Vitrification of Savannah River Site HLW Sludge Simulants at CEA Marcoule Industrial-scale Cold Crucible Induction Melter Demonstration Platform - 9186

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ABSTRACT

The Cold Crucible Induction Melter technology (CCIM) is considered worldwide for industrial implementation to overcome the current limits of high level waste vitrification technologies and to answer future challenges such as: new or difficult effluent compositions, need for improving waste loading, need for high temperatures, and corrosive effluents.

This technology is under consideration for waste glass melting at the US Department of Energy's (DOE) Defense Waste Processing Facility (DWPF), located at the Savannah River Site (SRS) in South Carolina, USA. Studies have concluded that adapting CCIM technology to the existing DWPF plant can increase the rate of waste processing while reducing the number of HLW canisters required to be produced over the life of the facility. These significant process improvements are achievable by increasing waste loading in the glass product and improving waste throughput, as compared to the plant's existing Joule-heated Melter technology.

In order to validate the advantages of replacing the current DWPF Joule-heated melter with a CCIM, a long-duration demonstration is to be performed by CEA-Marcoule on their existing "Creuset Froid Avancé" (CFA), an industrial-scale demonstration platform equipped with a 650-mm diameter CCIM. This demonstration is part of Phase II-A of the ART CCIM Project that was awarded to AREVA Federal Services LLC (AFS) by the DOE and is funded in phases under the Advanced Remediation Technologies (ART) program.

This paper describes the CFA large size platform and then discusses the very encouraging results obtained from demonstration runs completed at Marcoule in 2007. Two demonstration runs have been completed on the CFA platform with a liquid feed: an Sludge Batch 3 (SB3) surrogate representing a low solids, iron-rich SRS sludge in the alkaline form, and with waste loadings of up to 52wt%.

Finally, the last part of the presentation describes the Phase II-A demonstrations. To reach the targeted objectives two runs are planned in 2009, with a liquid feed representing the current DWPF flow-sheet (Sludge Batch 4 (SB4) type waste composition).

INTRODUCTION

In order to demonstrate the advantages of replacing the current DWPF Joule-heated melter with a CCIM, long-duration demonstrations have been proposed on the CFA large-scale platform at Marcoule [1], equipped with a 650 mm diameter CCIM. The demonstrations were performed with a slurry-type feed, representative of the waste currently treated at the DWPF. The demonstration program is divided into two parts: A first series of demonstration runs was completed in 2007, and a second set was performed under the ART CCIM Phase II-A project in early 2009.

The paper describes the CFA large size platform and details the significant improvements carried out to integrate the lessons learned during the 2007 CCIM demonstration using simulated SB3 sludge.

Two demonstration runs have been completed in 2007 on the CEA Marcoule CFA platform with a liquid feed: an SB3 surrogate representing a low solids, iron-rich SRS sludge in the alkaline form, and with waste loadings of up to 52wt%. The presentation provides the very encouraging results obtained from the demonstration performed at temperatures, specific throughputs and waste loadings that overcome current DWPF limits.

Finally, the presentation describes the ART CCIM Phase II-A demonstrations. To reach the targeted objectives two runs are planned, with a liquid feed representing the current DWPF flow-sheet (SB4-type waste composition).

DESCRIPTION OF THE PLATFORM

The demonstration platform is self-contained and comprises all the systems and components necessary to perform large-scale demonstration runs: a melter feed system, a 650-mm diameter CCIM, a glass pouring station, a canister filling station, a complete off-gas treatment system, and related auxiliary equipment, including the control system. The platform is installed on four floors covering 160 m² at ground level. Figure 1 is a picture of the CFA industrial-scale demonstration platform equipped with a 650 mm diameter CCIM at CEA Marcoule, France.

Fig. 1. General view of the 650 mm diameter CCIM demonstration platform – CEA Marcoule

Melter Feed System

The melter feed system includes a preparation and feed tank located inside the building. This tank is equipped primarily with heating coils (heated with steam) and a thermocouple for temperature measurement, and a mechanical stirrer capable of mobilizing and homogenizing highly concentrated slurries. The tank can be dried-fed from the top. The built-in stirring capability of the feeding tank is complemented by the implementation of a high flowrate (> 5 m^3/h) recirculation loop extracting the slurry from the bottom of the tank and re-injecting it at the top of the tank.
The tank is also equipped with dip tube bubbler-based level and density measurements. Due to the potential plugging of the dip tubes, the level measurement is now doubled by a radar-based measurement system.

The CCIM feed system was completely re-designed to integrate the lessons learned during the 2007 CCIM demonstration using simulated SB3 sludge. From the recirculation loop, the melter feed surrogate is transferred to the CCIM via two parallel feed lines, each equipped with a metering peristaltic pump. The feed rate is measured on each feed line using an electromagnetic flow-meter. Each CCIM feed nozzle is equipped with a mechanical device providing for de-clogging, if needed. The metering pumps used in 2007 were replaced by pumps with higher throughputs in order to be able to deliver the required feedrate with only one pump. The two lines can work in parallel if required.

The configuration of the CCIM feeding pipe was revised to minimize plugging. Flushing the feed lines can be performed using water before starting feeding and each time feeding is interrupted. The switch-over to water is automatic upon pump stop or low feed flow.

Sampling the simulated waste feed can be performed directly from the main re-circulation loop at the bottom of the tank and also now immediately upstream the metering pumps.

Vitrification System

The melter selected for the demonstrations is an existing 650-mm diameter cold-crucible induction melter that had been used previously on another platform at Marcoule. This melter was an early version used for development, and not representative of the robust design which has been qualified for radioactive operations in the La Hague vitrification plant. It does not include radiation resistant materials or remote maintenance devices.

The melter was powered by a ~270 kHz, 600 kW high frequency generator delivering power into a copper inductor wrapped around the melter sectored vertical wall. The power supply line to the inductor integrates a high frequency / high voltage line and an impedance adaptation device (capacity assembly) to adapt the generator to the load in the crucible. The tuning of this impedance adaptor is based on modeling and calculations run prior to the demonstration, which take into account the physical properties of the glass versus temperature (thermal conductivity, electrical conductivity, and viscosity) measured by CEA on representative glass samples.

The platform includes two new cooling loops with separate branches for the melter, the dome, and for ancillary equipment, as well as an emergency cooling system for the melter. Each branch is individually equipped with temperature and flow rate measuring devices to gather data inputs necessary for the development of a thermal balance. These cooling loops were re-designed particularly to allow higher flowrates.

The whole vitrification unit is surrounded by an electromagnetic barrier re-designed to better prevent exposure of the personnel to the magnetic field and prevent the operators from accessing hot or moving components.

A viewing system which includes a video camera is mounted onto the dome of the CCIM and provides for the remote monitoring of the cold cap. Figure 2 is a view of the cold cap through the viewing port of the dome. The video camera setup was re-designed to improve its performance: remote control of the camera, and more efficient anti-dust concept.

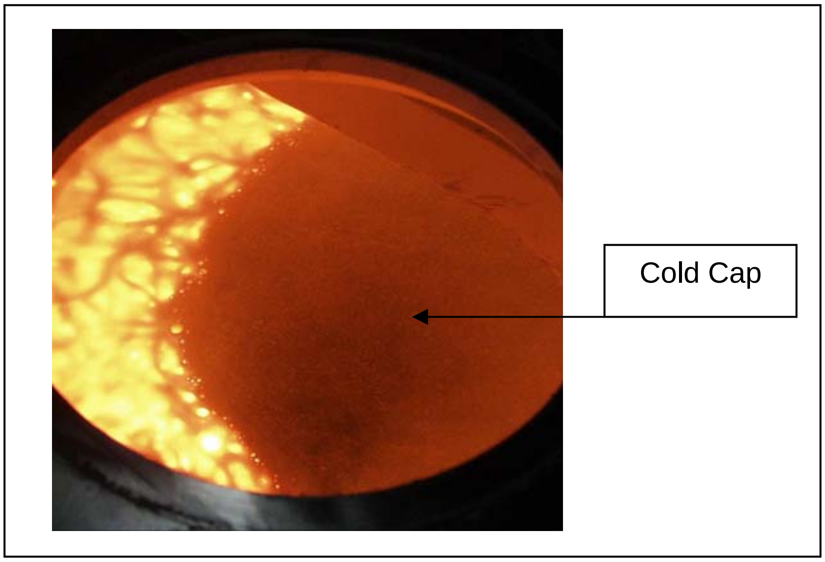

Fig. 2.View of the cold cap – CCIM - CEA Marcoule

Glass Pouring Enclosure and Canister Filling Station

During glass pouring, the receiving canister is located inside an insulated enclosure equipped with weighing scales. The weight of glass poured into the canister is monitored and the information reported to the control room. The canisters are made of standard carbon steel and can receive approximately 400 kg of glass. Glass sampling could be performed below the outlet of the CCIM pouring system by pouring small quantities of glass into steel or cast iron pans.

Off-Gas Treatment System (OGTS)

At the melter off-gas outlet, the vertical part of the off-gas pipe is equipped with a mechanical device (ram) allowing recycling any deposit into the melter. The horizontal pipe to the dust scrubber is equipped with water injection systems for the removal of potential deposits and with fittings for pressure and temperature measurements. The off-gas then flows through a dust scrubber, a condenser, and a washing column. A centrifuge extractor extracts the off-gas and provides for a slightly negative pressure in the system. The configuration of this off-gas treatment system is similar to the La Hague HLW vitrification facilities and is different from the DWPF OGTS. Figure 3 is a diagram of the CFA OGTS.

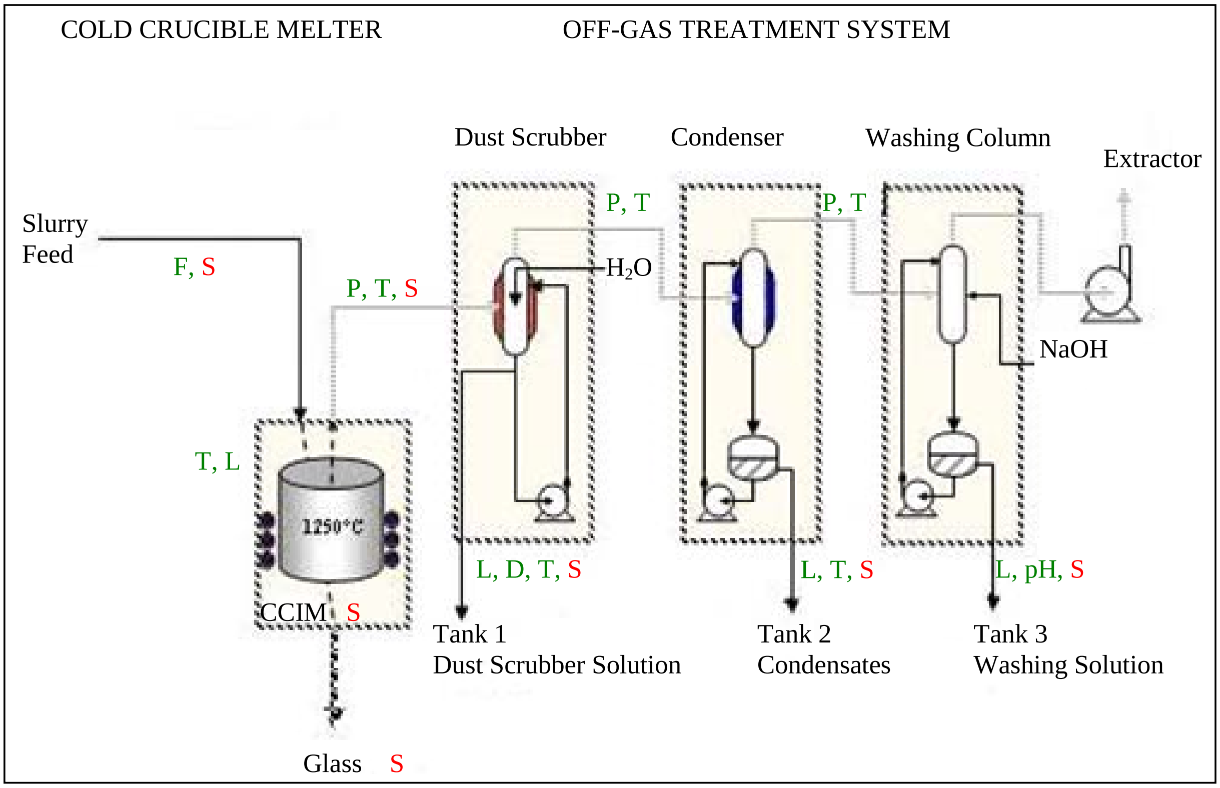

Fig. 3. Diagram of the off-gas treatment system – CCIM platform – CEA Marcoule

(L = Level; P = Pressure; T = Temperature, D = Density; pH = pH; F = Flowrate; S = Sampling)

The existing centrifuge extractor is now doubled by an axial flow liquid ring pump.

The dust scrubber is a heated vessel topped with a column in which the off-gas is contacted with a counter-current flow of liquid circulated from the vessel in order to trap the entrained particles. The dust scrubber is heated so that no condensation occurs in it. In normal operation, the dust scrubber is continuously fed with a small flow of fresh water, and the excess liquid, loaded with the collected material, is recycled to the CCIM with the main feed. For the two demonstration runs completed in 2007, the excess liquid was not recycled to the CCIM with the main feed but was diverted from the scrubber into a dedicated receipt tank, in order to measure the maximum achievable throughput in a configuration compatible with the actual DWPF system.

The cleaned off-gas then flows through a condenser where the moisture is condensed. The condensates are collected into a specific cooled tank. Downstream of the condenser, the off-gas flows through a washing column where it is contacted with a caustic solution to remove the acidic gases (NOx and others).

The three components can be sampled to support the evaluation of the distribution of entrained and volatilized species. Each of them is equipped with level and temperature measurement devices. Pressure is measured before and after each piece of equipment.

Control and Monitoring

The Large Scale Integrated CCIM Pilot Platform is fully instrumented and operated remotely using a Process Logic Controller and a Digital Control System with a multi screen display. All the process parameters can be monitored, time-stamped, and recorded to provide historical trend information. The control system includes warning thresholds on each critical measurement and automatic shut-down sequences to assure safe operation of the system. The system was up-dated to integrate all the modifications carried out on the platform.

FIRST SERIES OF DEMONSTRATIONS - 2007

Two demonstration runs have been completed in 2007 at Marcoule on the CFA platform with a liquid feed an SB3 surrogate representing a low total wt. % solids (38-43%), iron-rich SRS sludge in the alkaline form, and with waste loadings (the mass fraction of waste components in the glass) of up to 52 wt% [2].

The program was divided into two runs:

- Run #1, designed as an exploratory run, in order for the CEA to get acquainted with the waste, the glass, the type of feeding, while enabling the derivation of optimum operating parameters necessary for the performance of run #2. The operating temperature for this run was 1250°C.
- Run #2, during which stable and controlled operation at maximum throughput was to be demonstrated, for 1250°C and 1300°C, and a preliminary assessment of cesium volatility to be carried out.

Feed and Glass Selection

A SB3-type waste composition was selected for the demonstration since it was representative of a moderately washed, iron-rich sludge that was processed at the DWPF. The melt rate and waste throughput capability with actual radioactive SB3 waste was well characterized at DWPF. This allowed a comparison with the results obtained using the CCIM with SB3 simulant. However, it should be noted that the preparation of the melter feed was different that of DWPF. An acidic flowsheet is currently used at DWPF to prepare the melter feed. Based on constraints of the Marcoule facility, the SB3 melter feed simulant was prepared without acid addition, it was left alkaline and the uranium was removed from the simulant recipe composition. Thus the SB3 feed to be treated by the CCIM at Marcoule was then not fully representative of the DWPF feed.

One of the major advantages identified for the CCIM is its ability to operate at high temperature, a fact which allows processing melts with liquidus temperatures higher than those that can be processed in a traditional Liquid Fed, Joule-Heated Ceramic Melter. For those glass systems which are liquidus (TL) limited, use of the CCIM technology offers the potential to increase waste loading. It was the agreed to target a waste loading of 50 wt%, corresponding to an increase of 30 wt% when compared to the best performance of the DWPF with this type of waste (38 wt% waste loading). As it will be seen later an even higher waste loading was targeted for run #2.

SRNL developed a glass formulation and a frit compatible with processing in the CCIM (see Table I) [3].

Table I. Nominal Glass Frit and Glass Composition (50wt% waste loading)

Oxides	202-A-11 Frit	HTLG-21 target glass
Al_2O_3		8.45
B_2O_3	9.00	4.50
CaO		1.65
Cr_2O_3		0.10
CuO		0.04
Fe_2O_3		18.65
K_2O		0.17
Li_2O	6.00	3.00
MgO		1.91
MnO		3.54
Na_2O	3.00	13.59
NiO		0.96
SO_4		0.36
SiO_2	82.00	42.97
TiO_2		0.03
ZrO_2		0.09
Total	100.00	100.00

Throughput and Glass Durability

A maximum feedrate of 50 L/h was determined at 1250°C and 60 L/h at 1300°C (see Table II). Stable operation was demonstrated for a 13 hour period at 45 L/h.

With this specific feed composition, the maximum feed rate value of 50 L/h (feed flux of 150 L/h/m²) at 1250°C corresponds to a glass production rate of 20.9 kg/h (or a glass flux of 63 kg/h/m²) and a waste throughput of 10.9 kg/h (waste flux 32.7 kg/h/m²), that is about 44% of the waste throughput of the DWPF for the SB3-Frit 418 system [4]. The feed value of 60 L/h (feed flux 180 L/h/m²) at 1300°C corresponds to a glass production rate of 25 kg/h (or a glass flux of 75.4 kg/h/m²) and a waste throughput of 13 kg/h (or a waste flux of 39.2 kg/h/m²).

Table II. Calculation of Throughputs Achieved During Demonstration Run

Temperature	Feed rate @ 38 wt% total solids (Feed flux)	Glass throughput @ 417.1 g/l (glass flux)	Waste throughput @ 52 % WL (waste flux)	Waste throughput @ 53 % WL (Waste flux)
1250°C	50 L/h (150 L/h/m²)	20.9 kg/h (63 kg/h/m²)	10.9 kg/h (32.8 kg/h/m²)	11.1 kg/h (33.4 kg/h/m²)

1300°C	60 L/h (180 L/h/m²)	25 kg/h (75.3 kg/h/m²)	13 kg/h (39.1 kg/h/m²)	13.25 kg/h (39.9 kg/h/m²)

Samples form the pours performed during the last part of the run were analyzed by SRNL for chemical composition, crystallization and durability. The as-poured product was homogeneous, and a little more crystallized than the product from demonstration run, a fact that had to be expected since the waste loading was higher. The waste loading was estimated to lie between 52 and 54 %, probably around 53%. The chemical composition (see Table III) was stable and close to what was expected. The X-Ray Diffraction (XRD) results confirmed the findings of the formulation studies: no trace of nepheline or aegirine was detected in both the as poured and CCC (Centerline Canister Cooling)-treated samples.
The Product Consistency Test (PCT) results were in agreement with this observation: the leach rates were about an order of magnitude better than the standard EA (Environmental Assessment) glass for both the as-poured and CCC -treated samples. Scanning Electron Microscopy-Energy Dispersive Spectroscopy performed on samples taken from the canisters confirmed these observations. The only detectable crystalline phases were iron-rich spinels with varying levels of Cr and other elements.

Assessment of Cesium Volatility

For Run#2 cesium nitrate was added to the feed in order to get a concentration of 414 mg/l Cs, which with the expected calcine contents of the feed, would have correspond to a Cs2O concentration in the glass of about 0.092 %.

A preliminary evaluation of cesium volatility in the technology at these high temperatures conditions is feasible based on glass analysis. The glass analyses indicates (see Table III) that between 88 and 93 % of the cesium remained in the glass in these high temperature, high melt turbulence, but short residence time conditions. Although the time at 1300°C was reduced, there was no sign of increased volatility when the temperature was raised from 1250 to 1300°C.

Table III. Chemical analysis of glass sampled on pouring – demonstration run
(pour #7 & 8 : 1250 °C, 45 L/h, pour #9 : 1250 °C, 50 L/h, pour # 10 : 1300 °C, 60 L/h)

Oxide wt%	Target based on as-analyzed sludge composition	Pour #7 and 8 average	Pour #9	Pour # 10 average
Al2O3	8.91	8.93	8.87	8.74
B2O3	4.25	4.07	3.95	3.96
CaO	1.80	1.74	1.64	1.60
Cr2O3	0.10	0.11	0.11	0.11
CuO	0.09	0.04	0.04	0.04
Fe2O3	18.14	18.1	18.2	17.9
K2O	0.44	0.52	0.41	0.40
Li2O	2.76	2.53	2.56	2.56
MgO	2.10	2.13	2.12	2.12
MnO2	4.49	4.69	4.71	4.65
Na2O	13.44	15.4	15.6	15.0
NiO	0.94	0.83	0.87	0.88
SO4		0.35	0.37	0.29
SiO2	41.74	40.5	40.8	40.8

TiO2		0.114	0.07	0.06
ZrO2	0.09	0.13	0.13	0.14
Cs2O	0.092	0.081	0.086	0.082

These results are confirmed by the off-gas analyses. During the run#2, samples of the off-gas effluent were taken on a regular basis. A selection of samples taken during the 13 hour period of sable operation at 45 L/ h was analyzed. From these results a cesium flow sheet can be established. Figure 4 presents the cesium flow sheet for Top 50.25. The time markers are identified as “Top” which initiates (T 0) at the time of the first feed (time reflected in hours). For example the samples taken 1 hour and a half after the first feed are labeled “Top 1.5”.

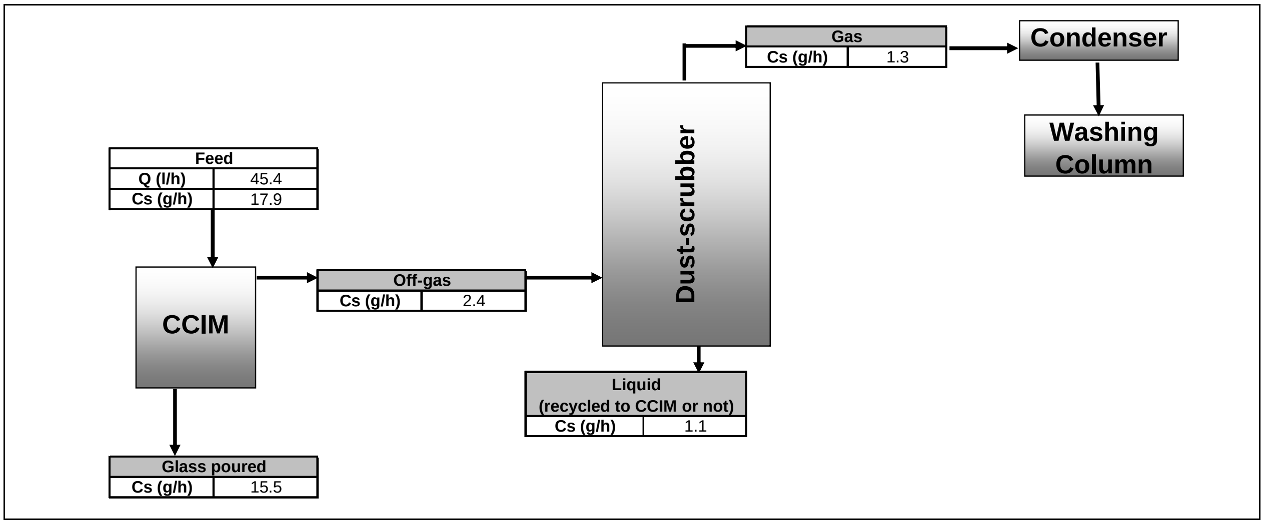

Fig. 4. Cesium Flow Sheet at top 50.25 (1250 °C, 45.4 L/h)

Table IV present the results for the other « top » of the steady operation at 45 l/h, expressed in weight percent: quantity of cesium flowing out of the dust-scrubber compared to the quantity of cesium in the feed.

Table IV. wt% of cesium flowing out of the dust-scrubber – Run#2

Top (h)	46.7	49	50.25	51	53
Cs (wt%)	13.95	15.35	13.45	16.25	15.40

Cesium volatility at the dust-scrubber was apparently around 15%. It should however be noted that the decontamination factor of the condenser and the washing column were not analyzed. Cesium volatility for the overall off-gas treatment system is expected to be lower.

Moreover it’s known that the recycle from the dust-scrubber, similarly to what is done at La Hague, have a good impact on the cesium balance. In normal operation, the dust-scrubber is continuously fed with a small flow of fresh water, and the excess liquid, loaded with the collected material, is recycled to the CCIM with the main feed. This represents around 10% of the feed. In order to evaluate the benefit of recycling part of the dust-scrubber effluent, it may be proposed to perform this analysis as a part of the Phase II-A demonstrations.

Redox

All the samples analyzed at SRNL had a Fe^{2+} / Fe_{total} ratio between 0.040 and 0.043. This is low when compared to the normal operating range of the DWPF (between 0.09 and 0.33). The glass is thus oxidizing when compared to that in the DWPF melter. This is to be expected since the feed did not contain any significant amount of reducing agent (apart from a very small concentration of oxalate).

Demonstration of compatibility with industrial operation

The ability to start the melter was demonstrated. The operating parameters of the power system were adjusted accordingly based on the glass properties. Over the two runs and the preparatory run, five start-up operations were performed without any difficulty. Startup for the two runs was very rapid. The average time between power ignition and start of feed was around 6 hours.

The ability to control and stabilize temperature in the melt for durations longer than 6 hours was demonstrated. For these runs, temperature was adjusted manually by acting on the power. Moreover, it was also demonstrated that short stops (for camera cleaning for instance) could be accommodated without significant disturbance. For stops for which the duration is expected to be longer, the stirrer is retracted but recovery is still easy after 20 minutes, although the melt had cooled down somewhat.

The availability of the platform was near 80%. During the two runs, the system underwent 3 breakdown events. These were unexpected events, with outside causes, and none of those three events gave rise to irreversible damage to the melter or the platform. In those three instances, full draining of the melter was performed safely within minutes of the breakdown, thus removing the hot melt from the operations area. Although 2 of these events occurred during run #2, it was possible to repair and start the platform again within one day, and to reach the maximum throughput at two temperatures before the end of the run. This illustrates the flexibility of the technology brought on by the possibility to stop power and evacuate the melt on demand, and on the short cooling time for the system. If one considers the period after the second mechanical failure the platform availability was 79%.

ART CCIM PHASE II-A DEMONSTRATIONS

This last part outlines the organization and contents of the ART CCIM Phase II-A CCIM pilot-scale demonstration activity to be performed on the industrial-size CCIM demonstration platform at Marcoule, and the expected outcome of these demonstration runs. To reach the targeted objectives two runs are planned, with a liquid feed representing the current DWPF flow-sheet (SB4-type waste composition).

Feed Selection

For this demonstration, only one composition of simulated SB4 sludge and one composition of glass frit will be used for the two CCIM runs. It has been agreed to select an aluminum-rich sludge surrogate for this demonstration, in order to explore the Heavy Metal-rich portion of the expected DWPF feeds. The composition is close to the current Sludge Batch 4 currently being processed at the DWPF, after removing uranium, lead and mercury, which are not accepted on the Marcoule platform.

The melter feed surrogate must be representative of an actual DWPF melter feed on both the chemical and rheological aspects. As a result it must simulate an alkaline sludge having undergone the various acidification, boiling, concentration and frit addition steps currently performed in the Chemical Processing Cell (CPC) at DWPF.

The oxide composition for this surrogate sludge is given in Table V.

Table V. Surrogate Sludge Batch 4 (SB4) Waste Composition

Oxide	Weight %
Al_2O_3	28.16
BaO	0.08
CaO	3.06
Ce_2O_3	0.24
Cr_2O_3	0.22
CuO	0.06
Fe_2O_3	32.03
K_2O	0.08
MgO	3.06
MnO	6.39
Na_2O	20.67
NiO	1.83
SO_4^{2-}	0.96
SiO_2	3.00
ZnO	0.06
ZrO_2	0.10
Total	100.00

In order to obtain Decontamination Factor data for the melter, the simulated melter feed surrogate will be spiked with CsNO3 to obtain a targeted Cs2O content of 0.5 wt% in the glass.

Based on the results of the glass formulation testing [5] it is recommended that the Frit 503-R6 composition (B2O3 = 14 wt%; Li2O = 9 wt%; Na2O = 3 wt%; and SiO2 = 74 wt%) be utilized for the ART Phase II-A CCIM demonstration. Furthermore, a waste loading of 46 wt% should be targeted pending chemical composition results of the actual simulant. The recommended frit and waste loading should produce a glass with acceptable durability with a liquidus temperature adequately below the 1250°C nominal CCIM operating temperature.

Based on this testing, it is recommended that the CCIM testing should be conducted using the REDOX control strategy developed for DWPF operations at 1150°C. A REDOX ratio of 0.06 to 0.10 Fe^{2+}/total Fe should be targeted for the demonstration.

Proposed Pathway and Conditions for Run #1 – Exploratory run

The initial run will be performed primarily to demonstrate safe operation of the platform. This run will use melter feed surrogate with the nominal organic contents. This run will include a progressive increase in feed rate up to (roughly) the maximum, coupled with data collection (such as pressure measurements, off-gas temperature distribution, CO/H2 analyzer if needed, etc.) in order to provide confirmation data to the Marcoule safety officials. During the run, a preliminary estimation of the maximum throughput at 1250°C will be obtained. The expected duration for this run would be about 72 hrs. Several modifications performed on the platform for improved safety and/or improved operation will be demonstrated and validated. This run will also allow understanding the behavior of this specific feed in the melter and identifying the best set of operating parameters for the next run (low and high level of glass, stirrer rotation speed, etc.).

Proposed Pathway and Conditions for Run #2 – Baseline pilot demonstration

The second run, is aimed at demonstrating steady state operation on an extended duration (about 9 days of operation), obtaining consolidated throughput data, determining a reliable cesium decontamination factor for the melter, evaluating the crystallization pattern and evolution in the melter, evaluate the impact on the cesium balance of operating with a recycle from the dust-scrubber and providing data inputs for future engineering design work. This run will be spilt in two sub-parts, with an interruption designed to induce a minimal disturbance of the crystals building-up in the melter (if any) and of the off-gas equilibrium. These subparts are described below.

Feed Flow Rate Ramping Up, Determination of the Throughput Limit at 1250°C, and Operation at Steady State

At 1250°C the feed flowrate will be set initially at a low value and will be increased slowly for the first batch in order to establish the skull (the layer of solidified glass in contact with the cooled equipments of the CCIM) over the whole operating melt height. After the first pour, the feedrate will be increased at a faster rate to reach the maximum value determined during run #1. The melter will then be operated at steady state, pouring glass when necessary.

The optimum melt height range will have been determined and confirmed from the first run.

Glass batches of the pre-determined size will be poured when reaching the maximum level of glass in the melter. While pouring glass, melter feeding will be maintained at a constant rate. Each glass pour will be received in a dedicated empty canister. Sparging and mechanical stirring will be maintained during pouring.

In order to gain some insight into the effect of glass pouring on the temperature profile in the canister, a canister containing a series of thermocouples will be used. This temperature data will be collected during a period of steady-state operation. Based on melter operation, if possible two successive pours will be received in that canister.

Run Interruption

Owing to workforce management on the Marcoule site, it is not possible to operate the platform during the week-end. On Friday afternoon, at the time of the last glass pour, feeding will then be stopped and the last pour will be performed. The volume of the glass pour will be slightly larger than for a routine pour, but the melter will not be drained completely. A sufficient layer of glass will be left in the melter, in order not to drain the eventual spinels that might have accumulated at the bottom of the melter. The melter will then be let to cool down under the effect of the cooling system.

Once the melter is cooled down, any liquid addition to the off-gas treatment system will be interrupted, in order to maintain the cesium equilibrium in the vessels. A last sampling of these vessels will be performed at that time. During the interruption, the vessels will be left untouched as much as possible.

On the day of re-start, the metallic ring will be positioned within the required amount of startup glass above the layer of frozen glass. The startup glass may be taken from the batches poured at steady state prior to the interruption, so as not to change the melt composition.

Feeding and pouring at steady state will then be continued as before the interruption.

Proposed Dust-Scrubber Recycling Test

During the last 48 hrs of the test, it is proposed to evaluate the impact on the cesium balance of operating with a recycle from the dust-scrubber, similarly to what is done at La Hague. A small quantity of a non-radioactive Cesium isotope as nitrate will be added to the feed in order to target a cesium oxide content in the glass of around 0.5 %.

The feed rate will be decreased by about 10% of the feed rate in order to incorporate the recycle stream from the dust scrubber. Sampling of the off-gas vessels and of the poured glass will be continued in order to observe the modifications in the cesium distribution.

End of Run

After cooling down, the platform and off-gas piping will be inspected and observations will be recorded. If there are deposits in the horizontal off-gas pipe, they will be analyzed and evaluated by weighing the pipe before and after cleaning.

Samples from the remaining material in the melter and from the glass poured or drained in the canisters will be taken and analyzed. The glass and off-gas effluent data will then be used to perform a cesium balance over the whole system.

CONCLUSION

The feasibility of deploying the CCIM technology in the DWPF Melt Cell has been assessed in a preliminary manner in the framework of phase I of the ART project. The main conclusion of the Phase I effort was that the CCIM vitrification technology is a credible mature technology that could accelerate DWPF glass production.

The very encouraging results obtained during a first series of large-scale CCIM runs completed in 2007 demonstrate waste throughputs 44 % [4] that of the DWPF in a 650 mm CCIM melter for the same waste type with the 150 L/h/m² demonstrated @ 1250 °C. The very high waste loading (above 52%) allows reducing the glass production by about 27% when compared to current DWPF operation for this specific type of feed, since 27 % less glass is needed to immobilize the same amount of waste. The technology allowed processing melts with liquidus temperatures higher than those allowed in the DWPF facility by at least 150°C to 200°C. The liquidus temperatures of the glasses were close to or above the DWPF melter temperature, and were poured easily from the CCIM. The product from the baseline demonstration run, with a waste loading of at least 52%, displayed a very good durability. Stabilized operation close to the maximum throughput was demonstrated. The cesium volatility for the overall off-gas treatment system is lower than 15%. The compatibility of the CCIM with industrial operation was demonstrated with an availability around 79%.

The Phase II-A CCIM pilot-scale demonstration activity to be performed in early 2009 on the industrial-size CCIM demonstration platform at Marcoule are aimed to validate the expected benefits of the CCIM vitrification technology for the DWPF that were identified during Phase I of the project.

REFERENCES

1 “INTEGRATED PILOT PLANT FOR A LARGE COLD CRUCIBLE INDUCTION MELTER”, WM’02 Conference, February 24-28, 2002, AZ, Tucson, USA

2 “Cold Crucible Induction Melter (CCIM) Demonstration Using a Representative Savannah River Site Sludge Simulant on the Large-Size Pilot Platform at the CEA – Marcoule”, WM08 Conference, February 24-28, 2008, AZ, Tucson, USA

3 D.K. PEELER et al–. « Data packet for the frit 202-A11 – SB3 glass system: a candidate for the Cold Crucible Induction melter (CCIM) demonstration” WSRC-STI-2007-00302 (June 2007).

4 “Feasibility Evaluation and Retrofit Plan for Cold Crucible Induction Melter Deployment in the defense Waste processing Facility at Savannah River Site - 8118“,WM08 Conference, February 24-28, 2008, AZ, Tucson, USA

5 J.C. MARRA et al., “Glass formulation development and testing for Cold Crucible Induction Melter Technology Retrofit and Deployment project – Phase II-A demonstrations – Lab-scale evaluation and assessment final report “, SRNS-STI-2008-00036 (2008).