RESULTS FROM THE NON-TRADITIONAL (SUB-SURFACE) IN SITU VITRIFICATION DEMONSTRATION FOR MIXED WASTE APPLICATIONS AT THE LOS ALAMOS NATIONAL LABORATORY

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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 the mixed-waste-contaminated absorption beds at Los Alamos National Laboratory's (LANL) Material Disposal Area-V (MDA-V) site. The MDA-V site contains three absorption beds that received effluent from a nuclear laundry as well as research-derived liquids from 1945 to 1978. The absorption beds and the volcanic tuff below them contain various radionuclides, inorganics and organic contaminants.

The project involved the performance of two large-scale demonstration melts. The first, termed the "cold" demonstration, was performed in an uncontaminated simulated absorption bed at the LANL site and was completed in April 1999. The second "hot" (radioactive) demonstration melt was successfully performed in April 2000 and was completed within LANL's MDA-V's Absorption Bed 1 at Technical Area 21.

The NTISV demonstration project successfully demonstrated the planar subsurface GeoMelt process for treatment of subsurface contamination zones. New treatment depth records were achieved, and the potential for even greater depth attainment was clearly shown. The demonstration showed the advantages of subsurface melting over conventional top-down ISV melting, which was the major objective of the demonstration. This includes increased operating efficiency due to the significantly reduced power requirements compared with conventional ISV. The subsurface melting also eliminated the release of radionuclides to the hood and off-gas treatment system. This results in decreasing the exposure potential for workers and reduces the amount of secondary wastes. The vitrified product produced during the cold demonstration was determined to be homogenous and extremely leach resistant based on standard leach test methods. The homogeneity and high degree of leach resistance of the cold demonstration

vitrified product provides confidence that the vitrified product resulting from the hot demonstration will have similar characteristics.

INTRODUCTION

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 the mixed-waste-contaminated absorption beds at Los Alamos National Laboratory's (LANL) Material Disposal Area-V (MDA-V) site. The LANL Environmental Division provided support and services for the demonstration project.

The MDA-V site contains three absorption beds that received effluent from a nuclear laundry as well as research-derived liquids from 1945 to 1978. The absorption beds and the volcanic tuff below them contain various radionuclides, inorganics and organic contaminants.

A competitive procurement of NTISV technologies selected an advanced NTISV technology involving joule-heated melting within the subsurface for demonstration at the MDA-V site. The GeoMelt technology was selected for the project. Advancements over the traditional ISV technology include performance of subsurface startup and melting, and employment of a new planar melting method. The demonstrations were performed using large-scale commercial GeoMelt equipment.

The project involved the performance of two large-scale demonstration melts. The project was designed to demonstrate the ability of GeoMelt to treat both the contaminated bed contents and underlying contaminated tuff to a depth of at least 6.7 m. The first demonstration melt, termed the "cold" demonstration, was performed in an uncontaminated simulated absorption bed and was completed in April 1999. Project participants from the Los Alamos National Laboratory selected an inactive absorption bed for the site to be treated during the second demonstration melt. The second "hot" (radioactive) demonstration melt was successfully performed in April 2000 and was completed within LANL's MDA-V's Absorption Bed 1 at Technical Area 21.

The cold demonstration was completed successfully and satisfied all of the objectives established for the cold demonstration. The hot demonstration was also completed successfully. Sampling and analysis of the vitrified product resulting from the hot demonstration melt has not yet been completed. A summary of the results available to date is presented in this paper.

The successful demonstration of NTISV at LANL provides a useful technology for the general DOE complex-wide remediation needs including potential site remediation needs of LANL for buried waste and other waste configurations.

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NTISV PROCESS DESCRIPTION

ISV is a mobile, thermal treatment process that involves the in situ electric 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.

Conventional ISV involves processing the soil / waste matrix in a top-down fashion. A horizontally oriented melt is established between four electrodes. The continued application of electrical power through the melt causes the melt to grow downward and outward until such time that the melt has encompassed the entire treatment volume from grade down to the desired depth.

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. When electrical power is shut off, the molten mass cools and 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. Individual melts in excess of 7 m deep; 12 m in diameter and up to 1,000 tonnes can be formed. Off gases generated by the process are contained under a steel hood covering the treatment area and are drawn to an off-gas treatment system.

The GeoMelt process has been used commercially to successfully treat all contaminant types (volatile and semi-volatile organics, heavy metals, and radionuclides) and all types of soil media (sands, silts, clays, and sludges). GeoMelt is also distinguished by its ability to tolerate significant amounts of debris within the treatment zone. Types of debris previously processed by GeoMelt in commercial operations include scrap metal, steel drums, concrete, asphalt, wood, plastic, paper, protective clothing, HEPA filters, and general construction demolition debris.

The competitive procurement of NTISV technologies resulted in the selection of an advanced NTISV technology, termed GeoMelt Planar ISV, which involves joule-heated melting within the subsurface. In this process, the horizontally oriented melt normally started at or near the surface between the four electrodes was replaced with two vertically oriented planar melts established in the subsurface between pairs of electrodes. The planar melts can be initiated at the desired depth and separation within the subsurface. The process results in two independent vertically oriented planar melts 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. Moreover, 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 to form a single melt, all volatile materials (e.g. – mainly water) will have been effectively and safely removed from the treatment zone.

NTISV PROJECT DESCRIPTION

The NTISV project involved the performance of two large-scale demonstration melts. The first "cold" demonstration, which was performed North of the MDA-V site, was performed in a simulated absorption bed, which contained no radioactive contamination (1). The simulated absorption bed was designed and constructed to represent the actual MDA-V absorption beds as closely as possible. This simulation included the use of similar construction materials (i.e., cobbles, gravel and sand), as well as the use of surrogate chemicals for radionuclides of interest.

The second "hot" (radioactive) demonstration melt was performed within MDA-V's Absorption Bed 1 at Technical Area 21. The MDA-V absorption beds received approximately 75,000 to 100,000 liters per day of liquid effluent, which amounts to approximately 150 million liters over the operating life. The absorption beds received liquid effluent primarily from a radioactive laundry facility, as well as intermittently from research facilities. Samples from the cobble area within the absorption bed indicated up to 525 pCi/g of plutonium 239/240 (2).

A target treatment depth of 6.7-m was established for both demonstration melts, to demonstrate the GeoMelt technology's capability to treat both the contaminated bed contents and underlying contaminated tuff.

Both demonstrations involved monitoring to gather performance data pertinent to evaluation of the technology for various applications at LANL and throughout the DOE Complex. The general objectives established for the NTISV project included:

- demonstrate the ability to safely and successfully install planar starter paths significantly below grade within the Bandelier Tuff formation

- demonstrate the ability to process the materials and surrogate radionuclides placed into the cold demonstration simulated absorption bed and present within Absorption Bed 1 at MDA-V

- confirm that the physical dimensions of the melts meet or exceed the desired treatment volumes

- obtain process performance information necessary to optimize the processing configuration and operational parameters, as well as improving the cost effectiveness

- characterize the vitrified products by performing geochemical analyses to determine the degree of homogeneity, as well as product quality (TCLP & PCT) leach tests

- obtain cost information to estimate large-scale operational remediation costs of the MDA-V, and to compare costs to the target level of $800/ton or less.

COLD DEMONSTRATION

The results from the cold demonstration have been previously reported (1,3). Consequently, only a summary of the results will be provided to provide background to the hot demonstration melt.

The cold demonstration was performed north of the MDA-V site in a simulated absorption bed, which contained no radioactive contamination. The simulated absorption bed was designed and constructed to represent the actual MDA-V absorption beds as closely as possible. This simulation included the use of similar construction materials (i.e., cobbles, gravel, crushed tuff and sand), as well as the use of surrogate chemicals for radionuclides of interest.

To form the simulated absorption bed for the cold demonstration, an excavation that was 3-m by 4.6-m by 1.8-m deep was made. Prior to commencing backfilling of the absorption bed, 6.5-kg of cesium carbonate and 30-kg of cerium oxide were added to the floor of the excavation to serve as surrogates for radionuclides that are present within the actual absorption bed at MDA-V. The cesium carbonate was added to represent cesium-137, whereas the cerium oxide represented transuranic radionuclides such as plutonium and uranium. The surrogates were used to assess the degree of homogeneity within the resulting vitrified product and to determine the leach resistance of the product. Since the surrogates were placed on the floor of the excavation, they represented a localized source of contamination that could be used to assess mixing and homogeneity of the resulting product. Once construction of the simulated absorption bed was completed, assembly of the GeoMelt equipment and preparation of the test area were performed.

Melting operations for the cold demonstration commenced on April 16, 1999. The melting process continued for approximately eight days, at which time all of the melting objectives had been met. The average power level delivered to the melt was 971 kW including the graduated start-up. The final melt depth as indicated by the electrode insertion depths 7.05 m (23.1-ft).

Post-test examinations indicated that the entire target volume and its contents were successfully treated and incorporated into the resulting vitrified monolith. Observations made when the completed product was exhumed (Figure 1) indicated that all of the contents of the simulated absorption bed comprising the target treatment volume were incorporated into the vitrified product, including the large (up to 0.6-m diameter) cobbles from the bottom of the absorption bed. A piece of the vitrified product is also shown in Figure 1.

As indicated by the data below, an extremely homogeneous and highly leach resistant vitrified product was produced by the cold demonstration.

The product was sampled and analyzed to determine the concentrations of surrogates (cesium and cerium) that were present within the product, the degree of mixing (or homogeneity) of the surrogates within the product, and the degree of leachability of the surrogates out of the product. To determine how well the surrogates were incorporated into and distributed within the resulting vitrified product, five samples were collected from the vitrified monolith and submitted for complete digestion and analysis. Analyses of these samples resulted in a value of 33 $\pm$ 0.7 ppm for cesium and 248 $\pm$ 3 ppm for cerium (see Table I). This indicates that all of the surrogates present in the simulated absorption bed were incorporated downward into the developing melt and distributed uniformly throughout the resulting product. This is typical within a GeoMelt-created product due to the convective flow patterns that develop within the melt.

Leach testing was also performed on the cold demonstration product to evaluate its resistance to leaching. Five random samples were submitted for product consistency testing (PCT) and toxicity characteristic leaching procedure (TCLP) testing. In all cases, none of the surrogate compounds were present in the leachate at or above the detection limits (DL) of the analytical procedures (see Table II). For the TCLP analysis, all five of the 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. The results of the PCT analyses were also extremely good in that the concentration within the leachate was less than the DL of 0.002 ppm for cesium and less than the DL of 0.006 ppm for cerium, which, when normalized on a surface area to unit mass of the finely ground product results in normalized release rates of <0.011 g/m^2 and <0.036 g/m^2 for the cesium and cerium, respectively (1). The data gathered from the two leach tests establishes that the product has a superior leach resistance compared with alternative solidification / stabilization technologies.

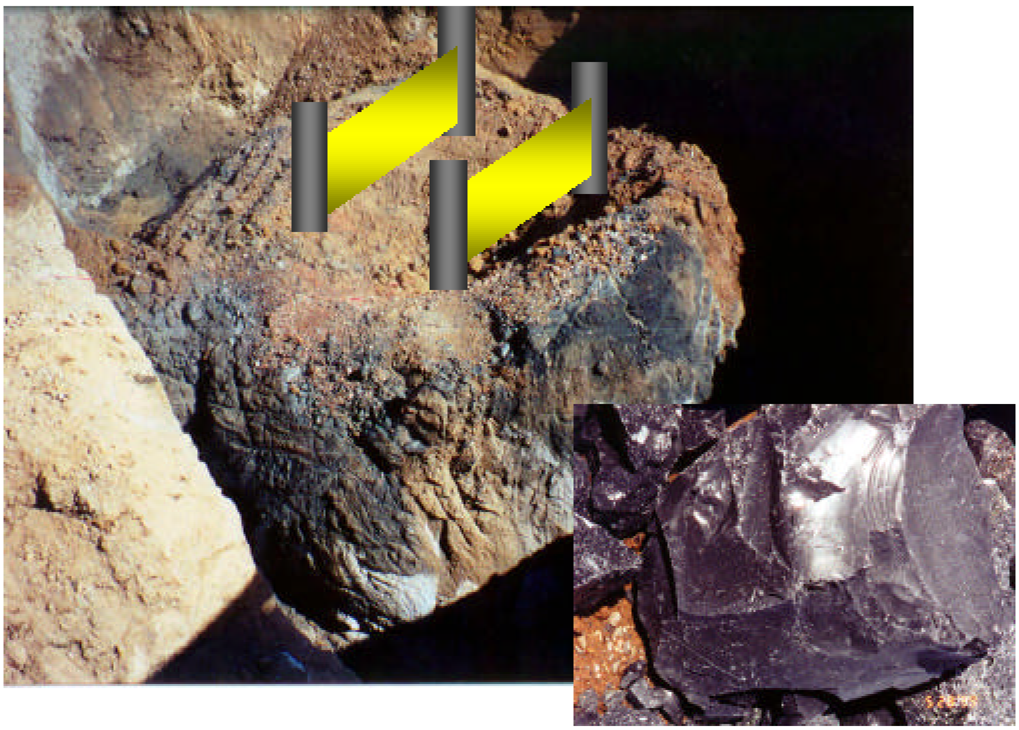

Fig. 1. Vitrified monolith and piece of vitrified product (inset) resulting from the cold demonstration. The position of the electrodes and the starting position of the starter planes are also illustrated. The starter planes were originally installed beneath the absorption bed.

Table I. Radionuclide Surrogate Concentrations in the Native Soils and in the Vitrified Monolith

	Cesium	Cerium
Background Concentration in Native Soils	3.5 ppm	110 ppm
Amount of Surrogate Added to Absorption Bed	6.5 kg	30 kg
Uniform Concentration Throughout the Monolith	33 ± 0.7 ppm	248 ± 3 ppm

Table II. Results of Leach Testing Performed on the Vitrified Product

Leach Test Method	Cesium	Cerium
TCLP	<0.29 mg/L	<0.056 mg/L
PCT	<0.011 g/m^2	<0.036 g/m^2

All phases of the cold demonstration were conducted safely and according to all of the applicable programs of LANL's integrated safety management program. Although the GeoMelt process uses high levels of power, generates significant amounts of molten soil subsurface, and requires the use of cranes, drill rigs, heavy equipment and high-pressure injection equipment, no accidents or near accident occurred during the cold demonstration.

Cost data collected during the cold demonstration indicated that the direct costs of the cold demonstration operations amounted to $684/ton for MSE-TA and Geosafe Corporation, the company that performed the vitrification operations. This cost includes labor, equipment costs, consumables, propane, and electrical energy used during the 8-day run. This cost per ton is below the established unit cost criteria established for the hot demonstration of $800/ton of treated soil.

HOT DEMONSTRATION

LANL subcontractors prepared the hot demonstration site by cutting all pipes entering the absorption bed area from the former laundry facility, thus electrically isolating the site. A layer of clean crushed tuff was placed on the surface of the absorption bed to provide a clean and level area for placement of the hood. Preconditioning of the target melt volume using the dynamic disruption technique was performed in mid-February, 2000. Disruption of the surrounding volcanic tuff was accomplished by using a hydraulic hammer to vibrate a steel probe down into the tuff in a grid pattern. By breaking up the tuff prior to treatment, the sloughing of the adjacent soil into the melt is promoted, as well as eliminating the potential for a steep wall of soil to cleave off and fall into the subsided area.

Electrode casings were then vibrated in place, and 300 mm (12-in) diameter graphite electrodes were placed into the subsurface. The casings were then vibrated back out.

Graphite-based starter-path material was then injected into the subsurface to form two vertically-oriented planes of starter material between each of two pairs of electrodes. The starter path injection was targeted for a depth of 2.75-3.7 meters (9-12-ft) below grade. Electrical conductivity measurements were made after injection to confirm that continuity existed between the electrodes.

The treatment operations commenced on April 4, 2000. An aerial view of the GeoMelt equipment at the site during the melting operations is shown in Figure 2. Both planar melts started without difficulty, and processing proceeded in typical fashion.

It was noted during the first few days of operation that subsidence of the overburden did not appear to be occurring. Some of the tuff soil above the melts bridged rather than collapsing down into the melts. Melting operations were interrupted for an 11-day period to evaluate options and implement a method to collapse the cavities. The cavities were collapsed in a controlled manner by vibrating in a long steel probe connected to a vibratory hammer attachment. This method was effective in collapsing the cavities above the melts and enabling normal subsidence of overburden materials throughout the remainder of the test. As overburden was slowly incorporated into the melt from above, additional overburden material (coarse gravel) was periodically added via a conveyor to maintain a good insulating cover over the melts. The interruption in melting did not pose any difficulties and the process was reinitiated without difficulty.

Fig. 2. Aerial View of GeoMelt Equipment During the Radioactive Demonstration

Melting was concluded April 28, 2000. At this point the average electrode depth was over 7.9 meters (26-ft). That is the deepest depth ever achieved by the GeoMelt process. All indications were that the processing could have been continued to much greater depths if desired; however, the processing was terminated in this case as depth and other demonstration objectives had been achieved.

An estimated 275-tonne melt was produced. It was notable that this melting was accomplished at an average power level below 2 MW; whereas similarly sized conventional top-down ISV melts generally require much higher power input levels. This difference is attributed to the higher thermal efficiency of subsurface melts due to the insulating benefits of processing under overburden. Use of overburden has been shown to increase the thermal efficiency of the melting process by up to 30%. This can provide significant cost savings both by reducing the power costs and by shortening the amount of run time to complete a given treatment volume.

Following the completion of the hot demonstration, the equipment was disassembled and removed from the site. The hood and the off-gas treatment system were found meet the radioactive contamination release criteria for LANL. The high degree of radionuclide retention in the melt is due to the subsurface melting and the use of overburden above the melt.

GEOPHYSICAL CHARACTERIZATION OF HOT DEMONSTRATION MELT

Seismic tomography was used to generate an image of the completed melt. Electrical resistance tomography (ERT) was also used, but due to equipment problems it could not be completed. Data acquisition required the installation of six boreholes installed in pairs and spaced 13.7, 15.2 and 16.8 meters (45-ft, 50-ft, and 55-ft) apart (see Figure 3). The boreholes were approximately 16.8 meters (55-ft) deep.

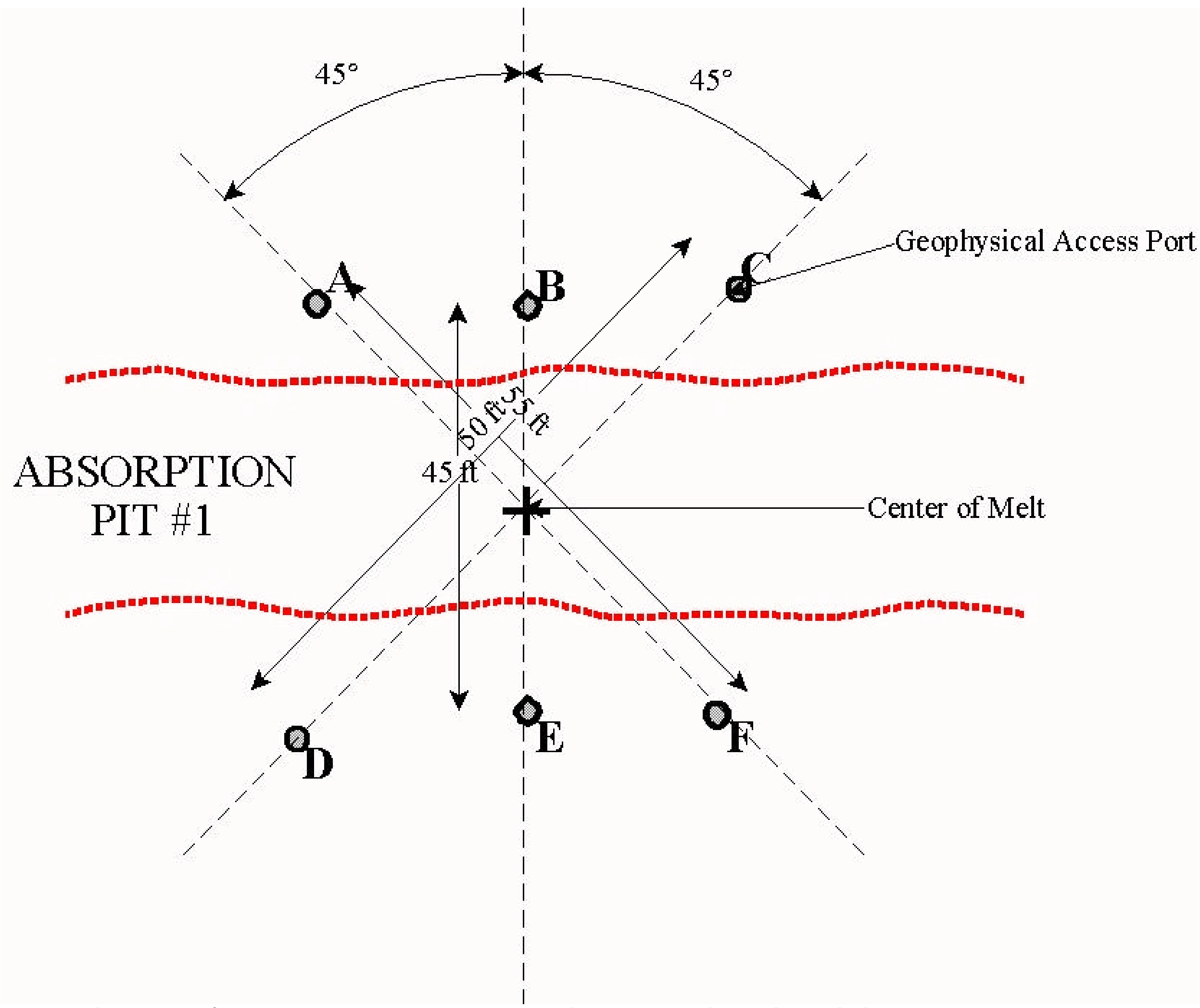

Fig. 3. Plan View of NTISV Hot Demonstration Site Showing Geophysical Borehole Locations

After the melt was completed, seismic tomography data were acquired. In addition, the melt size and shape were estimated using the final melt-electrode depths and subsidence measurements. The three data sets (seismic tomography, electrode depth, and subsidence volume) were correlated and an image of the melt between boreholes B and E was generated (see Figure 4).

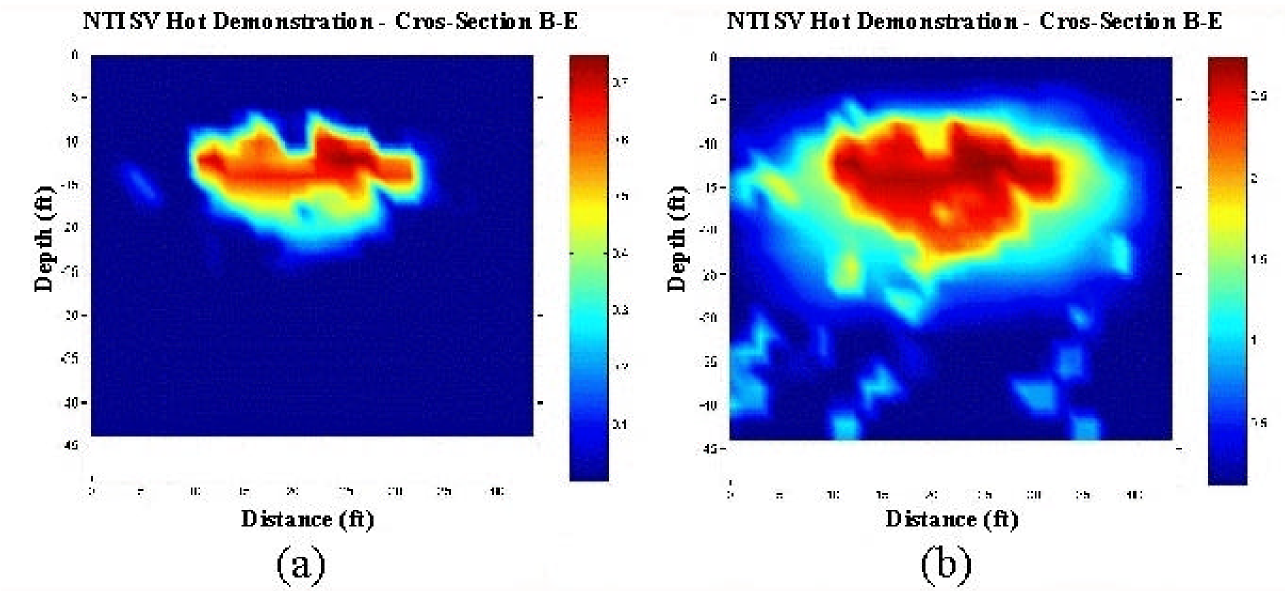

Fig. 4. Multiplicative (a) and Additive (b) Correlation Results for Cross-section B-E

The results indicate the melt starts about 2.4 meters (8 ft) below ground surface (bgs) and is approximately 7.6 meters (25 ft) wide and 4.6 meters (15 ft) thick along plane B-E. It appears the melt tapers with depth. An unusual "notch" can be seen on the upper surface of the modeled melt. This could be a result of the two planar melts coming together. A similar feature was observed during the excavation of the Cold Demonstration melt. Core drilling, which is planned for mid FY 2001, will provide useful data to help confirm the extent of the vitrified monolith.

REMAINING WORK

Core drilling, sampling, and analyses of the vitrified monolith by LANL were originally scheduled to occur during the fourth quarter of FY 2001. In October 2000, six months after the hot demonstration melt was completed, the temperature at the top surface of the monolith was still over 370 deg. C (700 deg. F). Current estimates by LANL are that it will take an additional nine months (April 2001) before the hot demonstration monolith has cooled sufficiently for drilling and analyses of the vitrified monolith to be performed. Preparation of a report on the hot melt as well as an Innovative Technology Summary Report (ITSR) are planned during FY 2001.

CONCLUSIONS BASED ON THE DATA AVAILABLE TO DATE

The NTISV demonstration project successfully demonstrated the planar subsurface GeoMelt process for treatment of subsurface contamination zones. New depth records were achieved, and the potential for even greater depth attainment was clearly shown. The demonstration showed the advantages of subsurface melting over conventional top-down ISV melting, which was the major objective of the demonstration. This includes increased operating efficiency due to the significantly reduced power requirements compared with conventional ISV. The subsurface melting also eliminated the release of radionuclides to the hood and off-gas treatment system. After the hot demonstration was completed, the equipment was found to be free of detectable levels of contamination. This results in decreasing the exposure potential for workers and reduces the amount of secondary wastes generated as a result of the process. The high degree of homogeneity and high degree of leach resistance of the cold demonstration vitrified product provides confidence that the vitrified product resulting from the hot demonstration will have similar characteristics. The testing and development of the seismic tomography technique is leading to a reliable tool that can be used with other data to confirm the extent of treatment in the subsurface.

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