HSS Independent Activity Report - Rev. 0	**Report Number:** HIAR-VSL-2013-11-18

Site: Catholic University of America – Vitreous State Laboratory (VSL)	**Subject:** Office of Enforcement and Oversight's Office of Safety and Emergency Management Evaluations Activity Report for Catholic University of America Vitreous State Laboratory Tour and Discussion of Experiments Conducted in Support of Hanford Site Waste Treatment and Immobilization Plant Select Systems Design

Date of Activity :	11/18/13	**Report Preparer:**	James O. Low

Activity Description/Purpose:

Bechtel National, Inc. (BNI) is the contractor responsible for the design and construction of the Hanford Site Waste Treatment and Immobilization Plant (WTP) for the U.S. Department of Energy (DOE) Office of River Protection. BNI is focused on developing the Low Activity Waste (LAW) Facility documented safety analysis (DSA) per 10 CFR 830, Subpart B. This Office of Health, Safety and Security (HSS) activity is part of a multi-phase review (Ref. 1) that focuses on the technical adequacy of the LAW DSA and supporting basis. BNI uses the Vitreous State Laboratory (VSL) experimental data and reports to develop and issue calculations that model LAW melter and off-gas processing system performance.

The HSS team met with VSL staff and discussed VSL test results for the melters and off-gas processing systems to gain insight into the VSL test data that BNI will use to support the design and calculated performance of selected LAW systems. The discussion focused on the data used for design of the LAW Melter Processing Primary Off-gas (LOP) and Secondary Off-gas Vessel Vent (LVP) systems. The HSS team will use these insights, along with the VSL test reports, for subsequent review of LAW safety basis documents and the flowdown of nuclear safety requirements into selected safety systems (e.g., LOP, LVP).

Result:

The HSS team met with VSL staff to discuss testing information regarding melter and associated off-gas systems. Other items discussed included system design, relative physical scales, system stability, and observed transients during operations. HSS team also toured the various VSL melter test systems. The VSL staff has designed, built, modified, and operated melter systems and issued test reports on various melters, including the DM10, DM100 and DM1200.

BNI and predecessor WTP contractors subcontracted with the VSL to test and evaluate small and pilot (1/3)-scale melters and associated off-gas processing systems that are intended to be prototypical of the WTP High Level Waste (HLW) facility. A portion of the LAW facility melter and off-gas systems design basis also relies on various VSL test reports. These reports determined production throughput of the melters, compared system design alternatives, and provided environmental permitting data. BNI-issued test specifications for VSL experiments did not specifically explore the potential for uncontrolled off-gas releases or the associated bounding conditions.

The VSL, established in 1968, has been operating melters since the mid-1980s and has been involved in the development of waste vitrification technologies for several DOE projects, including the West Valley Demonstration Project, Savannah River Site, and WTP. VSL operates several small-scale melters of increasing size, up to the WTP HLW pilot (1/3)-scale, which is known as the DM1200. In addition to the VSL, Energy*Solutions*, Inc. (as GTS Duratek) operated a pilot plant (DM3300) for the LAW facility, which was a 1/3 section of the full LAW melter (rather than 1/3-scale). The DM3300 off-gas system did not match the final LAW off-gas system design, but the off-gas system for the VSL DM1200 is prototypical of both the LAW and the HLW facilities. All the DM1200 melter off-gas streams are sampled at the melter outlet and multiple off-gas system sample points. BNI's support for VSL melter testing ended in 2006, but VSL continues to operate the DM1200 to support ongoing research.

Discussions between VSL and HSS staff were based on test reports, the melter systems tour, and the decades-long experience of the principal investigators. Salient information on melter and off-gas systems performance and other relevant items is listed below:

- Scaling: Data from small to 1/3-scale LAW melters was provided in a test report (Ref. 2). VSL staff reported that the melter and off-gas systems' performance and the measured melter emissions tended to be consistent and predictable during scale up from the DM100 to the DM3300 melters.
- Sulfates: Under abnormal conditions in the melter, sulfates can form a molten low-viscosity liquid layer on the surface of the glass. This liquid is highly corrosive and electrically conductive, and it can seep through refractory materials,

providing a current path as well as corroding the melter refractory and structure. Sulfate liquid layer formation is controlled by physical mixing (bubblers), glass formulation design, and limiting the sulfur input to the melter feed.

- Bubblers: Bubblers are used to mix the molten glass in order to achieve higher glass production rates and break up and absorb the sulfate liquid layer. Corrosion caused bubblers to fail, and VSL tested alternatives to extend bubbler life. VSL staff indicated that if two bubblers located next to each other fail, the result can be poor glass mixing and an increased tendency for molten sulfate layer formation in that location.
- Flammable off-gas: Melters can produce flammable off-gas in the various melter operating states and during transitions between operational modes. VSL tested the effects of abnormal mixes of melter feeds, variations of feed composition, and the resulting off-gas conditions at typical melter operating conditions. No flammable off-gas conditions were observed, and there was a substantial safety margin between observed off-gas concentrations and flammable limits. The only exception was that using formic acid as a reductant, instead of sucrose (the WTP baseline), resulted in significant generation of flammable gases and led to preemptive shutdown of the test.
- NOx: NOx is produced during normal operations due to breakdown of nitrates in the feed and is a significant hazardous component of the melter off-gas. The dependence of NOx production on melter plenum temperature, off-gas system air inbleed, and waste feed composition is well characterized.
- Glass foaming: Foaming is an unstable behavior involving finely divided gas bubbles in the liquid glass. Foaming can be caused by several factors, including changes in metal oxidation states in the glass, and is dependent on such parameters as glass viscosity, oxidation state, available oxygen, and temperature. If insufficient sucrose is added, an insulating layer of foam can form between the cold cap and glass, reducing production rates. This gas/foam insulation layer can also affect the concentration of hazardous materials in the off-gas. Feed sampling, sucrose addition, temperature control, and mixing (bubblers) are used to prevent foaming. Glass foaming was difficult to produce intentionally in the VSL or DM3300 melters.
- Submerged Bed Scrubber (SBS): SBS liquid condensate recycling (via the Pretreatment Facility) will return liquid waste to the melter feed stream and may concentrate the volatile and soluble species (e.g., mercury and technetium) within the SBS and other off-gas system components. No testing was performed to fully characterize the concentration of mercury compounds in off-gas system components over prolonged operations.
- Mounding of waste feed: Mounds of unreacted waste feed on the melter cold cap surface can result in off-gas surges and changes in the off-gas composition. The DM3300 and DM1200 operated more smoothly with simulated LAW waste than the DM1200 did with simulated HLW, which showed more extensive mounding. The cold cap for LAW feeds is more fluid, the rheology is less prone to mounding, and the melter bubbler density is higher. Feed mounding is controlled by a combination of glass formulation (selection of glass-forming additives), feed rate, and bubbler agitation (flow rate, bubbler location and design, number of bubbler outlets).
- Waste feed rate: The feed rate is determined by plenum temperature, since visual observations are not viable for controlling the LAW melter. The plenum temperature is maintained at approximately 400 C; lower temperatures indicate overfeeding and higher temperatures underfeeding.
- "Burn-off" tests: Some tests of the "burn-off" of the cold cap were performed on the DM1200 melter. When feed was stopped, the rate of off-gas emission decreased and NOx decayed quickly. No tests were performed for a cold cap "burn-off" concurrent with a reduced off-gas flow transient.
- Wet Electrostatic Precipitator (WESP) operation: Arcing in the WESP (when using simulated LAW feed) was eliminated by introducing an air dilution stream to the isolators. The daily deluge wash and subsequent drying period significantly reduced the overall WESP decontamination factor. With the WESP out of service, particulate and accumulated ammonium nitrate (NH_4NO_3) quickly plugged the downstream high efficiency particulate air (HEPA) filters, resulting in subsequent filter blinding. This event and the analysis of the deposits were reported to BNI (Ref. 3).

Additional general observations included:

- VSL is not tasked to support peer review of LAW process flowsheets for melter or off-gas systems.
- VSL is not tasked to support the startup or cold testing phase for LAW facility commissioning.
- LAW film cooler deposits were generally water soluble, but the HLW deposits were not.
- Increased air in-leakage dampens the effect of surges on observed melter pressure.

HSS Participants	**References**
1. (lead) James O. Low	1. DOE/HQ HS-45, Plan for the Independent Oversight Review of the Hanford Site Waste Treatment Plant Low Activity Waste Facility Documented Safety Analysis Development, April 22, 2013.

2. David Odland	2. VSL-04S4850-1, Comparison of Off-Gas Emissions from Tests with LAW Simulants on the DM100, DM1200, and DM3300 Melters, February 27, 2004.
3. Mary Miller	3. VSL Memorandum, Results from Inspections Downstream of the DM1200 WESP and Upstream of the Catalyst Unit for Ammonium Nitrate, September 30, 2003.

Were there any items for HSS follow up? ☐ Yes ☒ No

HSS Follow Up Items

- **None.**