Demonstration of Non-Traditional In Situ Vitrification Technology at Los Alamos National Laboratory

Gordon Huddleston [1], MSE-Technology Applications, Inc.
Brett Campbell, Integrated Environmental Technologies, LLC
Mark Ewanic, MSE-Technology Applications, Inc.
David Reichhardt, CH_2MHill Hanford Inc.
Marja Springer, Los Alamos National Laboratory
Leo Thompson, AMEC Earth and Environmental Inc.

Abstract: MSE Technology Applications, Inc., (MSE) in conjunction with DOE's Subsurface Contaminants Focus Area (SCFA), is conducting an evaluation of non-traditional in situ vitrification (NTISV) technology as a potential remedy for treatment of radioactive mixed-waste-contaminated absorption beds at the Los Alamos National Laboratory (LANL), Technical Area 21(TA-21), Material Disposal Area-V (MDA-V) site. A "cold" demonstration of the technology was successfully performed in an uncontaminated simulated absorption bed at the LANL site in April 1999. A full-scale "hot" (radioactive) site melt was completed in April 2000 within MDA-V Absorption Bed 1 at LANL TA-21. The absorption bed and the underlying volcanic tuff contain various radionuclide, inorganic, and organic contaminants. The results of these demonstrations show several advantages of subsurface melting over conventional top-down ISV melting including: achievement of greater melt depths; improved processing efficiency; decreased exposure potential for workers; and reduction in amount of secondary wastes produced. New treatment depth records were achieved, and the potential for attainment of even greater depths was clearly shown. The vitrified final waste form produced by the planar subsurface GeoMelt™ process was determined to be homogeneous and extremely resistant to leaching. The imaging results derived from seismic tomography monitoring data showed good agreement with physical measurements on the extent of subsurface treatment achieved.

Technology Description: In Situ Vitrification (ISV) is a thermal treatment process that involves the melting of contaminated soils, sludges, or other earthen materials and debris for the purpose of permanently destroying, removing, and or immobilizing hazardous and radioactive contaminants. Organic contaminants such as dioxins, pesticides, and PCBs are destroyed by the process. Heavy metals and radionuclides are retained in the melt and immobilized in the resulting product. Any off gases generated by the process are contained under a hood covering the treatment area and are drawn to an off-gas treatment system. When the molten mass cools, it solidifies into a vitreous and crystalline rock-like monolith with unequaled physical, chemical and weathering properties compared to alternative solidification / stabilization technologies. The resulting product is typically ten times stronger than concrete. Conventional or "traditional" ISV processes melt the soils/waste matrix in a top-down fashion with a horizontally oriented melt established at or near ground surface typically between four electrodes. Application of electrical power causes the melt to grow downward and outward until the melt encompasses the target treatment volume from grade down to the desired depth.

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[1] Project Manager, MSE Technology Applications Inc., 200 Technology Way, Butte, MT 59701, Phone 406.494.7382, Fax 406.494.7230, hudgj@mse-ta.com (corresponding author)

The “non-traditional” ISV technology selected for this demonstration project was the GeoMelt Planar ISV process, which involves joule-heated melting within the subsurface. In contrast to the horizontally oriented melt normally started at or near the surface, this process establishes two vertically oriented planar melts in the subsurface between pairs of electrodes. The planar melts can be initiated at the desired depth and separation within the subsurface, depending on the target treatment volume. Two independent vertically oriented planar melts are established during the initial stages of the process. This allows significant control of the initial melting process so that it can be focused for optimal treatment of the waste zone. Because the melts are initially separated and grow horizontally together late during the treatment process, the potential for restricting the flow of gases generated below the melts is significantly reduced compared to conventional ISV. By the time the melts have grown sufficiently to merge and form a single melt, all volatile materials will have been effectively and safely removed from the treatment zone.

NTISV Project Results: The NTISV project involved the performance of two large scale ISV melts at LANL Technical Area 21. A “cold” demonstration, conducted adjacent to the MDA-V site, was performed in a pit containing cobble, gravel, and crushed tuff to simulate the absorption bed with surrogate materials (cesium carbonate and cerium oxide) added to simulate radionuclides of interest. The cold demonstration was successfully completed in April 1999 with all test objectives achieved after eight days of operation at an average electrical power level of approximately one megawatt. The final melt depth achieved was 23 feet, exceeding the established target depth of 22 feet. The cold demonstration melt was excavated in May 1999 to verify the size and shape of the melt and to obtain samples for evaluation. Observations and analysis performed indicate that all the contents of the simulated absorption bed were incorporated into the vitrified product including large cobbles and the added surrogate materials. Analytical results and calculated standard deviations from five random samples showed 33± 7ppm for cesium and 248±3ppm for cerium, indicating that these surrogates were incorporated into the melt and uniformly distributed in the resulting monolith. This verified the expected results from the convective flow pattern typical of the GeoMelt process. Leach testing was performed on the vitrified product using the toxic characteristic leaching procedure (TCLP) and Product Consistency Testing (PCT) standard methods. In all cases surrogate compound concentrations in the leachate were found to be below instrument detection limits (DL). For TCPL analysis all samples were reported at less than the DL of 0.29 ppm for cerium and less than the DL of 0.056 ppm for cesium. For the PCT analysis all samples were reported at less than the DL of 0.002 ppm for cesium and less than the DL of 0.006 ppm for cerium. When the PCT results are normalized on a surface area to unit mass of the finely ground product, the results indicate normalized release rates of $<0.11 g/m^2$ for cesium and $<0.036\ g/m^2$ for cerium.

Following evaluation of the cold demonstration, a “hot” (radioactive) site melt was performed in April 2000 within MDA-V Absorption Bed 1 at Technical Area 21. During an approximate 20 year period from the 1940’s to the early 1960’s, the absorption beds at this site received liquid effluent primarily from a radioactive laundry facility and intermittently from nearby laboratory and research facilities. Samples within absorption bed 1 at MDA-V indicated up to 525 pCi/g of plutonium 239/240.

In preparation for the hot site melt, graphite based material was injected into the subsurface to form two vertically oriented planes of starter material between each of two pairs of electrodes at a targeted depth of 9 to12 feet below grade. Melting was initiated on April 4 and concluded on April 28 when a melt depth of 26 feet was reached. This exceeded the targeted depth goal and achieved a record melt depth for the GeoMelt process. During this period the GeoMelt process operated for a total of approximately 14 days at power input averaging about 2 megawatts. Melting operations were interrupted for a total of 11 days because subsidence of overburden material was not occurring; the tuff material above the melts bridged, creating cavities above both planar melt zones. The cavities were collapsed in a controlled manner by vibrating in a long steel probe connected to a vibratory hammer attachment. The melting process was reinitiated without difficulty following this interruption in operation. As overburden was incorporated into the melt, coarse gravel was periodically added to maintain an insulating cover over the melt area.

An important result is that this melt was accomplished at a much lower power level than would be required for a similarly sized conventional top-down melt. This difference can be attributed to the higher thermal efficiency of subsurface melting due to the insulating benefits of processing under overburden; the increase in thermal efficiency is estimated at approximately 30%. When the hood and off-gas treatment system were disassembled at the conclusion of the project, they were found to meet the radioactive contamination release criteria for LANL, indicating a very high degree of radionuclide retention in the melt. This result is also attributed to subsurface melting and maintaining overburden above the melt zone.

Seismic tomography data acquired after the melt was completed was used along with final melt-electrode depth, and subsidence volume to determine the size and shape of the final monolith. The vitrified monolith resulting from the hot site melt is estimated to be 25 feet wide and 15 feet thick with a vertical dimension extending from 8 feet to 26 feet below grade. In general the seismic imaging correlations showed good agreement with the vertical extent of melting indicated by electrode depth as well as verification measurements performed when the cold demonstration melt was excavated.

The melt is taking longer to cool down than was originally expected because of the insulating properties of the surrounding volcanic tuff material. The temperature at the top surface of the monolith was measured at 700 F in October 2000 six months after the melt was completed; that temperature had dropped to 320 F by late March 2001 after 11 months of cooling. Core drilling, sampling, and analysis of the vitrified monolith by LANL is planned during the last half of 2001, once sufficient cooling has occurred.

Acknowledgements: The NTISV project was conducted for the DOE Subsurface Contaminants Focus Area through the DOE-National Energy Technology Laboratory at the Western Environmental Technology Office under DOE Contract Number DE-AC22-96EW96405. LANL as the host site for the NTISV demonstrations, provided funding for their site support and technical assistance. AMEC is the worldwide licensee for the GeoMelt™ technology.