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VITRIFICATION OF UNDERGROUND STORAGE TANKS: TECHNOLOGY DEVELOPMENT, REGULATORY ISSUES, AND COST ANALYSIS

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Vitrification of Underground Storage Tanks: Technology Development, Regulatory Issues, and Cost Analysis

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INTRODUCTION

In situ vitrification (ISV), developed by the Pacific Northwest Laboratory (PNL) for the U.S. Department of Energy (DOE), is a thermal treatment process for the remediation of hazardous, radioactive, or mixed waste sites. The process has been broadly patented both domestically and abroad (1). Since the inception of ISV in 1980, developmental activities have been focused on applications to contaminated soils, and more recently the potential for application to buried wastes and underground structures (tanks). Research performed to date on the more advanced ISV applications (i.e., application to buried wastes and underground tanks) shows that significant technical and economic potential exists for using ISV to treat buried wastes and underground structures containing radionuclides and/or hazardous constituents. Present ISV applications are directed to the treatment of contaminated soils; the likelihood of using ISV to treat underground tanks depends on the resolution of significant technical and institutional issues related to this advanced application. This paper describes the ISV process and summarizes the technical progress of underground tank vitrification (UTV), discusses pertinent regulatory issues facing the use of UTV, and presents the potential cost of UTV relative to other remedial action alternatives.

PROCESS DESCRIPTION

ISV is performed by inserting an array of electrodes into the soil to a nominal depth (about two electrode diameters) above the waste site. The processing sequence as applied to underground tanks is depicted in Figure 1. Since dry soil is not electrically conductive, a starter-path material is placed between the electrodes to initiate soil melting when an electric potential is applied to the electrodes. Once molten, the soil becomes electrically conductive, and power to the melt is gradually increased. As the molten mass grows downward and outward (typically maintaining temperatures between 1400°C and 2000°C), it encompasses the tank, tank contents, and outlying contaminated soil. The melt incorporates radionuclides and nonvolatile hazardous elements, such as heavy metals, and destroys organic components by pyrolysis. An electrode feed system is used to control the vertical position of the energized electrodes in the melt; typically, the electrodes are allowed to feed downward by gravity, although they can be retracted, held, or advanced as necessary. A hood placed over the area being vitrified confines the gases emanating from the melt and directs them to an

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off-gas treatment system. Power to the melt is maintained until the desired depth is obtained and the soil and its contents are vitrified. Upon cooling, the resultant mass solidifies to form a high-integrity block resembling natural obsidian, with a leach resistance approaching that of high-quality laboratory glassware. Studies show that the ISV glass will retain its integrity for geologic time periods (2,3).

TECHNICAL PROGRESS

Underground storage tanks containing sludges and salt cakes composed of radioactive and/or hazardous wastes represent a significant environmental concern and a major technological cleanup challenge at many DOE sites. To date, four UTV tests have been performed--two engineering-scale, one pilot-scale, and one large-scale test. Current ISV development efforts are focused on closing out technical issues pertinent to contaminated soils applications. Once these issues are resolved, issues related to the more advanced applications can be addressed (e.g., containing transient gas releases from confined spaces, vitrifying to greater depths).

The development of the ISV process has followed a graduated risk philosophy in which issues and concepts are researched and tested in smaller, laboratory-scale experiments before progressing through larger, field-scale tests and demonstrations. Engineering calculations and computer modeling are used extensively throughout the process. This philosophy permits a reasonable expenditure of funds on experimental R&D work, besides ensuring the safety of personnel and equipment.

Engineering-Scale Test

The first UTV engineering-scale test, conducted by PNL in September, 1989 (4), successfully tested the feasibility of using ISV to remediate radioactive-contaminated underground storage tanks at DOE sites. The ISV engineering-scale system is a laboratory unit used primarily for treatability and proof-of-principle testing and concept development. It uses a 30-kW transformer and is capable of producing a vitrified block of 50 to 1000 kg. In this test, a 30-cm-diameter steel tank encased in concrete was converted into a solid vitrified block. The tank, which contained a simulated hazardous and radioactive sludge layer covered with a soil backfill and concrete outer layer, was buried 15 cm below surface (Figure 2). The contents of the tank were representative of material within the buried tanks and surrounding soil at the Oak Ridge National Laboratory (ORNL). The test was successfully completed and all the tank sludge was vitrified. Hazardous components of the tank sludge were immobilized in the vitrified product or removed and captured in the off-gas treatment system. The steel tank was converted to ingots near the bottom of the vitrified block, and the concrete shell was dissolved into the resulting glass and crystalline block.

Analysis of the vitrified product showed a homogeneous distribution of hazardous constituents, and the block was determined to be nonhazardous by the Extraction Procedure Toxicity (EP Tox) test. Samples of the vitrified product from the top, middle, and bottom of the vitrified block, as well as a sample of the metal ingot, were subjected to the EP Tox test, which at the time was the reference U.S. Environmental Protection Agency (EPA) method for characterizing toxicity levels of waste forms. The results obtained from the leach testing for all of the samples, for all hazardous metals, fell considerably below those limits prescribed by the EPA. In addition, no detectable transport of hazardous constituents to surrounding soil was observed.

Off-gas sampling with an EPA MM5 sampling train and various analyses were used to quantify the presence of contaminants in the vitrified product and processing equipment. The mass balance of each constituent was determined by chemical analyses of the vitrified product, off-gas fiber filters, off-gas sampler filters and impinger solutions, insulation placed over the melt area, a hood smear, and a rinse solution of the off-gas sample line. The efficiency of retaining or destroying hazardous chemicals and radionuclides by the ISV process can be expressed as a percent retention in the vitrified product. It is defined as follows:

$$\% \text{ Retention} = (1 - M_e/M_i) \times 100$$

where M_e = mass of species released to the off gas
M_i = mass of the species initially present in the soil.

High retention (>99.9%) was demonstrated for nonvolatile metals (Cr, U, Cs, Sr, and Tc) by the ISV process. These values are similar to previous results where only soil containing hazardous constituents was vitrified. Lower retention (15%-50%) was shown for Pb and Hg; however, volatilized species were almost completely contained in the off-gas treatment system by scrubbing and filtration. Previous field testing on contaminated soils has shown that retention of the hazardous constituents in the melt increases proportionally to the size and depth of the melt as well as the initial depth of the constituents (2).

An impediment to the development of UTV was the possibility of electrical shorting between the fixed electrodes through the molten metal pool that forms at the bottom of the melt as the tank melts. With electrode feeding, one or more of the electrodes is raised out of the molten pool when an electrical short occurs (5). During the engineering-scale test, the electrode feeding system, using pure graphite electrodes, was shown to work well for UTV. Based on results from the engineering-scale tank test, it was concluded that metal and/or concrete tanks can be vitrified by filling the tank with soil and using the ISV process.

Pilot-Scale Test

Following the engineering-scale tank test as described above, a pilot-scale test at Hanford in September 1990 successfully vitrified a 1-m-diameter stainless steel tank (6). The pilot-scale system is a mobile field unit with electrode power conditioning, off-gas treatment equipment, and process control located in a single trailer. It uses a 500-kW transformer and is capable of producing a vitrified block of 10 to 50 tons. The pilot-scale system is especially useful for demonstrating ISV operations and obtaining engineering performance data at a remote test site, and for testing new engineering designs in the field at a moderate size and expense. During site preparation, the 1-m-deep tank was encased in a 10-cm-thick layer of concrete, surrounded by a cocoon of limestone gravel (to simulate conditions at ORNL), and buried under 0.61 m of soil cover. The tank was filled approximately 30% with a nonradioactive simulated sludge representing refractory-type ORNL tank sludge. The sludge contained a variety of heavy metals and simulated radionuclides, as well as organic compounds. The balance of the tank was filled with ORNL soil. The tank, sludge, concrete pad supporting the tank, and surrounding soil were vitrified to the target depth of 2.4 m, producing a uniform glass and crystalline monolith with an estimated weight of 25 tons (Figure 3).

Process data analysis of target simulated waste components shows that the ISV process effectively destroyed, immobilized in the vitrified mass, or captured in the off-gas treatment system greater than 99.99% of all chemical species originally present in the tank sludge. For example, 89% of the lead was retained in the vitrified product and the remaining 11% was removed in the off-gas treatment system. As expected, 99.95% of the strontium was retained in the vitrified product. The glass and crystalline waste form resulting from the pilot-scale test easily passed the toxic characteristic leach procedure (TCLP) criteria for all regulated metals. The metal ingot from the pilot-scale test also passed TCLP leach test criteria for all regulated metals.

A previously unknown phenomenon affecting the ability of the off-gas hood to maintain a net inflow of air was identified and characterized during the test. Because of transient gas releases from the tank up through the molten glass, the top layer of frozen glass covering the melt was rapidly disrupted, causing the molten glass to instantaneously radiate heat to the particulate-laden gas in the containment hood. The brief period of positive pressure inside the containment hood provided cause for suspending the test to analyze the event. An engineered solution involving a radiant heat shield and a vent pipe in the melt was installed and the test was restarted and completed without further incident.

Electrode feeding technology proved to be invaluable in recovering from electrical short circuits when the electrodes approached or contacted the molten pools of metal in the bottom of the melt. By simply raising one or more electrodes a few centimeters off the bottom of the molten glass pool, recovery from electrical short circuits was successful.

Analyses of post-test samples and operation data support the thesis that the ISV process is a viable treatment technology for many underground tanks.

Large-Scale Test

The large-scale ISV system (Figure 4) is a transportable system housed in three trailers, with the off-gas treatment system, power conditioning equipment, and process control equipment contained in separate trailers. This system uses a 3.75-MW transformer and will vitrify approximately 200 to 1000 tons of soil in a single setting. Large-scale development and testing are necessary to acquire full-scale operating data that cannot be obtained in smaller scale tests, such as verification of equipment operation, scale-up, and design; validation of off-gas and molten glass decontamination factors; and operating experience with full-size equipment.

A UTV demonstration using the large-scale ISV equipment was performed in July, 1991. A 3-m-diameter by 3-m-tall stainless steel tank was encased in a 20-cm layer of gunnite (Figure 5), filled about 10% with a water-saturated

Hanford soil sludge, and buried with its top about 1.5 m beneath the soil surface. No hazardous materials were used in this test. The objectives of the test included the following:

- Demonstrate the applicability of ISV for remediating a 22,700-L (6000-gal) buried tank containing a sludge layer with a high water content. In addition, obtain temperature and pressure data on a full-scale system to determine the behavior of off-gases and measure and evaluate the effects of off gases on the vitrification process.
- Demonstrate the large-scale application of the electrode feed system. The use of electrode feeding eliminates the labor-intensive process of installing expensive fixed electrodes, thus reducing long-term costs. It also eliminates worker exposure to the intrusive process of placing electrodes into the waste site, and eliminates the secondary wastes generated during electrode placement.
- Demonstrate a material and a technique for filling the empty volume of an underground tank in preparation for vitrification.
- Demonstrate the ability to vitrify to depths practical for actual tank remediation activities.
- Obtain off-gas particle size and water balance data.

To demonstrate the feasibility of using a low-density material for filling tank volumes, an engineering-scale test was conducted in February, 1991. It was postulated that by filling the free volume of a tank with a low-density material, the subsidence will be increased, thereby reducing the overall vitrified volume and contributing to an increase in depth capability. The first engineering-scale tank test (described above) simulated ORNL conditions. In the engineering-scale test using low-density fill, the bottom 10% of the tank contained a simulated sludge composition of Hanford soil saturated with water, and the free volume was filled with pumice as was planned to be done for the large-scale test. No hazardous materials were used. The tank, similar to the one used in the first engineering-scale test, was placed in Hanford soil and vitrified. The density of Hanford soil is about 1.6 g/cm^3, while the density of the pumice is about 0.5 g/cm^3. Compared to the first test, this test displayed an increased melt rate and more efficient power usage. The amount of subsidence for the pumice test was about 45%, which is not as high as might be expected; however, since the original volume of the pumice is small compared to the overall volume of vitrified soil, the effect of the low-density material on subsidence is diminished. On the other hand, since the pumice has an extremely low moisture content, power is more efficiently used for vitrifying rather than boiling water, thereby contributing to the increased melt rate. This test showed the feasibility of using pumice as a tank fill material and justified its use on the large-scale test.

The large-scale tank test was initiated in July, 1991, and was operated for 6 days. On the sixth day, at a vitrification depth of about 3.5 m, molten glass was suddenly and unexpectedly expelled from the vitrification zone. The expulsion damaged the process containment hood, leading to the premature termination of the test. A pressurization event was not unexpected, as one was experienced during the pilot-scale test, and precautions such as a graphite vent pipe in the tank and a heat shield over the melt were used; however, the magnitude of the event was unexpected. Research is currently underway to develop an understanding of the mechanisms that caused the event in order to engineer solutions for future testing and demonstration. With respect to the test objectives described above, the following results were obtained:

- Critical data related to the soil temperatures in and around the tank, pressures within the tank, and temperatures and pressure transients within the hood during the vitrification process were collected.
- The electrode feed system was successfully demonstrated. Electrode breakage occurred early in the test, but after adjusting the alignment of a feeder and modifying the operating technique, the breakage problems did not reoccur during the test.
- The tank was filled with pumice using a conveyor system that moved the pumice into the containment. The conveyor system represented a technique that may be applicable in an actual low-level waste tank treatment. However, in this large-scale test it is possible that the void space was not completely filled, or a degree of settling occurred, as a slight positive pressure event was experienced in the containment hood coinciding with the breach of the top of the metal tank. Other low-density materials may be more efficiently applied.
- Soil temperature data indicate that the melt experienced little outward growth beyond the electrode array; moreover, the melt rate for this test was almost double that of previous large-scale tests. The target depth of 6 to 8 m was not achieved because of the early termination of the test. Power delivery to the melt was very efficient, and the rated power level of 3.75 MW was achieved for the first time ever.
- Particle-size data collected shows that the majority of the particulate is generated during the startup phase of the test, as expected. This data will be valuable for design of future off-gas treatment system equipment. The water balance data, which was to be used to support the theory that water-soluble contaminants are drawn toward the melt rather than driven away from it, were compromised because of the early termination of the test.

All of the objectives of the large-scale tank vitrification test were at least partially met, and three of the five objectives were fully satisfied. In spite of the significant pressurization event leading to the premature termination of the test, valuable process and equipment data were collected. The data will contribute to the ongoing research and development activities associated with ISV, most specifically understanding gas release behavior.

REGULATORY ISSUES

There is a need for UTV capability. Numerous inactive tanks at ORNL and Hanford require timely remediation to comply with state and/or federal environmental regulations. One hundred and forty-nine single-shell tanks at Hanford and 33 tanks at ORNL are no longer in service because they leak or because of other operational difficulties (7,8). Table 1 lists the remedial action milestones that have been established for regulatory compliance. Some of these highly contaminated tanks, tanks containing materials that cannot be economically or safely removed, and leaking tanks surrounded by contaminated soil are possible candidates for permanent remediation using UTV. However, the viability of application of this technology depends on the resolution of several technological, institutional, and regulatory issues.

There are numerous environmental, health, and safety laws and regulations that will govern, or have the potential to govern, the application of ISV for remediating underground tanks containing hazardous, radioactive, and mixed wastes. DOE Order 5820.2A establishes the policies, guidelines, and minimum requirements by which DOE manages its radioactive and mixed waste, including contaminated facilities, pursuant to the Atomic Energy Act, as amended. This Order specifically states, in part, that the management of radioactive wastes, including hazardous substances, shall comply with all applicable federal, state, and local environmental, safety, and health laws and regulations and DOE requirements. Of particular interest to the ISV program are the disposal requirements for hazardous waste, high-level radioactive waste (HLW), transuranic radioactive (TRU) waste, low-level waste (LLW), and radioactive mixed waste (RMW). Several of the regulations believed to have the most impact on ISV in general, and UTV specifically, will be addressed here.

Hazardous waste management is regulated at the federal level primarily by the EPA pursuant to the Resource Conservation and Recovery Act (RCRA), as amended by the Hazardous Substance and Waste Act. However, most states are authorized to implement RCRA within their boundaries, including Washington and Tennessee. RCRA requirements will be triggered when ISV is used to treat underground storage tanks containing hazardous waste. RCRA will also apply to the hazardous portion of a mixed waste. RCRA includes specific land disposal restrictions (LDRs) for hazardous wastes. Land disposal is defined as "the placement in or on the land and includes, but is not limited to, placement in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, salt bed formation, underground mine or cave, or placement in a concrete vault or bunker intended for disposal purposes." LDRs require that RCRA hazardous wastes must be treated to certain levels <u>prior</u> to land disposal. The implementing regulations for RCRA are 40 CFR 260-280. It has been demonstrated during numerous ISV tests that the vitrified soil product, as well as the metal ingot, pass the Toxicity Characteristic Leach Procedure (TCLP) for all regulated metals.

The EPA has determined that LDRs do not apply to in situ treatment methods. However, LDRs will apply to the removal of the ISV waste form for disposal elsewhere. Since the intended use for ISV is to treat contaminated materials that have already been disposed to land rather than treating hazardous wastes <u>prior</u> to land disposal, it is highly likely the regulators may choose to consider ISV as an innovative remediation technology involving previously disposed wastes.

The Nuclear Waste Policy Act created a federal program to develop a waste disposal system for HLW, and is primarily concerned with disposal in deep geologic repositories. Under the Nuclear Waste Policy Act, DOE is responsible for establishing permanent disposal facilities for HLW. The

Nuclear Regulatory Commission (NRC) has been given the authority to license the geologic repositories. However, the Nuclear Waste Policy Act does not specifically mandate that all HLW must be disposed of in deep geologic repositories. The implementing regulation is 10 CFR Part 60. All new and readily retrievable HLW will be sent to a geologic repository as specified under the Nuclear Waste Policy Act. However, DOE recognizes options under DOE Order 5820.2A for the permanent disposal of HLW that is not readily retrievable, such as single-shell tank (SST) waste. These include such methods as in-place stabilization (e.g., UTV), as well as retrieval and processing as required for new and readily retrievable HLW. One closure strategy considered by DOE for buried TRU waste is to leave the waste in place, use enhanced confinement or in situ immobilization, and provide enhanced monitoring.

Under the Low-Level Radioactive Waste Policy Act (LLRWPA), DOE remains responsible for disposal of DOE-generated LLW. Additionally, the LLRWPA made DOE responsible for other defense LLW and civilian LLW. LLW that results from NRC-licensed activities and is designated a DOE responsibility (i.e., civilian and military LLW) must be disposed of in an NRC-licensed facility. The implementing regulation is DOE Order 5820.2A. In April 1989, EPA published its proposed rulemaking (40 CFR 193) of environmental standards for the management, storage, and land disposal of LLW and naturally occurring and accelerator-produced radioactive material for public comment. These will apply to both NRC-licensed facilities and to DOE-operated disposal facilities. However, as of October 21, 1991, EPA has not established a date for reissuing these proposed standards [56 FR 54012, et. seq.].

The EPA has the charter to promulgate generally applicable environmental protection standards for the protection of the general environment from radioactive material pursuant to the Atomic Energy Act, as amended by the Reorganization Plan, No. 3, of 1970. EPA has issued standards regulating environmental releases from HLW and TRU waste sites in 40 CFR 191. EPA expects to issue a notice of proposed rulemaking in May, 1992 and finalize the rule in June, 1993.

The National Environmental Policy Act (NEPA) establishes a framework for requiring public disclosure and consideration of environmental impacts and protection of natural resources and the human environment during the planning phase of federally proposed activities. NEPA documentation will be required for all significant federal cleanup activities. DOE procedures for implementing NEPA for DOE-managed cleanup activities are found in DOE Order 5400.1C. This order requires that NEPA documentation be prepared separately from documentation prepared under other environmental programs (e.g., CERCLA). Thus, time needed to prepare NEPA documentation for DOE-managed environmental restoration and waste management activities must be factored into the planning phase of ISV. Data gathered as part of the CERCLA or RCRA cleanup process can be used to prepare the necessary NEPA documentation, and these efforts should be coordinated as such.

A majority of the federal and state environmental statutes, regulations, and Federal Facility and Consent Agreements require public participation to take into account the public concerns regarding proposed governmental actions. Public participation activities will not only provide input from the public on using ISV, but will also increase the public's understanding of ISV. It is clear that many of the potential regulations affecting the use of ISV for treating underground storage tanks in the DOE complex are not fully defined. On the other hand, the UTV technology has not been sufficiently developed to a point where it is ready for demonstration on waste tanks. As technical issues continue to be resolved concerning the field implementation of ISV for remediation of wastes sites, with the eventual possibility of underground storage tanks, the developers will also have to work closely with the regulators to ensure that the technology will meet the intent of the regulations as they are developed.

COST EVALUATION

Two separate discussions concerning the cost of using ISV to treat underground storage tanks are given. The first is an update of the cost analysis for ISV as originally performed by Buelt (2), now applied to a 50,000-gallon LLW tank. The second references work done by Boomer (9) as applied to the Hanford SSTs.

The first cost analysis is based on a large-scale system operating on an array of four LLW 50,000-gallon (6.1-m-diameter, 6.5-m-deep) tanks. It assumes that technology development is sufficiently advanced for the task and that site characterization is completed; therefore, costs are for remedial treatment operations only. Costs are given in 1991 dollars and results are for the cost of performing ISV; profit or overhead functions and equipment amortization have not been included. Other assumptions are stated as appropriate.

Site Activities

Site activities include transporting equipment to and from the ISV site, clearing and grading the area, removing a portion of the top layer of soil (overburden), filling the tank with soil or other material before vitrification, and acquiring and applying backfill material. These costs are estimated at $200,000.

Equipment Costs

Equipment costs were estimated based on actual costs of purchased equipment scaled up to 1991 dollars. Various equipment changes and improvements have occurred in the past few years. A new electrode feed system has been implemented, which allows the use of graphite electrodes rather than the combination graphite/molybdenum electrodes previously used (2). As discussed above, the feeding of graphite electrodes reduces both material and labor costs.

This analysis includes costs for two hoods and related equipment (electrode feed systems, off-gas lines and blowers) to enable setup of the next setting during vitrification of the current setting. The increase in capital costs is more than offset by the increase in productivity. Equipment costs are listed in Table 2 for a 3.75-MW ISV system with double containment of the off-gas treatment system for radioactive applications.

Labor Costs

Industry-averaged labor rates for operations were used in the cost estimate, representing typical costs of an Environmental Restoration and Management Contractor (ERMC). These are listed in Table 3. Labor costs will vary with the vitrification rate and overall operating efficiency. Table 4 gives an estimate of the vitrification rate, based on empirical data and process modeling and other pertinent process parameters. Four settings per site are assumed for an array of four tanks.

Table 5 shows the number and type of workers estimated per shift for setup and operations of LLW tank vitrification. In addition to vitrification time, time is estimated for setup. Setup involves moving the hood, preparing the electrodes, and wiring. As explained previously, two hoods will be used to enable the setup of the hood at the next setting while vitrification is taking place concurrently.

Consumable Supply Costs

Major consumable components include electrodes and power. Graphite electrodes are presently used for ISV. Four electrodes per setting are used, and the length of electrode used equals the depth of the melt plus the height of the feeders. The electrodes in the melt are not re-used. Electrodes are supplied in 2-m-long segments at a cost of $500/segment. Other various costs for maintenance tools and replacement parts and equipment are estimated to be an average of about $25,000 per setting.

The cost of ISV is highly dependent upon power costs. This analysis is presented using Hanford site power cost of $0.022/kWh. An estimate of 3.25-MW average power consumption is used for the purposes of this cost analysis. Obviously, the vitrification time required per setting is the determining factor for energy costs of ISV.

Secondary Waste Disposal

The off-gas system for ISV produces two types of secondary wastes. Both liquid scrub solutions and HEPA filters require periodic disposal. In the past, disposal of secondary process wastes has been a significant cost to ISV projects. Recent developments have shown that the generation of both the type and amounts of secondary wastes can be dramatically reduced. The type and amount of secondary waste may vary significantly with each site/setting; a conservative estimate of $100,000 is used for the total treatment and disposal costs of all secondary wastes for this cost analysis.

Cost Summary

The baseline cost of UTV is estimated to be about $434/m^3. However, these costs should be considered preliminary since the application of ISV to underground storage tanks is still under development. The costs for each category are summarized in Table 6. As shown by the table, the most costly component of ISV is labor.

Systems Engineering Study

A systems engineering study was performed by Westinghouse Hanford Company (WHC) to provide the technical basis to select the alternative for closure of the 149 single-shell tanks at Hanford (9). The technology options studied fall into two categories, retrieval and in situ; combinations of options for treating the waste, the tank, and the outlying contaminated soil are grouped into 16 alternatives (including no action as a baseline). Of the four alternatives with the lowest cost and best performance, three include ISV. In fact, the highest rated alternative uses ISV exclusively; this alternative is estimated to cost $3.7 billion compared to the baseline of $5.8 billion, and reduces the releases to groundwater of radioactive and hazardous chemicals (technetium and nitrate) by seven orders of magnitude. The WHC systems engineering study provides a complete description of technology alternatives. The study acknowledges that all of the technologies needed for closure of the SSTs will require a significant amount of development, some of which have not moved past the laboratory scale. The development and success of the ISV program is indicated as a key factor in managing the SST waste.

CONCLUSIONS

Application of ISV to underground tanks may be a cost effective, safe, and environmentally sound remediation technology for a number of underground tanks (and other underground structures) at DOE facilities. By filling tanks with clean or contaminated soil and vitrifying the tank, tank contents, and any contaminated surrounding soil, the tank is destroyed, and essentially all radioactive and nonvolatile hazardous constituents are immobilized in the glass for geologic periods. Even under treatment scenarios that would include removal of the tank contents, treatment of the tank itself and the outlying contaminated soil using ISV technology potentially remains an extremely efficient and cost-effective remediation method. To realize this potential, a number of technical, institutional, and regulatory obstacles will need to be overcome. Examples include containing or controlling transient gas releases, increasing ISV depth, confirming the capability of ISV for processing the salt cake-based tank wastes, and implementing regulations that are conducive to waste tank remediation.

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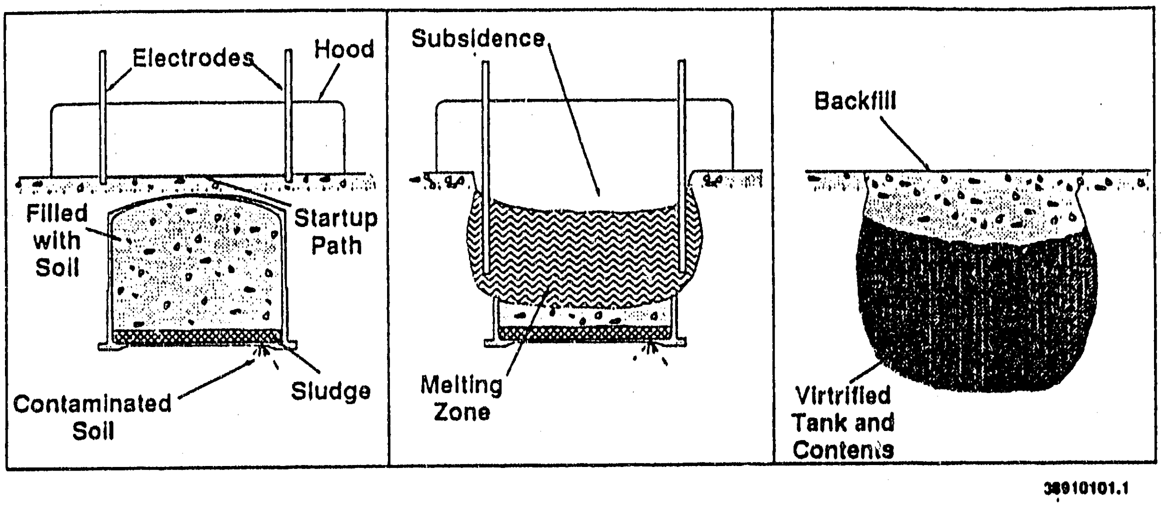

FIGURE 1. Schematic of Underground Tank Vitrification Using ISV

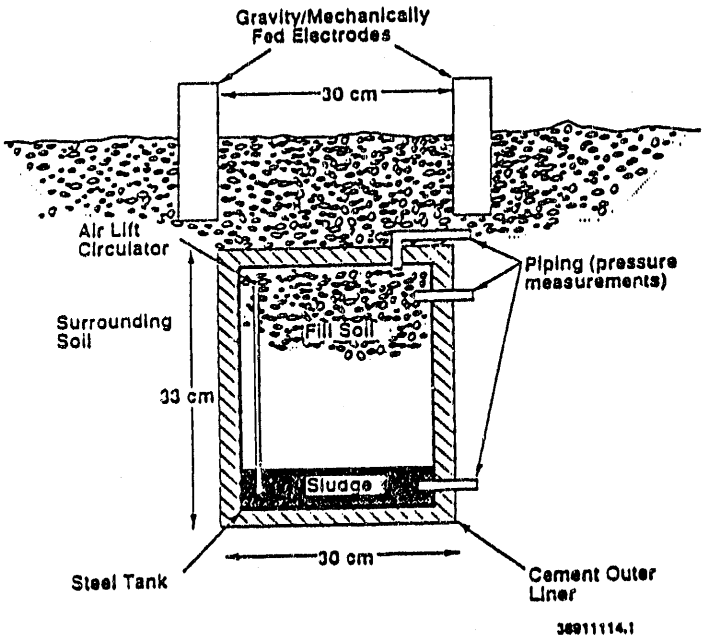

FIGURE 2. Tank Configuration for the Engineering-Scale ISV Test

FIGURE 3. Monolith Generated by the Pilot-Scale Underground Tank Test

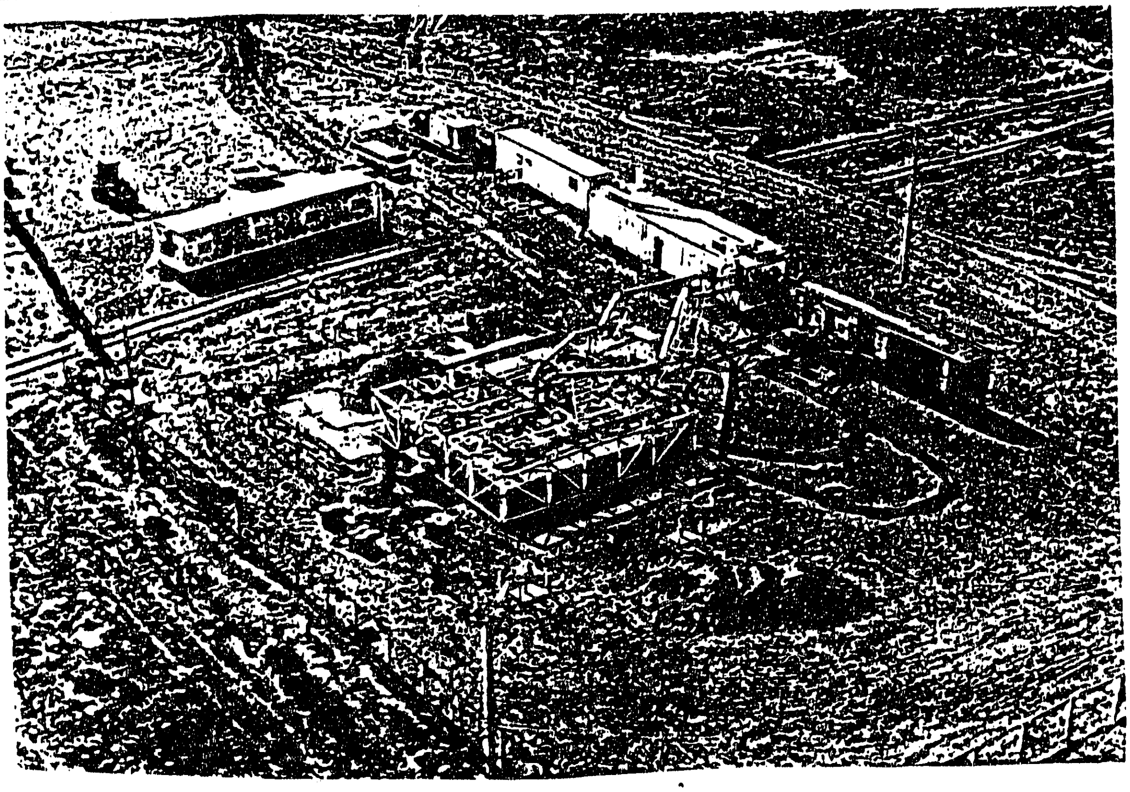

FIGURE 4. Large-Scale ISV Equipment

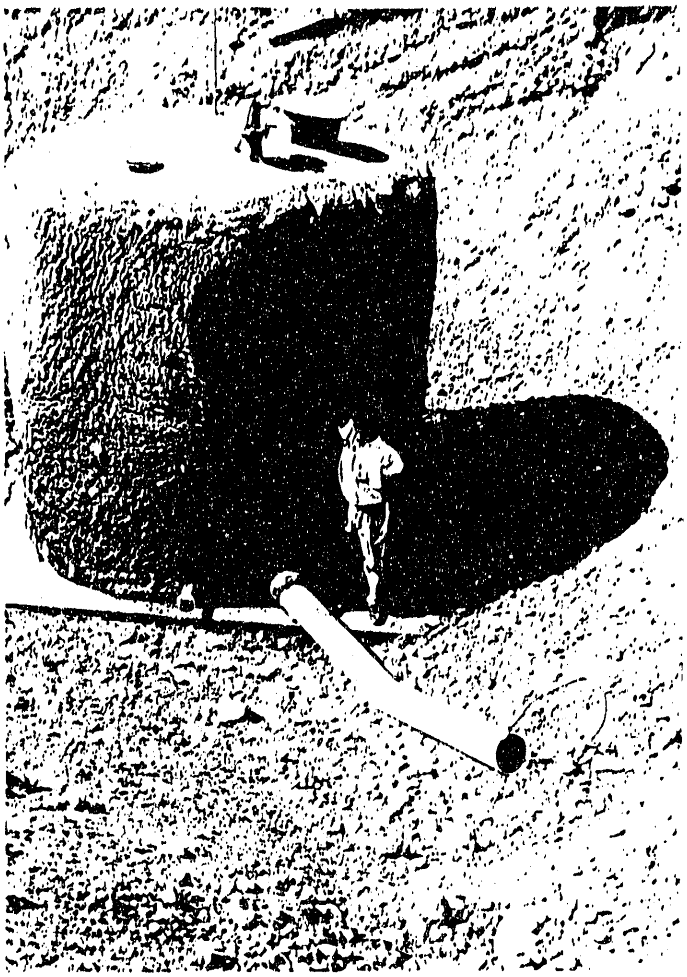

FIGURE 5. 6000-Gallon Tank Ready for Burial

TABLE 1. Underground Tank Remedial Action Schedule

Location	Description	Milestone
Hanford	Numerous underground structures; primarily single-shell tanks with residual wastes	Eng. Study, 1993 Draft SEIS, 1995 Final EIS, 1996
ORNL	Various inactive tanks, old Hydrofracture Facility, etc.	ROD WAG 1, 1993 ROD WAG 5, 1994

TABLE 2. Equipment Costs for In Situ Vitrification

Item	Cost ($K)
Backup Generator - 0.75 MW	35
Transformer	350
Electrode Power Cables	85
Electrode Feed Systems (2)	520
Off-Gas Lines and Hoods (2)	1,600
Back-up Hood Blower (2)	80
Off-Gas System	1,000
Process Control System	250
Crane (25-ton rubber tire)	200
Glycol Cooling System	45
TOTAL	4,165

TABLE 3. Manpower Rates for In Situ Vitrification

Job Classification	Manpower Rate, $/hr
Engineer, Manager	36
Crane Operator	25
Pipefitter	25
Operator/Technician	25
Electrician	25
Radiation Protection	30

TABLE 4. Vitrification Rates and Related Parameters

Vitrification time (h)	360
Set-Up Time (h)	80
Electrode Spacing (m)	3.5
Width vitrified per set(m)	10
Depth of setting (m)	7
Number of Settings	4
Vitrified Soil Volume per setting (m^3)	500
Total Volume vitrified(m^3)	2000

TABLE 5. Labor Requirements for Underground Tank Vitrification

Job Classification	Workers Per Shift (set-up/operations) Day	Swing	Graveyard
Project Mgr	1/1		
Engineer	1/1	0/1	0/1
Crane Operator	2/½		
Pipefitter	1/0	1/0	
Operator/Tech	2/2	2/2	0/2
Electrician	1/0	1/0	
Radiation Protection	1/1	1/1	0/1
Response Mgr	1/1		

TABLE 6. Cost Summary for Underground Tank Vitrification

	Labor	Supplies	Power	Waste Disposal	Site Prep	Total
$K/Setting	75	67	26	N/A	N/A	N/A
$K/Site*	298	267	103	50	200	918
$/$m^3$	149	134	51	25	100	459

* The site is an array of 4 tanks, each requiring a single setting, as described in the text.

N/A Cost not applicable to the individual setting

END

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