AN ONGOING EVALUATION OF IN SITU VITRIFICATION TECHNOLOGY FOR POTENTIAL APPLICATION TO A LLW DISPOSAL FACILITY

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ABSTRACT

The potential applicability of in situ vitrification technology for remediation of an assumed LLW disposal facility in Japan is being evaluated by Geosafe Corporation in cooperation with the Japan Research Institute, Limited. The assumed disposal facility is underlain by a sandstone and sandy pumice tuff soil, and is surrounded and covered by a mixture of bentonite and natural site soil. The facility contains asphalt- and cement-stabilized LLW disposed in 55-gal drums within cement filled cells. The 3-year evaluation project involves an iterative process of site characterization and experimental data generation followed by performance of an applicability analysis. The first year's program has been completed, including a preliminary applicability analysis. In addition, the second year's experimental program has nearly been completed, and an intermediate applicability analysis is underway.

Findings thus far indicate the promising potential of the ISV technology for remediation of the assumed LLW site. The ability of the process to satisfactorily melt the various earthen materials at the site and to treat the containerized waste materials has been geochemically modelled and empirically demonstrated. The Japanese soil materials of interest have been tested and found to be essentially the same as natural U.S. soils of similar composition. Site conditions posing particular challenges to the ISV technology include: 1) a processing depth of 7.5-m, 2) the presence of sealed containers within the treatment volume, and 3) a highly variable density profile offered by the numerous engineered materials present within the treatment volume. A calculational analysis of expected radionuclide content in the process off-gases indicates that the expected levels are within Japanese air emissions standards.

The preliminary applicability analysis is positive relative to the potential application of ISV to remediation of the site. No factors have been identified that indicate the unacceptability of the technology for this application. Various technical uncertainties still remain, however, as the study is only midway through the planned 3-iteration evaluation process.

ASSUMED LLW DISPOSAL FACILITY

In situ vitrification (ISV) is being evaluated as a potential remediation technology for application to LLW disposal facility conditions of interest to authorities in Japan. In order to perform the applicability analyses, an assumed LLW disposal facility design basis has been provided by appropriate Japanese parties.

The assumed LLW disposal facility is a structure composed of individual disposal "cells" into which 55-gal drums of stabilized LLW are disposed. Individual drums contain LLW stabilized either by cement (mortar) or asphalt; both types of stabilized waste are present at the site. Once placed in a disposal cell, a quantity of 320 drums are further stabilized by placement of cement around the drums, filling the cell. A quantity of 16 cells arranged in a 4x4 array make up a single disposal "pit"; 5 pits in a row comprise a "group" of pits; and the total number of groups at the facility comprise the complete "burial area".

The pits at the facility are buried below grade to provide additional environmental isolation. Sandstone and sandy pumice tuff soil natural to the site are present below each pit. A mixture of bentonite and natural site soil surrounds and covers each pit; and a layer of clean soil at the surface completes the disposal isolation. The arrangement of the disposal facility elements mentioned above is illustrated in Fig. 1.

A waste loading of 30 wt% within the drums is assumed. The waste consists of a mixture of combustible and metallic materials. Typical combustible materials include protective clothing, filters, and rags and other materials used to decontaminate equipment. Metallic waste includes tools and miscellaneous equipment items. The assumed radionuclide content of the waste materials is presented in Table I.

ISV APPLICATION CONCEPT

The ISV technology involves the electric (joule heated) melting of glass forming solids for purposes of: 1) thermally destroying/removing organics, other compounds, and vaporizable materials, 2) permanently immobilizing radionuclides and other heavy metals within the vitrified residual product, and 3) production of high integrity monolithic structures for barrier or construction uses. The typical ISV melt, which employs a setting of four electrodes in a square array, is initiated at the surface and progresses downward and outward to encompass the desired treatment volume. Significant volume reduction occurs due to removal of void volume, organics, and other materials that decompose and/or vaporize during processing. Figure 2 illustrates the basic ISV processing configuration and melt conditions for typical applications.

The ISV technology offers the following significant benefits for remediation of LLW disposal facilities: 1) ability to simultaneously process hazardous chemical, radioactive, and mixed waste materials, 2) ability to attain very high organic destruction and removal efficiencies (DREs), 3) ability to permanently immobilize heavy metals and radionuclides of interest in a residual product of unequalled physical, weathering, and chemical leaching properties, and 4) ability to be performed onsite and in situ, thus minimizing occupational, public, and environmental exposure risks.

The basic application concept being evaluated for treatment of the LLW disposal facility involves performance of one ISV melt setting for each cell of the facility as illustrated in Fig. 3. Sixteen melts would be employed to treat a complete disposal pit. Clean soil backfill would be placed within the subsidence volume to complete each melt setting.

APPLICABILITY ANALYSIS APPROACH

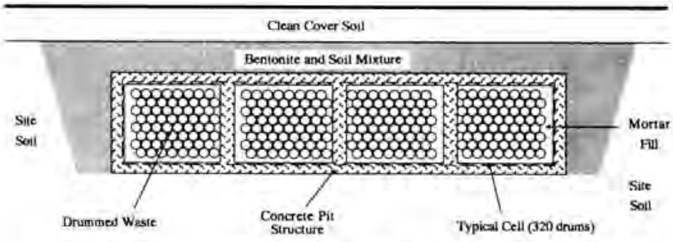

Fig. 1. Arrangement of materials at LLW facility.

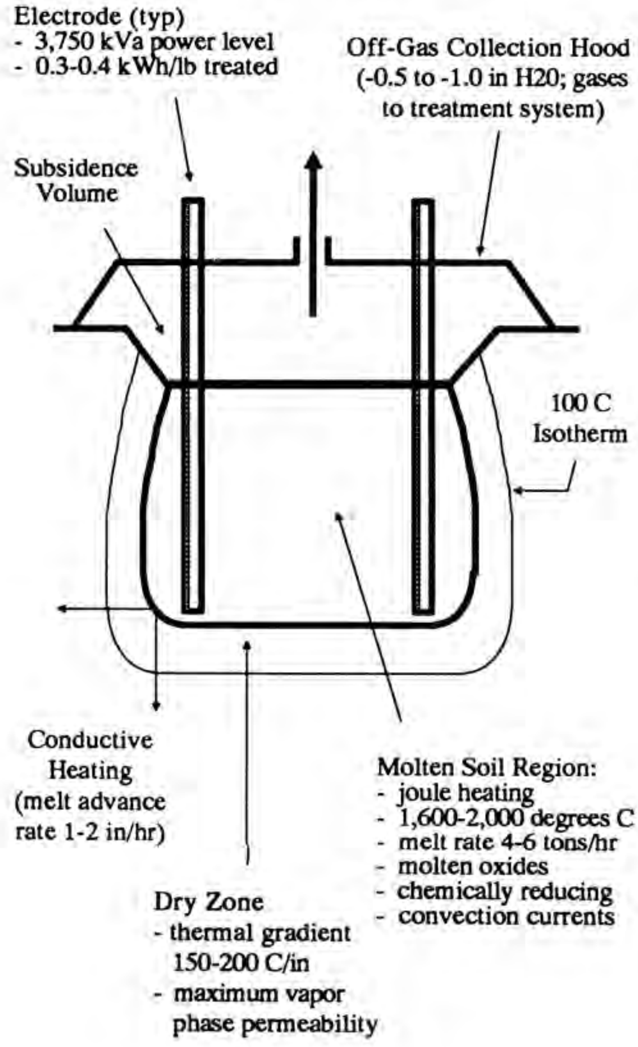

Fig. 2. ISV process conditions.

TABLE I
LLW Radionuclide Content

Radionuclide	Maximum Concentration in Bq/T	Maximum Concentration in Ci/T
H^3	3.00E+11	8.10E+00
C^{14}	9.00E+09	2.43E-01
Co^{60}	3.00E+12	8.10E+01
Ni^{59}	9.00E+09	2.43E-01
Ni^{63}	1.00E+12	2.70E+01
Sr^{90}	2.00E+10	5.40E-01
Nb^{94}	9.00E+07	2.43E-03
Tc^{99}	2.00E+07	5.40E-04
I^{129}	3.00E+05	8.10E-06
Cs^{137}	1.00E+11	2.70E+00

ISV applicability analyses first involve addressing the capabilities of the technology to satisfy the following basic requirements: 1) ability to melt and treat the soil/waste mixture present at the site in a manner achieving desired contaminant dispositions and residual product quality, 2) ability to apply the technology given the physical conditions present at the site, and 3) ability to control process effluents to required regulatory standards. Second, after satisfactory completion of these first 3 evaluations, the applicability analysis involves definition of an action plan to implement ISV remediation of the site, and an estimate of application costs.

The depth or quality of an applicability analysis depends on the completeness and quality of available site information and applicable prior ISV experience. Such information and experience typically increase in quantity and quality as a potential remediation project moves from the point of initial discovery and investigation through remedial design and preparation for remediation. Applicability analyses are termed "preliminary" when they are based primarily on assumed information for a site and only similar or related ISV experience. Applicability analyses are termed "intermediate" when actual site characterization information and applicable ISV experience base are available but incomplete. A "final" applicability analysis is possible when both site characterization and ISV experience information are considered adequately complete.

At the start of this project, neither site characterization information nor applicable ISV experience existed. Therefore, it was determined to perform initial work in both areas sufficient to allow performance of an initial, preliminary applicability analysis. An important element to be included in each applicability analysis was the definition of technical information items needed to allow progression toward a final applicability analysis. Assuming the preliminary results warranted further investigation, the process of investigation and evaluation would then be repeated through two more iterations, hopefully to allow a near final quality applications assessment. This iterative process is now midway through the second cycle. A preliminary applications assessment was completed after the first year of the program. The second year investigative program was defined based on findings of the first year's analysis. The second year's investigative work is

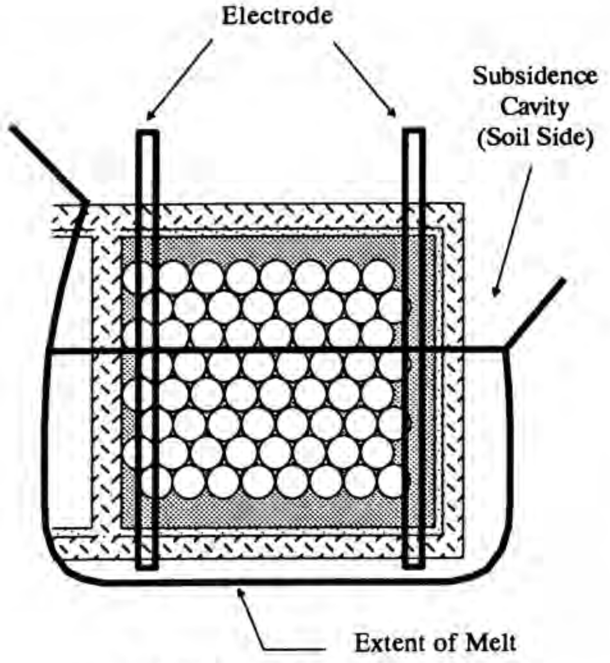

Fig. 3. Melt positioning on single cell.

now nearly complete, and the second evaluation is in progress. The findings and status of the work to date is discussed further below.

LEVEL 1 EVALUATION FINDINGS

First Year Experimental Investigation

Testing Objectives. The primary objective of the first year testing program was to evaluate the capabilities of the ISV process to vitrify the particular soil types, waste materials, and structural materials present at the site. The first year testing consisted of three engineering-scale ISV tests that were performed in the U.S. using U.S. soils, and one demonstration test conducted in Japan using native Japanese soils. The testing approach was designed to be a progressive process to gain as much usable data as possible while performing the tests safely.

The specific objectives of the first three tests were to: 1) confirm that U.S. soil and construction materials could be used to simulate Japanese soils and materials used at the site, 2) to verify the capability of the ISV process to treat these simulated materials, 3) to evaluate the response of concrete- and asphalt-filled containers to ISV processing conditions, and 4) to investigate the ability to process through a simulated concrete cellstructure containing containerized waste surrounded by cement.

Soil Simulation and Evaluation. The native Japanese soils and backfill material were simulated using soils and bentonite clay found in the U.S. It was necessary to simulate the Japanese soils due to import restrictions preventing the shipment of Japanese soil to Geosafe's test site. Whole rock analyses, which quantify the bulk chemistry of the material being tested, were used as a basis for determining suitable simulants. The whole rock analysis provides the quantity of glass forming ions, electrically conductive ions, and fluxing ions that exist within the material. The analysis results allow estimation of the propensity of the soil to form a suitable glass, and melting temperature and viscosity of the molten material.

Tables II and III present the compositions of the actual backfill and soil materials present at the site, and the U.S. materials used to simulate them. The native sandstone was simulated using sand and necessary amounts of CaO, Al_2O_3, and MgO.

Test Descriptions. The testing methodology provided for each test to build upon information gained from the previous test(s). Test 1 was designed to evaluate the melting behavior of the various simulated soils found at the site. In addition, two inclusions (one each of concrete and asphalt) were included within the treatment zone. This was done to permit the evaluation of the process capability to treat both concrete and asphalt prior to placing these materials in sealed containers as was planned for the second test.

Test 2 evaluated the pressure generation and release rate behavior of asphalt- and concrete-filled sealed containers during ISV processing. Data on the processing behavior of sealed containers is important to allow evaluation of the possibility of contaminant entrainment in off-gases during potential rapid depressurizations of the containers. Test 2 also included a layer of soil containing a high percentage of metal for purposes of examining the capabilities of the electrode feeding system to handle high metal content regions and the potential for an electrical shorting condition to arise from pooling of molten metal between the electrodes. It was calculated that each cell may contain 2-3 wt% metal from the presence of drums used to containerize the waste. A region of

TABLE II

Comparison of Japan Site and Simulated Backfill Materials

	Sand		Bentonite Clay	
Component	Japan	U.S.	Japan	U.S.
SiO_2	77.4	68.0	75	69
Al_2O_3	14.6	13.0	15	22
Fe_2O_3	1.6	6.2	2.7	4
MgO	1.6	1.9	2.7	2
CaO	2.6	4.3	1.6	0.4
K_2O	0.5	2.1	0.5	0.1
Na_2O	1.6	3.0	2.7	2.7
MnO	-	0.1	-	-
P_2O_5	0.5	-	-	-

TABLE III

Comparison of Japan Site and Simulated Site Soil Materials

	Sandy Pumice Tuff		Sandstone	
Component	Japan	U.S.	Japan	U.S.
SiO_2	66.3	68.0	50	52.1
Al_2O_3	17.7	13.0	17	16.2
Fe_2O_3	3.9	6.2	5.4	4.8
MgO	2.8	1.9	5.4	5.2
CaO	4.6	4.3	18	17.1
K_2O	1.6	2.1	0.6	1.5
Na_2O	2.8	3.0	1.8	1.9
MnO	0.5	0.1	-	0.1
P_2O_5	0.5	0.2	-	0.2
FeO	1.6	-	1.8	-

4.5 wt% metal was included below the containers as a worst case for evaluation.

Test 3 expanded upon the results of Test 2 in that the sealed containers were enclosed in a cement-filled concrete box (simulating a cell). Four scaled-down drums, fitted with temperature and pressure monitoring instrumentation and filled with concrete and asphalt (two containers each), were placed within the concrete box which was then filled with cement. The box was placed in the test arrangement with simulated sandstone beneath and simulated bentonite and site soil backfill material beside and above, so as to simulate the site. A layer of sand was then placed over the backfill material to simulate the cover soil at the site. Figure 4 illustrates the arrangement of materials in Tests 1-3.

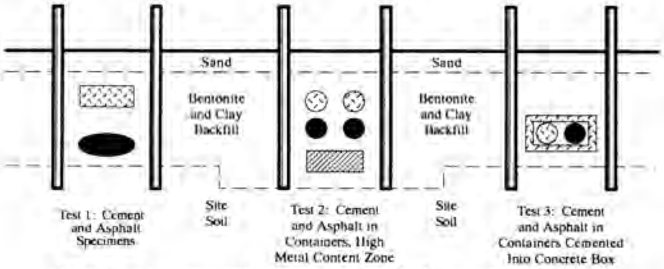

Fig. 4. Arrangement of materials in tests 1-3.

First Year Test Results. Testing of the stratified layers during the three tests resulted in relatively uniform melt rates, thus indicating similar melting properties for the different site materials. The melting efficiency of the process, which is a measure of the quantity of energy required to treat 1 kg of soil, ranged from 1.05 to 1.3kWh/kg of soil for the three tests. The typical efficiency for this scale of equipment ranges from 0.9 to 1.5 kWh/ kg of soil. It was evident from whole rock analyses and vitrification testing of the simulated soils that Japanese soils present at the site could be closely simulated by U.S. materials. This was later confirmed during demonstration testing on native soils in Japan. Similar melt rates and melting efficiencies were achieved for both the Japanese and simulated U.S. soils.

The compressive and tensile strengths of the vitrified products were evaluated using standard ASTM procedures for concrete testing. Compressive strengths of 19,000 to 47,000 psi, and tensile strengths of 1,700 to 3,900 psi were obtained. These results indicate the comparatively high strength of the ISV product. The volume reduction attained from all the U.S. and Japan tests were in the range of 42-50%.

Results of the container pressure measurements from Tests 2 and 3 indicated pressure generation rates within the cement- and asphalt-filled containers to be similar; however, the release of pressure from the asphalt-filled containers was several times faster than that from the concrete-filled containers. This was expected due to the relatively high porosity of the asphalt which allows for easy release of volatilized asphalt binder from the entire container. In contrast, concrete releases water vapor at a slower rate due to its comparative impermeability and slow degradation, which restricts the release of the free and bound water from the concrete.

Visual observations of the melt surface during the release periods reflected this difference in release rates. During release of gases from the concrete-filled containers, passive venting was observed throughout the melt. However, during release of gases from the asphalt-filled containers, shorter duration and higher intensity flaring was observed as the organic binder vapor or its pyrolysis products entered the oxygen-rich plenum region and combusted. Although the off gassing was more severe during release from the asphalt-filled containers, only a minimal (9C) rise in the plenum temperature and no loss in plenum vacuum was experienced. Pressure monitoring of the simulated cell structure during Test 3 resulted in minimal pressure generation (<1 psi) within the walls of the concrete box.

During the last two hours of Test 2, sufficient molten metal existed near the bottom of the melt to cause periodic electrical shorting. Due to metal being more electrically conductive than glass, long periods of metal shorting may decrease melting efficiency by decreasing the occurrence of joule heating within the molten soil. Recovery from electrical shorting was successfully achieved by using the electrode feeding system to lift one or both electrodes of the shorting phase up and out of the molten metal pool. This technique has been previously demonstrated on engineering-scale tests containing up to 17 wt% metals (1).

First Year Preliminary Applications Analysis

Ability to melt and treat the soil and waste materials. The ability of the ISV process to melt the various solids to be treated at the site was estimated by geochemical modelling and confirmed by engineering-scale melt testing. All observations indicated that the soil and waste materials could be melted within the envelope of typical ISV process conditions.

While the first year program did not quantitatively assess contaminant dispositions, it did include qualitative evaluation of the residual vitrified product, which was found to be typical for ISV applications on natural soils. The melting behavior of the soil and waste materials together with the quality of residual produced give strong indication that excellent contaminant dispositions may also be expected. Based on these findings, Geosafe's preliminary assessment was positive on the ability of ISV to melt and treat the soil and waste materials present at the disposal facility.

Ability to apply ISV to the given site conditions. The evaluation identified several features of the potential application that have not yet been adequately demonstrated to qualify them as being within the standard envelope of commercial ISV capabilities. These features included: 1) a target processing depth of 7.5-m (24.6-ft), 2) the potential of off-gas collection hood pressurization events due to processing sealed containers in the treatment volume, and 3) the potential to produce nonuniform melt shapes due to variable densities of materials within the treatment volume.

Geosafe's initial evaluation of these application features was positive in that they are believed to be matters that can be addressed by reasonable development work and extension of the technology's capabilities. For example, ISV has only been demonstrated thus far to a depth of 6.0 meters; however, numerous concepts exist for enhancing depth performance that are expected to be demonstrated within the next few years. Relative to gas generation rates and possible hood pressurization events, there is sufficient experience in the processing of sealed containers that indicates this potential problem area should be possible to overcome through additional development work and off-gas system design changes. In similar manner, Geosafe believes that the possibility of abnormal shape development due to density differences can be overcome through overmelting and process control features. It should be recognized, however, that since these capabilities are yet to be reliably demonstrated, these features of the application must be qualified as currently unresolved.

Ability of process effluents to meet regulatory requirements. The ISV process produces off-gas air emissions, and secondary wastes, including: 1) spent scrub solution, 2) HEPA filters, 3) activated carbon filters, 4) personal protective clothing, and 5) decontamination wastes. The most important of these effluent streams, relative to processing equipment capabilities and regulatory controls, is the off-gas emissions.

The first year applicability analysis included calculation of expected radionuclide releases to the off-gas and the resulting requirements for off-gas treatment. These calculations were based on assumed process performance values since the first year program was not directed to determination of radionuclide retention and release rates.

Calculations were performed for the concentrations of radionuclides within the off-gas collection hood, at the off-gas stack outlet, and for accumulations of radionuclides in the scrub solution and filter locations for both cement- and asphalt-stabilized LLW. The calculations indicated that radionuclide release from the treatment zone to the off-gases would be greater for the asphalt-stabilized waste because of the fact that the greater gas generation rates associated with the asphalt treatment would result in greater entrainment of particulates in the evolving off-gases. Table IV presents the results of calculations for the asphalt-stabilized waste.

The calculated values of radionuclide stack emissions, for an assumed off-gas treatment system, were compared to the current Japanese air emissions regulations for radionuclides. This preliminary analysis indicated that, if the calculations are representative of actual conditions, the stack emission levels should be acceptable for nuclear worker exposure. Further refinement of this analysis was identified as necessary because some acceptable dispersion model would necessarily be applied to the stack emissions to determine what the expected concentration of radionuclides would be in the vicinity of onsite nuclear workers, and to the public outside the controlled area.

Estimated cost of remediation by ISV. Initial estimates of ISV remediation cost at this stage of the project were made on the basis of costs for performance of the project within the U.S. This was done because of the difficulty involved in estimating the costs of performing ISV in Japan. On a U.S. basis, the estimated cost for ISV remediation was $590/tonne. Additional work is required to determine how Japanese regulations, cultural differences, or costs for labor, electricity, and materials would impact the cost of performing the project in Japan.

Needs for further study. The first year applicability analysis identified technical issues, concerns, and uncertainties that must be addressed to allow completion of a final applicability analysis. The primary needs identified are listed below and are related to the overall ISV processing system on Fig. 5.

1. Further definition of methods and demonstration of capability is needed regarding the ability of ISV to process sealed containers without off-gas collection hood pressurization events.
2. The ability to process to a depth of 7.5-m must be demonstrated.
3. The ability to control melt shape in the variable density media must be demonstrated.
4. Both the efficiency of radionuclide retention in the melt, and treatment system effectiveness for removal of radionuclides from the off-gases must be empirically determined to allow completion of the off-gas treatment and emissions analyses.
5. Methods to minimize and handle secondary waste streams must be defined and demonstrated.
6. Residual product physical, weathering, and chemical leaching properties need to be empirically determined.
7. Empirical data regarding the retention of C-14 and I-29 within the melt, and the behavior of these radionuclides within the off-gas treatment system is needed to allow further evaluation of the impact these materials may have on the potential ISV application.

TABLE IV

Calculated Radionuclide Emissions for Asphalt-Stabilized LLW

Radionuclide	Soil DF*	Off-Gas DF*	Max Conc. Bq/T	Waste Load. Tons/ton	Stack Emiss. Ci/m3	∑Emissions Ci/run
H^3	1.00E+00	1.06E+00	3.00E+11	1.30E-01	1.45E-03	7.78E+02
C^{14}	1.00E+00	1.00E+00	9.00E+09	1.30E-01	4.60E-05	2.48E+01
Co^{60}	2.00E+02	3.30E+04	3.00E+12	1.30E-01	2.32E-09	1.25E-03
Ni^{59}	2.00E+02	3.30E+04	9.00E+09	1.30E-01	6.97E-12	3.76E-06
Ni^{63}	2.00E+02	3.30E+04	1.00E+12	1.30E-01	7.74E-10	4.18E-04
Sr^{90}	3.30E+02	3.30E+04	2.00E+10	1.30E-01	9.39E-12	5.07E-06
Nb^{94}	2.00E+02	3.30E+04	9.00E+07	1.30E-01	6.97E-14	3.76E-08
Tc^{99}	2.50E+03	3.30E+04	2.00E+07	1.30E-01	1.24E-15	6.69E-10
I^{129}	1.00E+00	3.30E+04	3.00E+05	1.30E-01	4.65E-14	2.51E-08
Cs^{137}	3.20E+01	3.30E+04	1.00E+11	1.30E-01	4.84E-10	2.61E-04
Total			4.44E+12		1.49E-03	8.03E+02

* = decontamination factor

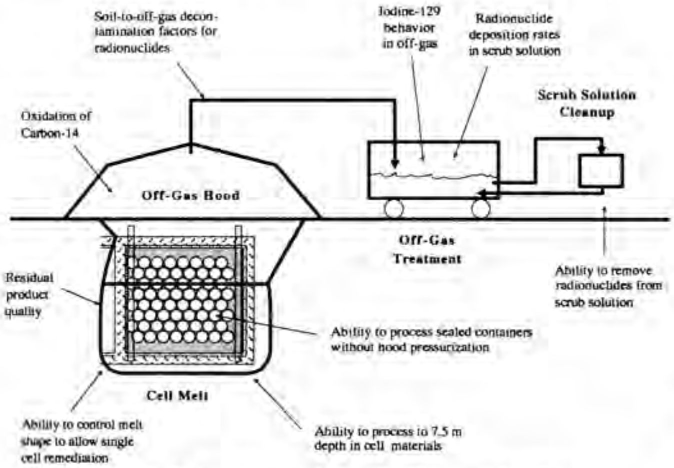

Fig. 5. Primary needs for further evaluation.

LEVEL 2 EVALUATION FINDINGS

Second Year Experimental Investigation

Testing Objectives. The primary objective of the second year testing program was to evaluate the disposition of contaminants resulting from the treatment of simulated contaminated materials by the ISV process. Tests 4 and 5 investigated the immobilization of non-volatile simulated radionuclides, and removal to the off- gas of volatile materials in either particulate or vapor forms. Vitrified product from the tests was also evaluated for physical properties and contaminant leach resistance.

A second objective of the second year test program was the generation of data to compare with the first year test results. Processing parameters and product characteristics that were evaluated included melt rate, energy consumption, melting efficiency, volume reduction, and container pressure data.

A third objective was to demonstrate the capability to scale the process up by a factor of 10 (to approximately a 1-ton melt), and to obtain confirming process performance information at that scale. The test plan called for one such test to be performed in the U.S., on simulated Japanese materials, and a confirming demonstration test in Japan, using actual site materials.

Test Descriptions. As in the first year, the second year tests were based upon the previous testing (both first and second year) to provide accurate control of test variables and produce as much usable data as possible. Test 4 was designed to evaluate the retention and release of simulated radionuclides during ISV processing of contaminated soil. Table V lists the radionuclides found at the site and the simulants selected to represent them. As in the first year testing, the native Japanese soils were simulated using soils and bentonite clay found in the U.S. A region of soil measuring 8-in. square by 8-in. deep was mixed with known amounts of simulants to form a contaminated zone centrally located in the treatment zone.

Sampling of the off-gas evolving from the melt was performed as well as pre- and post-test sampling of the soils, vitrified product, equipment wipes and rinses, and off-gas condensate resulting from the testing. All sampling performed during the second year testing program was performed in accordance with Test Methods for Evaluating Solid Wastes, Third Edition (2).

TABLE V
Actual and Simulated Contaminants

Radionuclide	Simulant	Simulant Form Added	Quantity Added (g)
Co^{60}	Co	CoO	15.1
$Ni^{59,63}$	Ni	NiO	50.1
Sr^{90}	Sr	SrO	20.0
Nb^{94}	Zr	ZrO	20.2
Tc^{99}	Mn	MnO	20.1
I^{129}	I	KI	20.0
Cs^{137}	K	KI	20.9

Test 5 was designed to evaluate the disposition of simulated radionuclide contaminants that had been stabilized with asphalt or concrete and then sealed in containers. The results of Test 5 would be compared to those of Test 4 to determine how the release characteristics of the sealed containers affected the retention of the simulated contaminants within the vitrified product. Test 5 included 16 sealed containers (eight each filled with concrete and asphalt) that were placed at two different depths in the treatment zone. Prior to placement in the containers, the asphalt and concrete were mixed with the simulated contaminants to desired concentrations. The eight concrete-filled containers were then sealed and placed at the 6 to 8-in. depth, and the asphalt-filled containers were placed at the 10 to 12-in. depth. The tests were designed in this manner to allow separate soil and off-gas sampling corresponding to contaminant stabilization material type. This was done by terminating off-gas sampling after the first layer of eight cans had been processed, the filters and impingers solutions changed and the sampler restarted prior to heating of the second layer of containers. As in the first year testing, pressure and temperature monitoring was performed on eight of the containers (four each of asphalt and concrete). The soil placement in the test container was performed identically to Test 4. Figure 6 illustrates the arrangement of materials employed in Tests 4 and 5.

Test 6 required the fabrication and use of a larger test container as the objective of this test was to produce a 1-ton vitrified block which is a factor of 10 times the typical engineering-scale product mass. Simulated bentonite and soil backfill material was placed in the entire treatment zone as a worst case for Test 6.

Second Year Test Results. Analytical chemistry work is not yet complete for all of the second year test samples. However, preliminary results indicate that the retention efficiencies for the heavy metal radioactive simulants in the vitrified product are high and similar to results obtained during previous ISV testing (3). Preliminary retention efficiencies calculated for Tests 4 and 5 are presented in Table VI.

Samples of the vitrified product from Tests 4 and 5 were submitted to Toxic Characteristic Leach Procedure (TCLP) testing to evaluate the leaching resistance of contaminants within the product glass. Results of the leach tests have been completed and are presented in Table VII. The results indicate the vitrified products are highly leach resistant and durable.

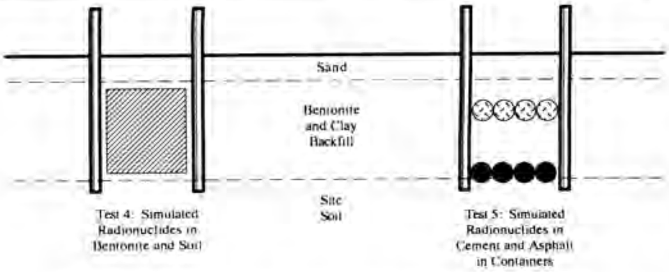

Fig. 6. Arrangement of materials in tests 4 and 5.

TABLE VI
Preliminary Retention Efficiencies for Tests 4 and 5

Simulant	Retention Efficiency
Cobalt	99.77 - 99.999
Manganese	99.95 - 99.999
Nickel	99.75 - 99.99
Potassium	99.7 - 99.9
Strontium	99.999
Zirconium	99.8 - 99.9

TABLE VII
TCLP Leach Testing of JRI Test 4 Vitrified Product

Constituent	Test 4 (mg/L)	Test 5 (mg/L)
Cobalt	0.008	0.09
Manganese	0.04	0.08
Nickel	0.10	0.16
Potassium	0.5	0.33
Strontium	0.05	0.05
Zirconium	<0.05	<0.05
Iodide	<1.7	<1.0

The volume reduction and melting efficiency values measured during Tests 4 and 5 were similar to the results produced by the first year tests. The melting efficiency of the process averaged 1.3 kWh/kg of soil and the volume reduction was in the range 38-44%.

Current Status of Second Year Applications Analysis

At the present time, evaluation of available data from Tests 4 and 5 is underway. Once all the data has been evaluated, the results will be incorporated into an intermediate (second level) applications analysis. Based upon the results of the second year testing, the first year preliminary applications analysis will be updated based on the new test data, and will identify technical issues, concerns, and uncertainties that need to be resolved during the third year experimental and evaluation program.

EXPECTED CONCLUSION AND USE OF STUDY

Geosafe's overall conclusion from the effort to date is that the ISV technology holds strong potential as a cost effective means of remediating a LLW site such as the one assumed. While the site poses significant challenges to the technology, none have been identified at this time that are considered beyond the reach of reasonable development and extension of the technology. Determination of the actual cost of performing ISV remediation within Japan requires translation from the U.S. cost basis; however, because of the technical challenge posed by this type of site, Geosafe does not expect that the cost translation will diminish ISV's cost competitiveness relative to alternative technologies.

Since this 3-year project has a budget which limits experimental work to engineering-scale, it is likely that the project will conclude with some technology features still requiring confirming demonstration at large-scale. Such demonstration needs are considered highly likely to be addressed by the orderly progression and development of the technology that is occurring and is projected to occur. Geosafe is confident that completion of the 3-year study and associated development work will qualify the ISV technology for LLW disposal facility remediation applications.

REFERENCES

1. R.K. FARNSWORTH, K.H. OMA, and C.E. BIGELOW, "Initial Tests on In Situ Vitrification Using Electrode Feeding Techniques," PNL-7355, Pacific Northwest Laboratory (May 1990).
2. "Test Methods for Evaluating Solid Wastes, Third Edition," SW-846, U.S. EPA (1986).
3. B.E. CAMPBELL, C. L. TIMMERMAN, and W. F. BONNER, "Underground Tank Vitrification: Engineering-Scale Test Results," PNL-7295, Pacific Northwest Laboratory (June 1990).