS Frit**	**AmCm-1a Glass (47% loaded)**	**AmCm-1a Glass (surrogate)**
Lanthanide Oxides				
La_2O_3	15.05	25.00	20.323	20.502
Ce_2O_3	12.94	-	6.082	6.260
Pr_2O_3	11.26	-	5.292	5.471
Nd_2O_3	32.80	-	15.416	15.595
Sm_2O_3	7.49	-	3.520	3.669
Eu_2O_3	1.56	-	0.733	0.912
Gd_2O_3	3.98	-	1.871	2.049
Tb_2O_3	0.36	-	0.169	0.00
Dy_2O_3	0.36	-	0.169	0.00
Ho_2O_3	0.36	-	0.169	0.00
Er_2O_3	0.35	-	0.165	0.00
Tm_2O_3	0.53	-	0.249	0.00

Yb_2O_3	0.35	-	0.165	0.00
Lu_2O_3	0.35	-	0.165	0.00
Actinide Oxides				
Am_2O_3	9.70	-	4.559	4.559 (Er_2O_3)
Cm_2O_3	2.38	-	1.119	1.119 (Er_2O_3)
Np_2O_3	0.00	-	0.00	0.00
PuO_2	0.00	-	0.00	0.00
UO3	0.00	-	0.00	0.00
Cs_2O	0.00	-	0.00	0.00
Metallic oxides				
Al_2O_3	0.01	24.87	13.186	13.186
B_2O_3	0.00	13.54	7.176	7.176
CaO	0.00	-	0.00	0.00
Cr_2O_3	0.00	-	0.00	0.00
Fe_2O_3	0.03	-	0.014	0.014
K_2O	0.00	-	0.00	0.00

MnO	0.14	-	0.066	0.066
Na_2O	0.00	-	0.00	0.00
NiO	0.00	-	0.00	0.00
SiO_2	0.00	33.68	17.850	17.850
SrO	0.00	2.91	1.542	1.542
ZnO	0.00	-	0.00	0.00
ZrO_2	0.00	-	0.00	0.00
Total	100.00	100.00	100.00	100.00

Table 4. Actinide-Bearing Feed Material, 25SrABS Frit Composition, and Target Glass Composition (actual and surrogate) on an Oxide (wt%) Basis

4.2.2 Product Density - The glass density as a function of temperature has not been determined. For material balance purposes, a density of 3.7 g/cc was used to calculate the volume occupied by 2.0 kg of glass. Work will be performed in the future to determine the high-temperature density of the various lanthanide-based glasses.

4.2.3 Product Viscosity - Table 5 gives the viscosity of AmCm-1a glass surrogate as a function of temperature. Glass viscosity data is critical in establishing the length and internal diameter of the drain tube and the temperature operating parameters to ensure a target glass pour rate of greater than 8.0 kg/hr is attained. It should be noted that the viscosity data for Am-Cm-1a is limited to a relatively narrow temperature range (approximately 1285° - 1385°C). This is a result of the steep dependence of viscosity and temperature for the lanthanide borosilicate glasses. Above 1385°C, the AmCm-1a viscosity approaches the lower detection limit of the viscometer. Below 1300°C, crystallization effects the viscosity measurement due to the liquidus temperature of the glass).

Temperature (C)	Viscosity (Poise)
1285	22.12
1334	12.38

1384	7.34

Table 5. Viscosity of AmCm-1a Glass Surrogate as a Function of Temperature

4.3 Product Performance

4.3.1 Durability - An acceptable durability (as defined by the Product Consistency Test (PCT)) is equal to or better than the EA glass limit based on B release (with the appropriate confidence limits applied). Typically, Na and Li are also tracked but the SrABS frit does not contain either Na or Li and only Na exists in the waste stream at an extremely low concentration.

4.3.2 Recoverability - The recoverability criteria is 98% of the total lanthanides with concentrated (15.7 M) nitric acid within two hours with heating (110°C) and the glass ground to approximately 60 mesh.

5.0 Conclusion

The Cylindrical Induction Melter System currently in use at SRS is a pilot demonstration version of a more robust and remotely operable system to be installed in the Multi-Purpose Processing Facility (MPPF) in the F Canyon at SRS. The initial runs have proven the ability of the system to meet the requirements for producing glass of the desired quality for the transportation and storage of the Am/Cm material to the Oak Ridge facility in Oak Ridge Tennessee. Future work on the CIM will bound the process parameters to ensure proper glass is made in the MPPF facility in the future. Operating bounds and power profiles will be developed to ensure safe and effective use by site operators.

Reference

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