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3. ACTIVITY DESCRIPTION

The ISV project being conducted at the INEL represents a portion of a systems approach to the solution of a complex problem, the remediation of buried wastes at the Subsurface Disposal Area (SDA) of the INEL's Radioactive Waste Management Complex (RWMC). ISV is being considered for use in three environments, contaminated soils, buried wastes, and underground structures. This project addresses the adaptation of the ISV technology, which was originally developed for treatment of contaminated soil, to the challenges posed by buried wastes. These challenges include both

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**Idaho National Engineering
Laboratory In Situ Vitrification
Project FY-91 Progress Report**

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*Work performed under
DOE Contract
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Idaho National Engineering Laboratory
In Situ Vitrification Project
FY-91 Progress Report
EGG-WTD-10033

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ABSTRACT

This document presents a summary of the activities conducted under the In Situ Vitrification Project at the Idaho National Engineering Laboratory (INEL) during FY-91. The In Situ Vitrification Project is an integrated project that includes laboratory (i.e., engineering-scale) tests, field tests, evaluation of the vitrified test products, and analytical models of the in situ vitrification process. This project is directed at examining the application of the in situ vitrification process to buried wastes contaminated with transuranic compounds and other contaminants disposed of at the INEL Subsurface Disposal Area of the Radioactive Waste Management Complex. Data collected in the course of these efforts will be used to assess in situ vitrification according to the nine remedial technology evaluation criteria set forth in the Comprehensive Environmental Response, Compensation, and Liability Act.

SUMMARY

The FY-91 In Situ Vitrification (ISV) Project at the Idaho National Engineering Laboratory (INEL) centered on identifying technical issues for the application of ISV on buried wastes, equipment setup and personnel training required for laboratory testing capability at the INEL, completing activities associated with laboratory and field tests conducted during FY-90, continuing development of analytical models, and preparing for further laboratory and field testing.

FY-91 activities consisted of integrated activities directed primarily at determining the applicability of ISV to remediation of buried wastes at the INEL. In addition, technical issues relative to buried wastes across the Department of Energy (DOE) Complex were started to be addressed by the ISV project at the INEL.

An ISV Steering Committee was formed to provide technical planning, control, and focus for the INEL ISV project. The Committee's charter was to broadly define technical issues associated with application of the process to the Subsurface Disposal Area (SDA), evaluate the relative importance of each issue during the treatability investigation, propose requirements for closing each issue, and develop a roadmap for obtaining closure of each issue. The closure requirements will provide direction for the entire ISV project.

Laboratory testing activities during FY-91 included preparations for laboratory testing at the INEL test facility and the evaluation of results from four laboratory-scale tests conducted during FY-90. Setup, modification, and documentation of the INEL laboratory test and support equipment was completed. DOE Idaho Field Office (DOE-ID) approvals are pending of the hazard classification, safety analysis report, and operational readiness review process documentation. Training program development was completed and implementation was begun for all laboratory test personnel.

Test reports evaluating the results of four laboratory-scale tests performed at Pacific Northwest Laboratory (PNL) and Geosafe during FY-90 have been drafted. Results indicate that INEL soils and waste can be processed into a highly durable waste form; pressurization of the ISV hood and off-gas system are not expected to be significant; and high destruction and removal efficiencies for volatile, halogenated hydrocarbons can be expected.

Also completed during FY-91 were the interim and final reports for the Intermediate Field Tests conducted at the INEL during FY-90. Test results indicate that ISV is a viable process for application to buried waste and provide clearer definition of data to be pursued during future laboratory and field testing.

Additional FY-91 field testing activities included a review of noninvasive geophysical methods, planning for two field tests to be conducted by PNL, investigation of power availability for intermediate and large field test activities at the INEL, planning for an ISV demonstration at the SDA Acid Pit, and waste minimization and waste management efforts.

Product evaluation strategies defined during FY-90 were implemented during FY-91 to determine the chemical and physical properties of the ISV product produced during laboratory-scale and field tests. Other activities included reduction/oxidation studies and analytical methods development; laboratory pyrolysis testing to understand the chemical dynamics of organic materials, support ISV analytical modeling efforts, and determine the usefulness of rare-earth oxides to simulate plutonium behavior; and analysis of proof-of-principle testing of acoustic tomography during the FY-90 intermediate field test.

ISV modeling activities during FY-91 included further model development through modification and extension of existing codes, and development of new models and codes. Graphical and visualization software was also developed. Evaluation and validation activities were begun in the modeling of melt volume, determination of the dominant parameters in the melting process, and analysis of pressurization due to water vapor.

Public education and communication efforts continue to be broadly based, reaching management, technical, non-technical, and academic audiences.

Planning for FY-92 was begun for further analytical model development to support test planning and applied research, laboratory-scale test series design, and a demonstration of the ISV process at the SDA Acid Pit. Technical issues identified during FY-91 provided the planning basis for each of these activities.

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ACRONYMS

BWP	Buried Waste Program
DAS	data acquisition system
DOE	Department of Energy
DOE-ID	Department of Energy Idaho Field Office
DQO	data quality objectives
DT&E	development test and evaluation
EIRC	Environmental Restoration Program Independent Review Committee
FSAR	Final Safety Analysis Report
HEPA	high efficiency particulate air (filter)
ICP-MS	inductively coupled plasma atomic emission spectroscopy-mass spectroscopy
IFT	Intermediate Field Test
INEL	Idaho National Engineering Laboratory
ISRC	Independent Safety Review Committee
ISV	in situ vitrification
LFT	large field test
MM5	Modified Method 5
MTF	Memorandum to File
NEPA	National Environmental Policy Act
NIST	National Institute of Science and Technology
ORNL	Oak Ridge National Laboratory

ORR	Operational Readiness Review
PNL	Pacific Northwest Laboratory
PRA	probabilistic risk analysis
PSRT	Pilot-Scale Remedial Test
R&D	research and development
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
TAN	Test Area North
TCLP	toxicity characterization leaching procedure
TRU	transuranic
TSR	technology status report
USGS	U.S. Geological Survey
WRRTF	Water Research Reactor Test Facility

**Idaho National Engineering Laboratory
In Situ Vitrification Project
FY-91 Progress Report**

1. INTRODUCTION

The purpose of this report is to present an overview of activities conducted under the In Situ Vitrification (ISV) Project at the Idaho National Engineering Laboratory (INEL) during the 1991 Fiscal Year. The report will concentrate on describing the activities being conducted by the ISV project at the INEL and the advances made in this project during FY 1991. Because detailed descriptions of the ISV process are available elsewhere (Arrenholz et al. 1990, Callow et al. 1991a), this discussion will not be repeated here.

2. CONCLUSIONS

The conclusions and recommendations are as follows:

- An ISV Steering Committee was formed in FY 1991 to define technical issues associated with ISV processing of buried waste sites at the INEL Subsurface Disposal Area (SDA). The Steering Committee identified a total of 35 ISV technical issues, with 25 applicable to the SDA Acid Pit and all 35 applicable to the Transuranic Pits and Trenches (TRU-PTs) at the SDA. A report on the ISV Steering Committee activities was published in FY-91 (Stoots et al. 1991).
- An ISV Laboratory Test Facility was setup in the Hot Cell Annex at Test Area North in FY 1991. The Lab Test Facility was modified to a double hood/offgas system configuration to allow for safe operation of ISV lab tests with sealed containers of pressurized, hazardous materials (such as in the TRU-PTs at the INEL SDA). All of the documentation necessary to operate the ISV Lab Test Facility has been completed. The ISV Lab Test facility has been approved for startup by EG&G Idaho, but still needs startup approval from the Department of Energy Idaho Field Office (DOE-ID). This is expected in FY 1992.
- A total of six series of laboratory tests were identified for the ISV Lab Testing Task in FY 1991. A number of these tests are to be performed in FY 1992, pending startup approval from DOE-ID, and availability of FY 1992 funding.
- The final report for the 4th Engineering-scale test on INEL soils was published by Pacific Northwest Laboratory (PNL) in June 1991 (Shade et al. 1991). The December 1989 test involved INEL soils containing all eight of the toxicity characterization leaching procedure (TCLP) metals along with a simulant of the Rocky Flats Series 743 sludge that is buried in the SDA TRU-PTs. The test resulted in an ISV waste form with excellent quantities of heavy metal retention and no significant transport of hazardous contaminants. In addition, the ISV waste form completely fused with a layer of basalt in the test, with no change in product quality at the glass/basalt interface.
- Draft reports of three other engineering-scale tests (ES-5, ES-6, and ES-7) were completed by PNL and Geosafe in FY 1991. The tests evaluated different configurations of sealed containers containing a composite simulant of the Rocky Flats Series 74 sludges that are buried in the TRU-PTs. Preliminary results show that the pressurizations were primarily a result of the presence of nitrates and organics in the sealed containers, a condition not expected to be present in the TRU-PTs. However, it was also found that only 50% of the affected canisters ruptured with an off-gas release significant enough to pressurize the engineering system containers.

3. ACTIVITY DESCRIPTION

The ISV project being conducted at the INEL represents a portion of a systems approach to the solution of a complex problem, the remediation of buried wastes at the Subsurface Disposal Area (SDA) of the INEL's Radioactive Waste Management Complex (RWMC). ISV is being considered for use in three environments, contaminated soils, buried wastes, and underground structures. This project addresses the adaptation of the ISV technology, which was originally developed for treatment of contaminated soil, to the challenges posed by buried wastes; these challenges include the presence of large objects, large amounts of metals, containerized wastes, and highly variable waste composition and soil content.

The ISV project is comprised of several tasks integrated to achieve a common goal. Analytical studies, laboratory pyrolysis tests, laboratory tests, field tests (including intermediate-scale tests conducted in FY-90 and planned large-scale tests), evaluations of the ISV waste form, and development of analytical models of the various aspects of the ISV process are all involved in addressing the issues associated with buried wastes. Support for these efforts is being provided by Battelle at the Pacific Northwest Laboratory (PNL) and by the Geosafe Corporation, both of Richland, Washington. The common goal of these efforts is the eventual remediation of all or a portion of the transuranic waste containing portions of the Subsurface Disposal Area at the INEL Radioactive Waste Management Complex.

ISV activities efforts are currently focused upon the needs of two operable units at the SDA, the Acid Pit and the Transuranic (TRU) Waste Pits and Trenches. The Acid Pit, which was closed in 1961, is an area previously used for the disposal of radioactively-contaminated acids and solvents; it is, thus, a contaminated soil situation. The TRU Waste Pits and Trenches contain TRU waste, primarily of Rocky Flats Plant origin, and are highly heterogeneous in nature. These areas contain large amounts of organic and inorganic compounds, metals, and radionuclides. Waste streams present in these pits and trenches include boxes, drums, loose wastes, and a variety of bulky items (Arrenholz and Knight 1991).

4. ACTIVITY RESULTS

4.1 Technical Issue Steering Committee

One of the activities of the INEL ISV project during FY-91 was the formation of the ISV Steering Committee. This Committee is composed of key technical staff of the ISV project and is chartered to provide technical planning, control, and focus for the INEL ISV project. As such, this Committee has become the primary integrating entity for ISV activities at the INEL.

The mission of the Committee is to define technical issues associated with the proposed application of ISV at the SDA, evaluate the importance of each issue relative to the treatability investigation, propose requirements for closing the issue, and develop a roadmap for obtaining closure of the issue (Stoots et al. 1991). Technical issues will be identified with respect to the global needs of ISV without regard to the specific operable unit being examined; specific technical issues will be addressed by the committee when more information about the particular operable unit and waste forms to be remediated, or tested, are known. The recommended closure requirements for the individual technical issues will determine how that issue is addressed in the ISV project (e.g., will closure necessitate field testing or is laboratory testing sufficient, can the issue be closed through analytical modeling, will "hot" testing be required to close the issue or can it be achieved through "cold" testing?). As a result, these closure requirements will focus and direct planning and execution of the ISV project.

Further detail on the Steering Committee, the technical issues associated with ISV, approaches to resolution of these technical issues, and the relation of these technical issues to the operable units under consideration are presented in the Steering Committee report, "Technical Issues Associated with In Situ Vitrification of the INEL Subsurface Disposal Area, Volume 1" (Stoots et al. 1991).

4.2 Laboratory Testing

The purpose of the INEL ISV laboratory testing program is to provide research and development (R&D) activities that support development test and evaluation (DT&E) studies on the suitability of ISV for remediation of all or some of the SDA at the INEL RWMC. The program involves laboratory-scale (also known as engineering-scale) tests that provide information on the effect of various process and compositional variables on ISV processing performance; this information can then be used to improve operation of the full-scale ISV equipment during demonstration testing. The program also involves the use of analytical modeling and engineering calculations to provide closure on technical issues that have been identified by the ISV Steering Committee.

4.2.1 Accomplishments

In FY-91, the objective of the ISV laboratory testing program was the setup and implementation of a laboratory-scale ISV testing facility at the INEL. To accomplish this objective, it was necessary to divide the work into two parts. These were as follows:

- The setup of the INEL ISV laboratory testing facility, including equipment setup, completion of the necessary startup documentation, and training of ISV laboratory staff
- The development and design of a number of laboratory tests and test series that would serve to answer many of the technical issues identified by the INEL Steering Committee.

Work for the INEL ISV laboratory program was also performed in FY-91 by both the Geosafe Corp. and PNL. The activities focused on the evaluation and reporting of the results of three engineering tests that were conducted by Geosafe and PNL in the fourth quarter of FY-90. Geosafe also assisted in the setup of the ISV laboratory test facility, and PNL developed a test plan for a series of two ISV laboratory tests involving sealed containers of hydrogen (test #1) and boxes of cellulose and nitrates (test #2). Further details of the work performed under the laboratory testing program is presented below.

4.2.1.1 Laboratory Test Facility Setup. The setup of the ISV laboratory testing facility at the INEL was started in FY-90, during which EG&G Idaho purchased the ISV lab test equipment from the Geosafe Corp. Activities conducted during FY-91 associated with the setup of the ISV laboratory test facility have included the following:

- Setup and modification of the ISV lab test equipment
- Acquisition and setup of equipment in support of the ISV lab test equipment (e.g., secondary off-gas sampling systems, data acquisition system)
- Completion of the documentation and reviews necessary to begin operation of the INEL ISV equipment.

4.2.1.1.1 ISV Lab Test Equipment Setup—The ISV lab test equipment arrived from Geosafe in the first quarter of FY-91 and was set up at Test Area North (TAN 633), room 9. Plans to modify the existing lab equipment were initiated in December 1990 after calculations showed that there was a potential for hazardous emissions into the immediate work area, resulting from tests involving sealed containers of hazardous materials. To eliminate this potential release, it was necessary to modify the existing INEL ISV lab test setup such that the ISV testing equipment would have a primary and secondary hood and off-gas system, rather than a single hood and off-gas system. Use of this double-hood arrangement eliminated the potential for hazardous off-gas emissions to the immediate area. Details of the equipment as set up are given in Figure 1.

4.2.1.1.2 ISV Lab Testing Facility Support Equipment—INEL ISV lab test support equipment activities included the development of a data acquisition system (DAS) and the purchase of a continuous mass spectrometer, a Modified Method 5 (MM5) stack (off-gas) sampling system, and a continuous mercury analyzer. All of the off-gas sampling equipment was in place and operational by the end of FY-91.

ISV LABORATORY EQUIPMENT MODS

PRIMARY SYSTEM FLOW

SECONDARY SYSTEM FLOW

Figure 1. ISV laboratory equipment mods.

4.2.1.1.3 Startup Documentation and Reviews—National Environmental Policy Act (NEPA) documentation for the ISV laboratory test facility was approved [Memorandum to File (MTF)] by DOE-ID in October 1990. In addition, an Air Permit Exemption was granted, by both the State of Idaho and DOE-ID, for ISV laboratory operations in October 1990. The approved MTF limits ISV lab test operations to a total of 600 g of hazardous organics and 3,900 g of hazardous inorganics per test.

Following approval of the NEPA documentation, a Tentative Hazard Classification document was developed for the laboratory ISV system. This tentative hazard classification identified the ISV lab testing activity as Low Hazard, and further limited the total amount of hazardous inorganics in a test to 721 g mercury and 154 g lead. Internal approval of the Low Hazard Classification was granted by EG&G Idaho's Independent Safety Review Committee (ISRC) in March 1991.

The Low Hazard classification required the development of a Final Safety Analysis Report (FSAR) for ISV lab testing activities. The FSAR for ISV lab testing activities was approved by the ISRC in June 1991, and submitted to DOE-ID for their review and approval. DOE-ID approval of the SAR is expected early in FY-92.

In addition, other documentation, required prior to startup, was written for laboratory test operations. These included Detailed Operating Procedures for both single-hood and double-hood operation, a Standard Operating Procedure for the ISV equipment, a new Lock and Tag Procedure for ISV Operations, a Generic Test Plan for ISV Lab Operations (including the generic Sampling and Analysis Plan), a specific test procedure for the ISV Training Tests, a Waste Minimization Plan, and a Spill Prevention, Control, and Countermeasures Plan. All of these documents have been reviewed and approved by either the TAN Independent Review Committee or the Environmental Restoration Program Independent Review Committee (EIRC) at EG&G Idaho.

An Operational Readiness Review (ORR) of the ISV laboratory test facility was held by EG&G Idaho in June 1991. Comments from the ORR were incorporated into the existing documentation, and approval for startup of the ISV laboratory testing facility was granted by the ORR chairman in July 1991. DOE-ID is presently conducting an internal ORR. Approval for startup is expected in FY-92.

4.2.1.2 Laboratory Test Design Activities. Six laboratory tests and test series were proposed in FY-91. These proposed tests were based on test specifications developed by the ISV Steering Committee to resolve many of the technical issues identified by the ISV Steering Committee. Most of the proposed tests are applicable to the TRU Waste Pits and Trenches at the SDA, as well as to resolving technical issues associated with remediation of the SDA Acid Pit. Details on these proposed tests can be found in Section 5.2.

4.2.2 Pacific Northwest Laboratory Activities

In FY-91, the activities performed by PNL for the ISV laboratory testing program were the evaluation and reporting of results from engineering-scale ISV tests 4 (ES-4) and 5 (ES-5), which used INEL soils. These tests, which were performed in FY-90, were the first two engineering tests involving INEL soils contaminated with hazardous materials.

4.2.2.1 Engineering-scale Test 4. The final report for ES-4 was published by PNL in June 1991 (Shade et al. 1991). This test, which was performed in December 1989, involved INEL soils that contained all eight of the toxicity characterization leaching procedure (TCLP) designated inorganics (arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver). This test also contained a calcium silicate-based sludge containing all four of the halogenated hydrocarbons [carbon tetrachloride (CCl_4), tetrachloroethylene (PCE), trichloroethylene (TCE), and 1,1,1-trichloroethane (TCA)] that are expected to be present in Series 743 sludge, which was received from the Rocky Flats Plant and is buried in the TRU Waste Pits and Trenches at the SDA. The purpose of this test was to determine the ability of the ISV process to effectively process TCLP inorganics and halogenated hydrocarbons that might be present in a typical buried waste environment at the SDA.

The results of this test showed that the contaminated soil could be processed into a durable ISV waste form with excellent qualities of heavy metal retention, and no significant transport of volatile organics or semi-volatile inorganics into the soils surrounding the ISV melt. In addition, the test successfully demonstrated the ability of the ISV melt to vitrify into and fuse with a layer of basalt, with no appreciable change in product quality at the glass/basalt interface.

4.2.2.2 Engineering-scale Test 5. The ES-5 final report is expected to be published in FY-92, following analysis and interpretation of data conducted during FY-91. This test, which was performed in September 1990, involved ISV processing of INEL soils containing a close-packed layer of sealed canisters that extended outside of the zone to be vitrified. The sealed canisters were each filled with a composite, simulated mixture of the five Series 74 sludges from Rocky Flats Plant that have been disposed of in the TRU Waste Pits and Trenches. The purpose of the test was to determine the effect of this close-packed canister layer on (a) the transient pressure and temperature responses in the ISV hood plenum and (b) the potential volatilization, entrainment and migration of the five hazardous materials within the Series 74 sludges (mercury, and the four halogenated hydrocarbons, CCl_4 , PCE, TCE, and TCA).

The results of this test showed that approximately 50% of the depressurized canisters ruptured with an off-gas release significant enough to positively pressurize the engineering system container. However, it was determined that the driving mechanism behind these pressurization was the presence of nitrates in combination with organic materials. These pressurization are not expected to be as significant in actual buried waste conditions, in which the waste containers (i.e., drums) have deteriorated and the nitrate wastes may be separated from the organic sludges.

4.2.3 Geosafe Activities

In FY-91, activities performed by the Geosafe Corporation for the INEL ISV laboratory testing program were the completion of a 40-hr training session on ISV theory that was given to ISV laboratory testing personnel in July 1991, and evaluation and reporting on results of engineering-scale tests 6 and 7 (ES-6 and ES-7) of INEL soils, which were performed by Geosafe at the end of FY-90.

4.2.3.1 Engineering-scale Test 6. The ES-6 final report is expected to be published in FY-92 following data analysis and interpretation conducted during FY-91. Test ES-6, which was performed in September 1990, specifically tested the effect of ISV processing on a random array of 40 sealed canisters in three layers that extended outside of the zone to be vitrified. The canisters contained a composite, simulated mixture of the five Series 74 sludges from Rocky Flats Plant that were typically buried in the TRU Waste Pits and Trenches at the SDA.

The results of this test were similar to the results of ES-5, which involved a layer of close-packed canisters. The results showed that there was a significant interaction between canister depressurizations and hood temperatures, and SO_x and NO_x emissions. The results also indicated destruction efficiencies for the volatile, halogenated hydrocarbons of greater than 88%. This level of efficiency should result in a total destruction and removal efficiency of 99.99% to 99.999% for the ISV off-gas system.

4.2.3.2 Engineering-scale Test 7. The ES-7 final report is expected to be published in FY-92. This test, which was also performed in September 1990, specifically tested the effect of ISV processing on three canisters within the melt. The first two cans contained a composite, simulated mixture of the five Series 74 Rocky Flats sludges that were routinely buried in the SDA; the upper canister was perforated, however, and the second canister was sealed. The third canister, which was also sealed, contained pure Texaco Regal oil (a nonhazardous type of machining oil typically used in Rocky Flats Plant operations). The purpose of this test was to evaluate the different effects associated with ISV processing of sealed and unsealed containers.

The results of this test showed that only two canisters experienced a build up in pressure. Although one test canister had a significant increase in internal pressurization, reaching a maximum of 10.5 psi prior to rupturing, the pressurization in the other canister was less rapid and reached a maximum pressure of only 5.2 psi prior to rupturing. Two explanations behind these differences have been put forth. One, the procedures for sealing the pressure sensing lines are under suspicion. Two, the pressure differences may be due to differences in mechanical soil failure. Testing using the INEL laboratory equipment should be more conclusive.

4.3 Field Tests

The Field Test effort was directed at two major areas during FY-91. Work begun in FY-90 in support of the development of the ISV technology for the SDA TRU Waste Pits and Trenches operable unit application was continued. In addition, work was initiated on a demonstration of the

technology at the SDA Acid Pit operable unit. As mentioned previously, the Acid Pit, unlike the TRU Waste Pits and Trenches operable unit, does not contain buried waste forms. Thus, the development needs for the applications are significantly different.

4.3.1 SDA TRU Waste Pits and Trenches Application

The field test activities associated with application of the ISV technology to the SDA TRU Waste Pits and Trenches were directed at completing the evaluation of the nonhazardous/radioactive Intermediate Field Tests conducted in FY-90 and preparing for future intermediate and large field tests aimed at resolving technical issues. Specifically, test planning and preparation was initiated for a nonhazardous/radioactive Intermediate Field Test to investigate the phenomenon of gas release mechanisms from sealed waste containers.^a

4.3.1.1 FY-90 Intermediate Field Tests. Work was completed in FY 1991 on the Intermediate Field Tests (IFTs) conducted at the INEL in June and July 1990. These tests were conducted as a cooperative effort of the INEL and PNL. FY-91 activities focused on site restoration, data analyses, and reporting. Information on the design of the test pits and the objectives of the tests can be found in Callow et al., (1991a).

Several reports were issued to publish the results of the IFTs. An interim report was published in February 1991 (Callow et al. 1991a). This report included both operational data and data obtained during excavation of the products. A final report was published in August 1991 (Callow et al., 1991b); this report included information from the interim report supplemented by additional results from product evaluation studies, tracer studies, and analytical modeling of hood pressure and temperature transients experienced during the tests. The results from these field tests indicate that ISV is a viable process for application to buried waste.

Key conclusions from these IFTs include the following:

- In situ vitrification is a feasible technology for application to buried wastes. The process incorporated and dissolved simulated waste containers into the melt to produce a durable glass and crystalline product. The electrode feed technology was successful in processing the high metal content waste.
- Refinements in equipment design are needed for production-scale processing equipment. A robust off-gas processing system will be required to effectively contain the off-gases inside the hood. The hood must be designed to accommodate the relatively slow developing pressure spikes created by gas releases from containers, combustion, and thermal expansion of gas. The hood must be capable of withstanding contact from

a. At the time of this writing, funding guidance for FY-92 will not support conductance of this test, which was originally scheduled to begin in November 1991.

splatter of molten glass and must be capable of accommodating short duration gas temperatures in excess of 700°C.

- Order-of-magnitude estimates for amounts of tracer materials released into the off-gas system for Test 1 were several grams to several tens of grams. This corresponds to up to several percent of the amounts initially added to the pit. The data suggest that during buried waste ISV processing, the release of rare-earth tracers in the melt is greater than values previously reported for plutonium release during processing of contaminated soil. These tests are inconclusive regarding the amount of expected plutonium release associated with ISV processing of buried waste. Additional efforts are required to assess the adequacy of these tracers to simulate Pu compounds found in buried waste. Similarly, additional theoretical insight is needed in understanding the mechanisms of contaminant release from the melt.

Additional test conclusions, related to evaluation of the ISV waste form produced during these tests, are presented in Section 4.4.2.1.

4.3.1.2 Geophysical Methods Investigation. Currently available noninvasive geophysical methods that may be of use in ISV applications were also investigated. The principal ISV applications fall into the areas of site and waste characterization, monitoring of the ISV melt during processing, and product characterization. The study reviewed literature and information available in scientific fields that utilize geophysics, conducted several surveys at a demonstration (nonradioactive and nonhazardous) burial site at the SDA, and made recommendations on geophysical techniques currently available that would be most useful for ISV applications.

The findings of the study are contained in a series of documents, *Use of Noninvasive Geophysical Techniques for the In Situ Vitrification Program*, with volumes entitled *Literature Review* (Josten et al. 1991a), *Demonstration at the Simulated Waste Pit* (Marts et al. 1991), and *Overview and Recommendations* (Josten et al. 1991b). A fourth document, providing an executive summary of the findings of the study and the reviews, will be completed in November 1991.

4.3.1.3 Large Field Test Equipment. Planning begun during FY-90 and continued through FY-91 included the conduct of Large Field Tests (LFTs) of the ISV process at the SDA. Although these plans were changed during FY-91, as part of these efforts several equipment design activities were conducted and completed during FY-91. These activities were primarily related to documentation preparation and review, rather than actual purchase of equipment. These efforts are now considered to be ready for technology transfer to a private sector industrial partner.

Documentation completed during FY-91 included Functional and Design Requirements (Bonnenberg 1990) and System Design Requirements for the LFT equipment, and Operational Requirements for LFT measurement and control instrumentation. Procurement specification documents were completed and issued for several components of the LFT ISV processing equipment.

These components include transformers, measurement and control instrumentation, off-gas processing wet scrubber systems, off-gas blower systems, and a current controller.

4.3.1.4 ISV Safety/Hazards Analyses. Activities regarding the determination of safety concerns and the hazard classification of the ISV process during FY-91 were centered around the large field tests (LFT) which were planned during FY-90. Although these tests are not currently funded in future years, the activities performed during FY-91 are of value in their applicability to the planned ISV demonstration at the SDA Acid Pit, as well as future applications of ISV for remediation of buried wastes at the SDA.

Much of this effort was centered around the probabilistic risk analysis (PRA). These activities included a preliminary analysis of hazards associated with a large field test of ISV (Wierman and Purser 1991) and the development of accident scenarios for ISV LFTs.^b The culmination of this effort was the development of the hazard classification of LFTs of the ISV technology in SDA Pit 9 or a similar environment. The methods used in determination of this LFT hazard classification are presented in Enyeart.^c

An important area of concern from the standpoint of safety is the LFT off-gas treatment system. These concerns have led to the development of a model that will be used for analyzing off-gas transport during both normal operation of the ISV LFT system and off-normal (i.e., accident) events. In addition, a report^d was prepared to document potential failures of the various off-gas system components in the different configurations being considered for the LFTs.

4.3.1.5 Future Field Test Planning. Planning activities and design of additional field tests were conducted in FY-91 utilizing information gained during the INEL FY-90 IFTs. These planned field tests will also be intermediate size tests and will be conducted in conjunction with PNL at Hanford, Washington. These tests are designed to further define the mechanisms of off-gas release from the melt, which can result in hood pressure and temperature transients.

Two test pits have been designed at Hanford for these future tests. As part of the test planning process, a summary test plan^e was prepared by EG&G Idaho. This summary plan provides

b. Unpublished work by F. E. Purser on hazard class and facility classification for the ISV large field test for Rocky Flats pits and trenches, August 1991.

c. Unpublished paper by T. D. Enyeart, G. D. Lassahn, F. E. Purser, T. E. Wierman, 1991, *Hazard Class Determination for a Large Field Test of ISV*, in 1st International Mixed Waste Symposium, Baltimore, MD.

d. Unpublished report by F. B. Purser, *Single Component Failures for Different Off-gas System Configuration in ISV-LFT*, 1991.

e. Unpublished work by R. A. Callow and M. D. Herd, *Summary Test Plan for ISV Buried Waste Tests 3 and 4*, 1991.

the background for the test objectives and defines how the test objectives fit into the overall planning for the ISV project. Thus, the plan provides a link between closure of ISV technical issues, as defined in Stoots et. al. (1991), and the specific test objectives.

As part of the planned field tests, several prototype pressure suppression systems for the off-gas hood will be designed and tested. The designs and fabrication are being done by PNL with INEL oversight and concurrence. Design reviews were conducted during FY-91 in support of this activity.

4.3.1.6 Power Availability Studies for Future Field Tests. ISV field tests require a power supply of 0.5 to 4.5 megawatts, depending on the test equipment used (intermediate versus large). Engineering studies were conducted during FY-91 to identify and evaluate power supply options for ISV field tests at the INEL. Power supplies were investigated for both intermediate and large ISV test equipment for use not only at the SDA, but also at other sites around the INEL.

The SDA lacks adequate electrical power for ISV large field tests. An engineering study^f examined three alternatives to supply sufficient power for large field tests of the ISV technology at the SDA. For limited ISV testing at the SDA using large field test equipment, it was determined that the most cost effective approach would be to lease three 1.5 mVA diesel generators, along with switchgear and transformers, from the U.S. Army Field Support Center in Ft. Belvoir, VA. These units are modular in design and are housed in large transport containers that can easily be transported via railcars or flatbed trucks. It is estimated that the cost of leasing this equipment from the military would be an order of magnitude cheaper than leasing similar equipment from commercial vendors.

A second power study (West 1991) was conducted to develop power supply options for large field tests, which require approximately 4 to 4.5 megawatts of power, at other INEL sites. Identified in this power availability study were three potential ISV cold test sites at the INEL where nonradioactive testing could be conducted using large field test equipment. The three sites selected in this second power study were: Test Area North-Water Research Reactor Test Facility (TAN-WRRTF), Test Area North-Loss Of Fluid Test, and Power Burst Facility-Organic Moderated Reactor Experiment. Pending funding and program guidance from DOE, it was recommended that future large cold ISV field tests be conducted at the TAN-WRRTF site.

4.3.2 SDA Acid Pit Application

The other major area of ISV Field Test effort during FY-91 came about as a result of a request from both Environmental Restoration Program and Waste Technology Development Department management to begin preparation for a demonstration of the ISV technology at the SDA Acid Pit. The Acid Pit, a contaminated soil site, was used from the mid-1950s until 1961 for disposing of a variety of liquid wastes, including organic solvents, radioactively contaminated acids, and miscellaneous laboratory chemicals.

f. Unpublished research on the ISV field tests portable power study by J. P. Walrath, May 1991.

The ISV project has defined the characterization data required to support preparation for an ISV demonstration at the Acid Pit.^g The data are required to: determine the feasibility of applying ISV in the Acid Pit environment, evaluate the potential environmental impacts, determine the hazard classification of the demonstration and conduct risk and safety analyses, assist in developing test plans and test procedures through test predication analyses, and identify and assess the technical issues associated with this application of the ISV technology.

Sampling of the Acid Pit is scheduled to begin during October 1991; as a result, initial characterization data will not be available until December 1991. Despite the lack of characterization data, however, several activities were completed. These activities include: power availability studies, preliminary identification and determination of closure requirements for technical issues associated with this ISV application, and initial preparation of a demonstration work plan and an environmental checklist.^h

4.3.2.1 Demonstration Planning Documents. Preliminary demonstration objectives have been determined. As mentioned previously, initial identification of the technical issues associated with applying the ISV technologies as a remedy for the Acid Pit has been completed. Issues that must be resolved prior to conducting a safe demonstration at the Acid Pit will be resolved through analytical studies (i.e., modeling) and laboratory testing. The requirements for closing these technical issues are being defined and will be documented early in FY-92. An Environmental Checklist was also prepared for the ISV Acid Pit demonstration to initiate the NEPA and other permitting processes.

4.3.2.2 Power Availability at the Acid Pit. A power design studyⁱ indicated the availability of sufficient power, except at peak times during the year, to conduct an Intermediate Field Test (which requires approximately 300 to 400 kilowatts) at the RWMC. This study determined the most feasible and cost effective power supply option for an Acid Pit demonstration was the use of existing power, which would require a line extension and additional transformer.

4.3.3 Waste Minimization and Management

Another important area of concern to the field testing of the ISV technology is in the area of waste minimization and waste management. Although ISV is a process for the remediation of wastes, the process itself generates wastes in the form of high efficiency particulate air (HEPA) filters and scrub solutions from the off-gas treatment system. During the ISV process, organics present in the

g. Unpublished letter report from L. L. Fritz to R. M. Lugar presenting ISV modifications to the draft Acid Pit sampling and analysis plan, June 1991.

h. Letter report from S. K. Merrill to J. R. Jansen submitting the environmental checklist for the ISV Acid Pit demonstration, August 26, 1991.

i. Unpublished research on conceptual design of ISV temporary electrical power installation by G. S. West, September 1991.

wastes are destroyed by combustion and pyrolysis and most metals and radionuclides are incorporated into the vitrified mass; however, volatile metals (such as mercury) and particulates (which may contain small amounts of metals and/or radionuclides) are removed in the off-gas system and must be treated in accordance with the appropriate regulations.

A waste minimization plan^j for the ISV project was written to identify the waste minimization objectives of the ISV project. The plan identifies current objectives for waste minimization in the ISV off-gas scrub and condensate collection systems, off-gas filtering, test completion and clean up process, and in the sludge and other chemical mixing processes. Minimization in these areas will be accomplished through source reduction in processing and in material procurement.

Waste management activities conducted by the ISV project during FY-91 were mainly concerned with the disposal of wastes generated during the FY-90 IFT tests. In addition, wastes generated by the Geosafe Corp. during their conduct of two engineering-scale tests (ES-6 and ES-7) for the INEL ISV project were returned to the INEL.

4.4 Product Evaluation

The purpose of the product evaluation effort is to determine the properties of and evaluate potential impacts from the product produced by the ISV process. This includes general activities, such as determining reduction/oxidation chemistry and evaluation of the combustion products resulting during ISV processing, and the evaluation of samples from laboratory and field ISV tests. Each of these areas will be discussed below.

4.4.1 General Activities

4.4.1.1 Reduction/Oxidation Studies. The probable equilibrium composition of the ISV product resulting from a demonstration of the technology on buried waste in Pit 9 of the SDA was estimated using STEPSOL, a PC compatible version of SOLGASMIX. The results of the calculations show that silica and silicates dominate the product. The carbon compounds were found to be good reducing agents. Metallic iron and nickel were the major forms of these metals. Carbon monoxide was found to be the major gas produced at temperatures above approximately 1000 K (727°C). Plutonium and uranium were not reduced and remained as oxides in the slag and melt.

4.4.1.2 Analytical Development Studies. This work involves the development of analytical methods that can be used to characterize soil and vitrified ISV product samples and to establish on-Site (INEL) capabilities for these analyses. Emphasis during FY-91 was placed on developing procedures for the inductively coupled plasma atomic emission spectroscopy-mass spectroscopy (ICP-

j. Unpublished research by B. M. Gardner on the waste minimization plan for the ISV project, May 1991.

MS) with a laser ablation system; the procedures examined include sample preparation requirements for different sample types and development of reference calibration curves for the ICP-MS system.

Sample preparation requirements for various sample types (powders, whole solids, glasses, etc.) were examined. The results of these investigations indicate that whole solids, glasses, and metals require little to no sample preparation.

Instrument response (i.e., calibration) curves for the laser ablation sampling method were established using National Institute of Science and Technology (NIST) Standard Reference Materials and U.S. Geological Survey (USGS) rock standards. Problems were encountered with selective vaporization of several elements, making them difficult to determine accurately. It has also been found that selection of the internal standard element, which is used to anchor the sample responses to the calibration curve, is an important factor in the accuracy of the analysis.

Literature and laboratory investigations indicate that laser ablation ICP-MS is a valuable tool for the semi-quantitative and qualitative analysis of solids. Its development as a fully quantitative technique, however, is hampered due to the current lack of available solid standard materials.

A procedure for rapid chemical analysis of the ISV waste form was also developed. Results to date indicate that useful chemical data may be obtained using x-ray photo electron spectroscopy and auger electron spectroscopy. Additional work to obtain quantitative data using this method is continuing.

4.4.1.3 Laboratory Pyrolysis Tests. In order to increase understanding of chemical dynamics with regards to organic materials, similar to those found in Pit 9, during the ISV process, and to obtain data specific to the requirements of the ISV analytical modeling efforts, a series of laboratory pyrolysis tests have been conducted.^k These tests were performed in a controllable environment with the pyrolysis products being analyzed both qualitatively and quantitatively to determine the species and amounts of chemicals resulting from alteration and degradation of organic wastes at the temperatures encountered during ISV processing of the wastes. In addition, the data generated in these tests will also be used in support of ISV off-gas monitoring and treatment systems design efforts.

Included under these efforts was a study to compare, through a comprehensive literature review, the high temperature chemistry and thermal and thermodynamic properties of plutonium and rare-earth oxides. The purpose of the study^l was to determine if certain rare earths simulate plutonium behavior (i.e., act as tracers) in the high temperature environment of the ISV melt. The

k. Letter report from R. E. McAtee to K. P. Lange on ISV laboratory pyrolysis studies of the high temperature chemistry of organic materials in RWMC soils, October 1, 1991.

l. Unpublished research by R. E. McAtee and M. Beal, *Comparison of the High Temperature Chemistry of Plutonium and Rare Earths, A Review Study*, September 1991.

results of the study show the chemical similarity of plutonium and cerium; thus, cerium could be considered the most conservative plutonium tracer.

An extension of this tracer assessment was initiated and continues into FY-92. This additional work will supplement the previous work by comparing transport properties of plutonium and rare-earth oxides. A review of mass transport theory has been conducted which indicates that simulation of transport behavior primarily relates to similarities in molecular properties and viscosities. Quantitative comparisons based on this technique will provide additional theoretical foundation to support the use of tracers as plutonium surrogates in future tests.

4.4.1.4 Acoustic Tomography Studies. A draft report has been received from ORNL on the acoustic tomography activity that was conducted at the INEL in collaboration with ORNL during the FY-90 IFTs. The tests at the INEL were successful in demonstrating the potential use of acoustic tomography in ISV monitoring for determining the size and location of the ISV melt and waste form.

4.4.2 Laboratory and Field Test Product Evaluations

4.4.2.1 IFT Product Evaluation. During FY-91, the waste forms produced from the FY-90 intermediate field tests (IFT 1 & 2) were evaluated in detail. These evaluations were divided into three general categories:

- Sampling and bulk description of the waste form to provide representative samples to generate a general description of the ISV monolith and a gross identification of the different bulk phases
- Evaluation of the waste form's chemical and physical properties to determine the elemental composition and mechanical properties of the waste form
- Dissolution behavior testing to determine the ability of the glass and crystalline phases in the ISV monolith to retain the contaminants incorporated into the melt during ISV processing.

Although details from the product evaluation of samples taken from the IFT vitrified products can be found in the final report on IFT 1 and 2 (Callow et al. 1991b), brief highlights of the findings of each of the major product evaluation activities are presented below.

4.4.2.1.1 Sampling and Bulk Description—A careful and systematic excavation of the ISV processed pits was conducted in order to obtain physical descriptions of the waste pit morphology, the processed waste, and the vitrified product. Additionally, samples were collected for chemical and physical analysis and durability testing. Cores were drilled into the waste form and metal that pooled in the bottom of each pit to obtain analytical samples.

During cooling, devitrification occurred within the glass monolith, producing a feather-like crystalline phase called augite. Augite is a common, naturally occurring pyroxene found in volcanic rocks, such as the basaltic rocks found at the INEL, which have compositions and cooling histories similar to the vitrified material resulting from the INEL Intermediate Field Tests.

4.4.2.1.2 Chemical and Physical Properties—Solids characterization of the ISV products showed that the ISV melt environment is reducing, resulting in Fe^{2+}/Fe ratios >90%. Under equivalent closed-system conditions, as might occur during the slow migration of water through cracks in the solid mass, the reaction of the ISV glass with water reduces the redox potential to the lower stability limit of water. Under these conditions, several redox sensitive elements such as Se and Pu are expected to be sequestered in an alteration layer on the glass surface resulting in a smaller predicted release rate than calculated from the matrix dissolution rate alone.

4.4.2.1.3 Dissolution Behavior—Dissolution behavior testing was divided into three types of leaching tests. The first, the Environment Protection Agency's TCLP, meets the minimum regulatory testing requirements established for landfill disposal. However, the TCLP does not address radioactive waste components or provide a technical basis for assessing long-term durability. To provide this information, additional durability tests were conducted. These additional tests fell into two categories: comparative testing (comparing ISV waste forms to similar waste forms and natural analogs) and testing to determine the forward rate of waste form dissolution.

Highlights from the durability testing of the IFT vitrified products are presented as follows:

- TCLP testing confirmed that the IFT waste forms do not exhibit hazardous characteristic of TCLP toxicity with most results being below detection limits or 10 to 100 times lower than the maximum acceptable concentrations.
- Differences in durability corresponded to the degree of crystallinity in the samples. Samples that appeared to the eye to be completely devitrified (approximately 50% by volume) show consistently lower releases for Ca, Mg, Al, and Si compared with samples that analyzed x-ray amorphous. Because most of the ISV monolith was devitrified and no waste component segregation was observed, the lower release rates for the devitrified phase of the ISV waste form will result in a lower (than all glassy phase) overall release source term for health-based risk assessments.
- Based on MCC-1 leach testing data, the durability of the IFT waste form is comparable to obsidian and granite, and is 4 to 10 times more durable than typical high-level nuclear waste glasses.
- Preliminary results from intrinsic rate constant measurements using pH stat/ISE and soxhlet extraction methods show that the intrinsic dissolution rates are 10 to 100 times smaller than measured for a typical borosilicate nuclear waste glass.

4.4.2.2 Laboratory (Engineering-scale) Tests Product Evaluation. As with the analysis of the IFT products, product evaluation of the vitrified products resulting from engineering scale (i.e., laboratory) tests of ISV can be divided into the same three general categories, sampling and bulk description, chemical and physical properties, and dissolution behavior. During FY-91, product evaluations were conducted on samples from engineering-scale (ES) tests ES-4, ES-5, ES-6, and ES-7, which were conducted during FY-90.

4.4.2.2.1 Engineering-scale Test 4—Engineering-scale test 4 (ES-4) was conducted on soil with added hazardous and nonhazardous constituents. Specifically, TCLP toxic metals, an organic sludge mixture, combustibles, and steels (see Section 4.2.2.1) were added to INEL soil and placed above a block of basalt to simulate the INEL geologic setting. The megascopic description and chemical and physical property characterization of the ES-4 product demonstrate that the product is heterogeneous in composition. The following paragraphs discuss the major findings of the analysis of the vitrified product resulting from ES-4 (Loehr et al. 1991):

- Megascopically, the ES-4 product glass is dark green with less than 1 vol% vesicles and commonly exhibits round to nodular magnetic inclusions less than 2 mm in diameter. Metal occurs as round to nodular masses up to about 3 cm in diameter and also as unmelted or partially melted articles, such as bolts, nuts, rods, and plates; because most of the metal is adjacent to the basalt that was placed in the bottom of the test container, the metal is believed to have settled to the bottom of the melt
- Analyses of the ES-4 product material confirm that vitreous, crystalline, and metallic phases coexist in the ES-4 product. Although the phases coexist in a complex manner which has only been investigated in a preliminary fashion, it was determined that: two silicate liquids are generated in the test, metallic phases occur in glass at the center of the melt as well as at the bottom of the melt with the unmelted metal articles, evidence indicates that melt conditions are very reducing, and TCLP toxic metals are retained in the ES-4 product in association with iron metallic phases
- The ES-4 product TCLP analysis results are varied; the leachate of many samples did not exceed the TCLP limits, but several did exceed the limits for Pb and Cr. Because of this fact and the fact that all samples that were entirely metal were not subjected to the correct test, but one that would be expected to leach a lesser amount, the TCLP results for the ES-4 product as a whole are inconclusive. However, the degree to which the metal phases are subjected to chemical dissolution depends on the overall mechanical durability of the product because the glass product fused to the basalt.

4.4.2.2.2 Engineering-scale Tests 5, 6, and 7—The ES-5, ES-6, and ES-7 test objectives focused on determining the effect of ISV on sealed containers of sludge. The makeup of the composite sludges and setup of the tests are described in greater detail in Sections 4.2.2.2, 4.2.3.1, and 4.2.3.2 for test ES-5, ES-6, and ES-7, respectively. The product evaluations of the waste forms

from these tests indicate that the waste forms from these tests are very similar to the waste form produced in the ES-4 test (Loehr and Weidner 1991).

The products from ES-5, ES-6, and ES-7 were megascopically quite similar,^m despite test configuration differences that could lead to differences in cooling time and composition of the products. Generally, the product was green or greenish-black glass with varying amounts and sizes of vesicles (i.e., bubbles), depending on location in the product block. There was evidence, in the form of swirly patterns of rind and other material in the glass prevalent near the soil edges, that mixing in the melt was incomplete. In general, however, the glassy product materials were homogeneous at the macroscale and were very similar in chemical composition to the natural volcanic material andesite. Such a glassy waste form would, therefore, be expected to be stable in the natural environment for time periods similar to their natural counterpart.

4.5 Modeling

The ISV modeling activities for FY-91 encompassed a variety of both model development efforts and analysis applications in support of the ISV project. The model development effort is directed towards modifying or developing a set of computer codes to simulate the ISV process. These codes will be used to: perform safety and environmental hazards analyses, assist in experimental test planning and design, assist in equipment design and development of operating procedures, and provide enhanced understanding of the ISV process.

4.5.1 Model Development Activities

Model development activities in FY-91 involved modifying and extending existing computer codes and the development of new models and codes. The initial versions of the APOLLO, MAGMA, and VESTA codes were completed and the capabilities of the VULCAN and TOUGH computer codes were enhanced with the addition of new models this year.

The transient three-dimensional computer codes that are used for simulating the ISV processes produce large volumes of data, the analysis and comprehension of which is a formidable task. To aid in this effort, graphical and visualization software that make the data much easier to comprehend were developed during FY-91. This software uses data files produced by the various codes to produce three-dimensional color images that greatly enhances understanding of the ISV processes.

4.5.2 Applications and Analysis Activities

Several calculations and analyses were performed during FY-91 to evaluate and validate the computer codes, resolve technical issues, and enhance the general understanding of the ISV process.

m. Detailed comparisons were not made because of the sample identification integrity problems described in Loehr and Weidner (1991).

The following sections present a brief description of these analyses and the more important conclusions from these studies.

4.5.2.1 Validation Activities. Validation activities have thus far centered around the VULCAN code. As part of this validation, the Pilot-Scale Remedial Test (PSRT), which was performed at PNL in 1987, was simulated using the VULCAN code. The melt volume calculated using VULCAN was 4.6 m^3 ; when uncertainties in the input data are taken into account, this agrees quite well with the measured PSRT melt volume of 4.8 m^3 .

In order to help determine the accuracy required for experimental measurement of the physical properties of the melt, and to determine the dominant parameters in the melting process, a series of calculations were conducted with the VULCAN code to examine the effects of various parameters on the melting process (Fryer et al. 1991). The results of this study indicated that melt volume was most significantly affected by specific heat, followed by thermal conductivity, with electrical conductivity having an even lesser effect on melt volume.

4.5.2.2 Submelt Pressurization Analysis. Simultaneous transport of energy and moisture in the region surrounding the ISV melt zone is of interest due to its potential impact on process safety. Because of heating of the soil, the vaporization of liquid water results in pressurization of the gas phase and subsequent gas flow. In certain situations, pressure under the melt due to water vapor may become sufficiently high to result in the ejection of molten material from the melt.

A series of calculations were performed using the TOUGH computer code to examine the effects of initial water saturation, melt permeability, and stray current joule (i.e., resistance) heating on gas phase pressure and direction of flow. The results from these calculations indicate that high initial water saturation, in combination with low soil permeability, can lead to excessive gas pressures below the melt. Stray current joule heating below the melt can also contribute to the pressure buildup.

In an effort related to these submelt pressurization analyses, INEL ISV project personnel supplied support to both Geosafe and PNL investigation teams, which were formed to analyze failure events occurring during an Operational Acceptance Test at Geosafe and an Underground Tank Test at Hanford (PNL).

4.5.2.2.1 Geosafe Operational Acceptance Test Event—During the second operational acceptance test being conducted by Geosafe at their Richland ISV test site, approximately 25 tons of glass were expelled from the melt causing a breach of hood confinement and a fire on the fabric material used for construction of the hood. Because of the importance to the entire ISV community of an understanding of the causes of this event, an investigating committee was formed including participants from Geosafe, INEL, PNL, and Oak Ridge National Laboratory (ORNL). Investigations yielded a number of potential contributing mechanisms to the event. Of high importance to the INEL ISV project was the indication that release of water vapor confined below

the melt was a significant factor. Computer modeling studies are being used to define the ranges and combinations of soil and operating parameters that can lead to pressure buildup beneath a melt.

4.5.2.2.2 PNL Underground Tank Vitrification Test Event—During a pilot-scale test of an underground tank (a sealed version used for test purposes) being conducted at Hanford by PNL, an expulsion of glass from the melt caused some hood damage and forced termination of further operations. An investigating committee was formed by PNL and included participation by PNL, Geosafe, INEL, and ORNL. Although investigation findings have not been finalized, this event bears some similarities to the Geosafe test event particularly in the apparent release of water vapor confined in the area beneath the melt. Further analytical and empirical studies are needed to delineate causes of the event and potential significance for other test situations. Computer modeling studies described previously will allow evaluation of potential related concerns if they exist for the INEL buried waste.

4.6 Program Support

In addition to the test-oriented efforts under the ISV project, described above, there are additional efforts that serve to support the entire program. These efforts include public education and communication, and data life cycle (data quality objectives and data management). These efforts are discussed in the following paragraphs.

Public education and communication efforts continue to be broadly based, providing information about the ISV process to EG&G Idaho and DOE management, the general public, educators and students, professional societies, and the media. Internally, presentations were delivered to EG&G Idaho, DOE (Headquarters and Idaho Field Office), INEL waste technology personnel, laboratories participating in the Buried Waste Integrated Demonstration, and the National Academy of Sciences. Externally, approximately 25 presentations were made to the media, civic organizations and professional societies, and to workshops organized by the INEL. Information and presentation materials have been provided for public meetings held in conjunction with the development of the *Community Relations Plan for Remedial Investigations at the Idaho National Engineering Laboratory*.ⁿ

Efforts under ISV Data Life-Cycle Design have been focused in the areas of data quality objectives (DQO) guidance for the ISV project and the design and set up of a data management system for ISV testing. Data quality objective efforts were concerned with providing guidance on planning of ISV tests and experiments to the ISV Steering Committee in the area of planning of ISV experiments; the major part of this support was the development of Quality Planning Matrices, which are included in the Steering Committee document (Stoots et al. 1991). The other major area of Data Life-Cycle Design effort was in designing a data management system for the processing, storage, and retrieval of information collected in the process of testing the ISV technology; this system includes

n. Issued and released to the public by DOE in accordance with agreements with the EPA and State of Idaho, September 1991.

a local area network, which was set up during FY-91, among ISV personnel involved in the different technical areas (i.e., field tests, engineering tests) of the ISV project.

5. FY-92 PLANNED EFFORTS

Efforts planned for FY-92 under the ISV project at the INEL can be divided into three general areas, laboratory testing, preparation for a field demonstration at the SDA Acid Pit, and supporting analyses. Although the actual activities that will be performed are, of course, dependent on the level of funding provided by DOE, these areas of investigation are discussed in the following sections.

5.1 Laboratory Testing

As a result of planning conducted during FY-91, several series of laboratory tests have been designed to be conducted at the INEL using the test facility established at TAN during FY-91.

The first proposed test series involves ISV lab tests on soils contaminated with mercury (Hg), carbon tetrachloride (CCl_4), and tetrachloroethylene (PCE). The tests will evaluate the effect of different ISV process conditions (soil depth, power level, and electrode feed rate) on the potential migration of volatile and semi-volatile contaminants during ISV processing. The results of this test series will be useful in resolving technical issues associated with migration of semi-volatile inorganics and halogenated hydrocarbons from either the SDA Acid Pit or the TRU Waste Pits and Trenches.

The second proposed test series involves tests on soils containing a representative volume of buried waste materials typical of that found in the SDA TRU Waste Pits and Trenches. These tests will evaluate the effect of different process variables (e.g., power level, soil depth electrode feed rate, and off-gas flow rate) on ISV processability of the buried waste. The results of this test series will be used to arrive at a suggested set of operating conditions for ISV tests involving sealed containers of buried waste materials.

The third proposed test series is a compositional variables test series. In this series, tests will be used to evaluate the effects of differing waste compositions and soil waste/volume ratios on ISV processing performance, and product quality. The waste composition and soil/waste ratios for these tests will be varied in a manner that "brackets" the typical variation in buried waste composition at the SDA. Results from these tests can then be used to determine the appropriate operating parameters for a given SDA site. In addition, the results of product quality tests on each of the ISV waste forms can be used to determine how the variation in waste form composition affects the quality of the ISV melt form.

The fourth proposed ISV test series involves laboratory tests on contaminated soils simulating the conditions found at the SDA Acid Pit. The technical issues to be answered by these tests are (a) a determination of whether the relatively high alkaline conditions in the Acid Pit are processable using ISV and (b) a determination of the rates and amounts of acid gases that may be released during ISV processing of the Acid Pit, and whether they may affect the ISV off-gas equipment performance. The test specification for these tests will be developed after the Acid Pit characterization data have been received (anticipated in December 1991).

The fifth test series involves tests on different types of buried waste materials that can be considered as an "energetic" materials. The term "energetic materials" refers to those buried waste materials which are considered explosive in nature and may or may not require oxygen to detonate. The purpose of these energetic tests will be to see how ISV processing is affected by these potential "show stoppers." In addition, these tests may also help to answer many technical issues associated with underground fires (resulting from layers of "energetic materials" extending outside of the immediate melt area).

The sixth test series is designed to evaluate the effect of scaling issues on the ISV process. The test series is necessary to determine which TRU Waste Pits and Trenches technical issues can be answered by ISV laboratory tests. The test series will involve at least one laboratory-scale ISV test and a large or intermediate-scale test that is geometrically similar to the laboratory tests that were performed. Extensive process monitoring will be used on both scales to determine what technical issues are directly scaleable.

5.2 Acid Pit Demonstration

The demonstration of the ISV technology at the SDA Acid Pit is scheduled to support the Buried Waste Program (BWP) treatability study phase during FY-92 and 93. The ISV demonstration is scheduled for FY-93. Results of the demonstration will be evaluated and reported during FY-93 and 94.

The Acid Pit demonstration will be a collaborative effort with PNL. PNL's pilot-scale system, which was used during the FY-90 field demonstrations discussed previously, will be used for the Acid Pit demonstration. Personnel from PNL, Geosafe, and INEL will operate the equipment during the demonstration.

The technical issues associated with the Acid Pit demonstration have been identified previously (Stoots et al. 1991). The results of sampling of the Acid Pit, which is to be conducted by the Environmental Restoration Program during early FY-92, will be used to validate the previously identified technical issues. After this validation, if treatment of the Acid Pit appears to be feasible, the ISV project will proceed with preparation of the required NEPA and Safety Analysis (SA) documentation, operational document preparation (including test plans, test procedures, test equipment functional requirements, and operational procedures), and operational setup. Thus, FY-92 field testing efforts will focus on preparation for the actual FY-93 Acid Pit demonstration.

5.3 Analytical Modeling Activities

Modeling activities planned for FY-92 can be divided into two broad areas, test planning support and applied research. These areas are discussed in the following sections.

5.3.1 Test Planning Support

Test planning support activities include the following:

- Support for preparation of a strategy to use characterization data to evaluate ISV applicability to remediation of the Acid Pit. This involves definition of parameters needed for using the analytical models to predict melt behavior and, thus, assist in the evaluation of the applicability of ISV
- Support for preparation of a Test Objectives Document (i.e., define test objectives). Certain test objectives will consist of supplying data that can be used to assess and further refine the analytical models. This will increase the validity of the models for future use in predicting ISV behavior
- Evaluation of site characterization data. As a followup, once the data is obtained, and a strategy for the use of the characterization data has been developed, actual site (i.e., Acid Pit) properties will be used in the models and analyses to evaluate the applicability of ISV
- Support for the definition of data needed from the tests and the quality required for those data (i.e., DQOs)
- Performance of pretest predictive analyses. Some parametric computer studies (scoping studies) will be conducted to provide a range of potential melt behaviors. These parametric studies will supply a range of predictions consistent with uncertainties in the site characterization data
- Provide environmental documentation support. Analytical modeling will support definition of source terms to be used in environmental and safety documentation required prior to conducting the tests.

5.3.2 Applied Research Modeling Support

Applied research modeling activities are described as follows:

- Water vapor analytical studies. This work is a followup to the March 1991 melt ejection event at Geosafe (see Section 4.5.2.2) and is intended to develop a model of vapor transport in the vicinity of the melt suitable for all ISV applications
- General technical issue studies. Work continues on the use of analytical modeling to address technical issues for both the Acid Pit and the TRU Waste Pits and Trenches. Wherever possible, these analyses will be used to provide or assist in the closure of these issues

- Laboratory-scale test analyses. In support of laboratory-scale testing, pretest predictions will be made using the analytical models and will be compared to actual test data in order to refine analytical understanding of the ISV process
- Support for preparation of a technology status report. A technology status report (TSR) will be prepared based on analytical studies and laboratory testing. The TSR is intended to determine whether a field demonstration test of ISV should be conducted. (A prerequisite to this is that sufficient laboratory testing and analyses must be done to offer the necessary support).

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