IMPROVED CONFINEMENT TECHNOLOGY FOR BURIED TRANSURANIC WASTE

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ABSTRACT

Since 1954, defense-generated transuranic (TRU) waste has been received at the Idaho National Engineering Laboratory (INEL) Radioactive Waste Management Complex (RWMC). Before 1970, approximately 57,100 cubic meters of transuranic waste were buried in shallow-land trenches and pits at the RWMC.

A major objective of the Department of Energy (DOE) Nuclear Waste Management Program is the environmentally safe management of defense-generated transuranic waste. Strategies have been developed for managing INEL buried TRU waste and have been incorporated in the DOE Defense Waste Management Plan(1). The INEL is conducting studies to develop technology to support selection of a long-term management alternative for INEL buried TRU waste in 1995. In situ grouting is being evaluated as an improved confinement technique for INEL buried TRU waste. During this 2 year program different grout formulas were developed for arid unsaturated conditions; a simulated test pit was constructed, instrumented, and in situ grouted; and post-grouting examination of the pit was completed.

INTRODUCTION

The Idaho National Engineering Laboratory (INEL) covers 2305 km^2 of semiarid land in southeast Idaho near the center of the Snake River Plain. The Radioactive Waste Management Complex (RWMC), which encompasses 58 ha in the southwestern corner of the INEL, was established in 1952 as a controlled area for burial of solid radioactive wastes generated by INEL operations. In 1954, the RWMC was designated as a disposal site for solid defense transuranic (TRU) waste generated by operations conducted for the U.S. Atomic Energy Commission and its successor agencies, now the U.S. Department of Energy (DOE). Burial of TRU wastes ceased in 1970. Transuranic waste is defined as material that has negligible economic value, and is "contaminated with alpha-emitting transuranic radionuclides with half-lives greater than 20 years and concentrations greater than 100 nCi/g"(2). The total volume of TRU waste disposed at the RWMC was 57,100 m^3, containing 357 kg of TRU radionuclides. A major objective of the Department of Energy (DOE) Nuclear Waste Management Program is the environmentally safe management of defense-generated TRU waste. The DOE Defense Waste Management Plan(1) is the reference plan for managing TRU wastes. The reference plan for buried TRU waste is to monitor the waste, take necessary remedial action, and periodically reevalute the safety of the buried waste. To implement the DOE plan, the INEL has developed a strategy for managing the buried TRU waste. The strategy involves: (a) environmental monitoring, (b) remedial action if necessary, (c) assimilation of data from on-going waste management activities, and (d) selection of a long-term management alternative in 1995.

The INEL Buried TRU Waste Studies (BTWS) are being conducted to provide the technical basis for selection of the long-term management alternative. Alternatives being considered for long-term management of the waste are: (a) leave the waste in place, as is; (b) leave the waste in place, but improve waste confinement; or (c) retrieve the waste, process and certify as necessary for disposal at a federal repository.

The INEL BTWS Program is currently evaluating technologies for improving confinement of the waste. Improving waste confinement would provide additional protection against water infiltration, wind erosion, and intrusion by animals, plants, and people. The improved confinement technique under evaluation is in situ grouting. Grouting is the process of introducing a fluid (grout) into the void space of a soil or rock formation which, after the grout solidifies, results in a cohesive mass of lower permeability. Test objectives include evaluation of grout permeation in the buried soil/waste matrix to reduce subsidence and determination of bulk hydraulic conductivity.

A 2 year in situ grouting feasibility test was initiated in FY-1985 to demonstrate the applicability of grouting technology to the INEL's arid, unsaturated soil conditions. This test, for discussion purposes, was divided into the following

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activities: (a) grout development, (b) grout injection techniques, (c) test pit design, (d) grouting operations, and (e) post-grouting evaluation.

Grouting Development

Development of a suitable grout formulation for INEL arid soil conditions was performed by the Oak Ridge National Laboratory (ORNL)(3) in support of INEL buried TRU waste studies. Both particulate and chemical solution grouts were considered for development and application in the grouting test. Particulate grouts evaluated included both large void-filling grouts, such as Portland cements, and small void permeation grouts such as microfine grouts. Several performance criteria were established for grout development studies and included:

1. Hydraulic Conductivity - The grout was required to provide a minimum two orders of magnitude reduction in the hydraulic conductivity of INEL undisturbed soil. Target value was 10^{-8} cm/s or less.

2. Freeze/Thaw Deterioration - Grout specimens were subjected to freeze/thaw tests. Temperatures were cycled 30 times between -25 and +60°C with 50% relative humidity maintained at the 60°C temperature.

3. Strength - The unconfined compressive strength was a minimum of 3.5×10^4 kg/m^2 with expected grout strengths in the range of 1.4×10^5 to 5.6×10^5 kg/m^2.

4. Flow Characteristics - Grouts were required to flow easily through small passages over 0.6-0.9 m distances without plugging the passages, and permeate soil pore voids such that a cohesive monolithic mass of grout and waste would result.

5. Grout Shrinkage - Grout formulas developed were required to resist or preclude syneresis. Less than 1% shrinkage by volume of the grout was acceptable.

6. Phase Separation - Phase separation refers to the liquid (water) phase that forms during curing of the grout. Grouts were required not to initiate a free-water front during curing of the grout.

7. Compatibility - Developed grout formulations were required to be chemically and physically compatible if multiple grout formulations were to be used in the same grouting region.

Literature investigations conducted by ORNL(3) indicated that inorganic and organic solution grouts could be unstable under INEL arid conditions. These grouts have been found to deteriorate under freeze/thaw and wetting/drying cycles and may not provide long-term durability and resistence to INEL conditions. In addition, the chemical solution grouts have low-compressive strengths and may not provide the required subsidence control.

The ORNL was successful in developing both the ordinary particulate grout and a permeation (microfine) grout. The purpose of the ordinary particulate grout was to fill large voids within the waste/soil matrix. The ordinary particulate grout was primarily expected to provide stabilization of the waste test pit and reduce subsidence. The permeation or microfine grout was expected to fill small, remaining voids in the waste/soil matrix and provide hydrological isolation of the waste test pit.

Only the microfine grout was used in grouting of the experimental test trench. The system used to inject the grout into the trench was capable of dynamically consolidating large voids. Therefore, the ordinary particulate grout formulation was not required. ORNL test results indicate both the ordinary particulate and microfine grouts met or exceeded performance criteria.

The small void-penetration or microfine cement recommended for use(3) was a commercially available grout from Avanti International, Webster, Texas. The grout mix, which contained two weight percent methylene sulfinate set retarder, was mixed at a ratio of 3.64 kg solids per 3.78 L water. Test results are presented in Table I.

TABLE I

TEST RESULTS FOR MICROFINE PARTICULATE GROUT

24-hour phase separation (vol%)	0[a]
Water permeability (Darcy)	4.2×10^{-6}
Hydraulic conductivity (cm/s)	4.1×10^{-9}
28-day compressive strength (MPa)	11.5
Apparent viscosity (cp) at 300 rpm	6.5
Density (g/cc)	1.4

a. Zero vol% after 48h.

Grout Injection Techniques

Various techniques are available in the United States for the injection of grout into a subsurface formation such as shallow-land buried TRU waste. These techniques range from commercially available methods such as lancing to advanced methods such as jet or dynamic consolidation grouting. The application of these methods is highly dependent on the physical attributes of the host soil and the performance criteria of the resultant grouted media.

The INEL is characterized as an arid, unsaturated site. The RWMC consists of alluvial silt/clay deposits overlaying beds of highly fractured basalt. The soil has a moisture content of 13 wt %, a density of 1.52 g/cc, with 40-60 wt % measuring less than 1.0 mm in particle diameter. The technique selected for in situ grouting INEL shallow-land buried TRU must meet the following criteria to be considered a viable long-term management technique:

1. Minimum Void Fill: A minimum of 80% of the hydrologically accessible voids within the buried waste site needs to be filled to provide geomechanical stability of the site from soil subsidence. Soil subsidence may cause pathways that rainwater can transport radionuclide contamination away from the waste site.

2. Minimum Hydraulic Conductivity: A minimum of two orders of magnitude hydraulic conductivity reduction relative to the

surrounding undisturbed soil needs to be provided. Hydrological isolation is obtained by making the buried waste more impermeable than the surrounding undisturbed soil to rainwater or other transient water infiltration. A bulk hydraulic conductivity of 1×10^{-8} cm/s was required for hydrological isolation. This value is two orders of magnitude lower than the average permeability of the undisturbed soil at the RWMC.

3. Emissions: Emissions generated by the grouting process was undesirable. The selected grouting process would minimize or eliminate such emissions. The emissions, if generated during grouting of actual radioactive wastes, would result in spread of radioactive contamination.

Several grouting methodologies were evaluated. Lancing techniques, in which grout is pressure injected into subsurface formations via pipes, is the general method used for particulate grouting in the United States. This method is typically effective for filling large voids or in coarse sandy soil, which ensures uniform distribution of the grout in the formation(4). European improvements to the lancing method, such as Tube'-Manchette or sleeve pipe grouting, injects grout in finite levels along the pipe. This method has several advantages over lancing, but is more labor intensive. Significant problems occur when particulate grout is injected into medium silt or finer gradation formations such as found at the INEL. These formations tend not to allow particulate grout permeation into the soil pore voids. Hydrofracturing of the soil formation is a common occurrence. This hydrofracturing phenomena is undesirable since it could release radioactive contamination if used in stabilizing INEL buried TRU waste.

Advanced methods have been recently tested in the U.S. for particulate grouting in silt and clay soil formations. Jet grouting(5) has been used in Europe for the creation of monolithic soil columns for the stabilization and hydrologic isolation of clay soils. This method uses high-energy jets of water to cut, liquify, and excavate soil such that the resultant void in the formation is filled with particulate grout. An experimental method developed for low-level radioactive shallow-land buried waste consolidation is a dynamic compaction and grouting method developed by Rockwell Hanford Operations (RHO) for DOE. This method provides for dynamic consolidation of large voids in a subsurface formation by vibration and grout fill of smaller voids by simultaneous grout injection(6).

Based on detailed evaluations, the RHO dynamic-compaction/ grouting system was considered the best technique for meeting specified performance criteria. Conventional grouting methods of lancing and sleeve pipe grouting would not provide required grout permeation of the RWMC soil. Jet grouting, a method that ordinarily would be used for this soil condition, was deemed undesirable because of the amount of emissions that could be released by the grouting process.

Test Trench Design

Figure 1 shows the simulated (nonradioactive) waste test trench constructed for the in situ grouting demonstration. The trench measures approximately 6.1 x 2.1 x 4.3 m deep, and has a waste trench volume of 56.6 m^3. The 3.0 m thick layer of simulated waste is contained between approximately 1m of underburden and overburden soil. The waste forms used simulated the TRU waste received for burial at the INEL. These forms included process sludges, soil, cement, wood, construction material, combustible and metals. These waste forms were packaged in either 208 L metal drums or 1.2 x 1.2 x 2.4 m wooden boxes.

The trench was excavated, loaded with the waste containers, and backfilled with excavated dirt. This excavated dirt was mixed with water to allow for additional void fill and soil subsidence.

The trench was instrumented with a combination of neutron logging access wells and hydrologic conductivity screen wells. These devices provide quantitative and qualitative assessments of the hydrologic state of the test trench before and after grouting operations have been completed. Pregrouting tests of the trench indicated there were approximately 5.9 m^3 of hydrologically accessible voids and a mean hydraulic conductivity of 5.9×10^{-3} cm/s. The voids were spatially located in the waste containers and the soil region immediately adjacent to the waste containers(7).

Grouting Operations

The RHO dynamic-compaction/grouting system, as shown in Fig. 2, was moved to the INEL and the test trench in situ grouted in late summer of 1986. Results of the grouting operations are summarized below(7):

- Approximately 11.04 m^3 of grout was injected into the test trench. This volume represented 187% of the theoretically hydrologically accessible voids within the trench. The main cause for this phenomenon is believed to be densification of the host soil and grout fill of large voids within the trench.
- Grout injection progressed under gravity feed conditions.
- The RHO system can penetrate most of the volume of the trench.
- The RHO grouting system requires a minimum flow of grout to increased penetrability into the test trench.
- Penetration of the grout injection to the basalt level was not always successful, which may result in less grout take at depth than near the trench surface.
- Fluorescent dye contaminants, used to simulate TRU contamination, and waste materials were released from the waste containers in some grout holes, but were observed incorporated in the grout. Improvements could be made during actual grout operations that would be expected to reduce or eliminate this problem.
- Gases and low-density materials tend to float to the top of the grout holes. Improvements could be made during actual grout operations that would be expected to reduce or eliminate this problem.
- Large accessible voids, such as the plywood boxes, were readily grouted.

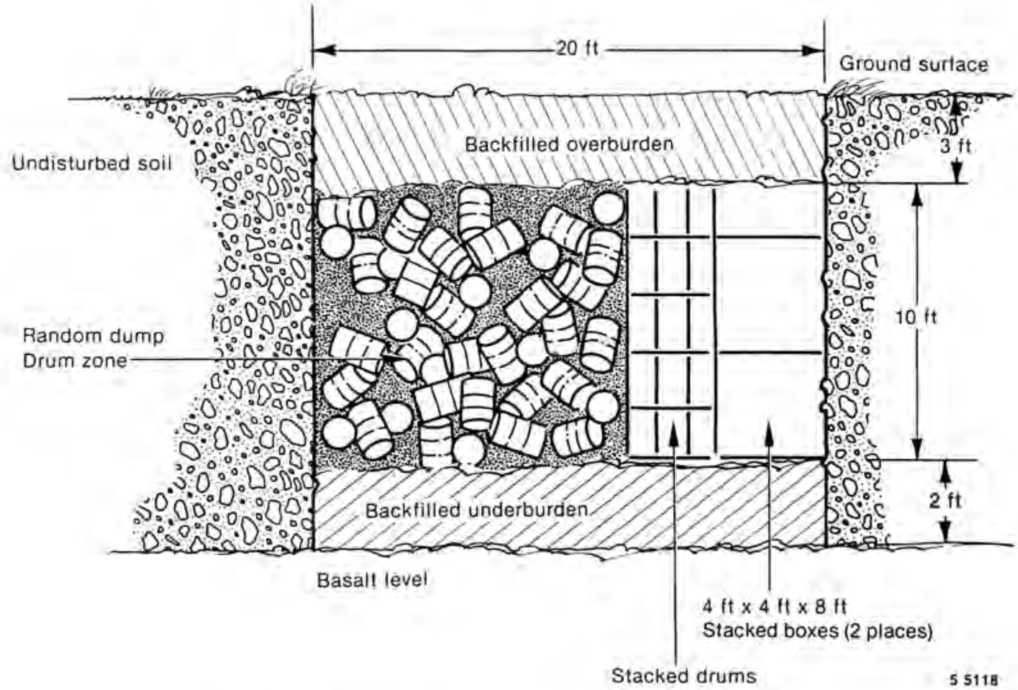

Fig. 1. Detail of test trench design.

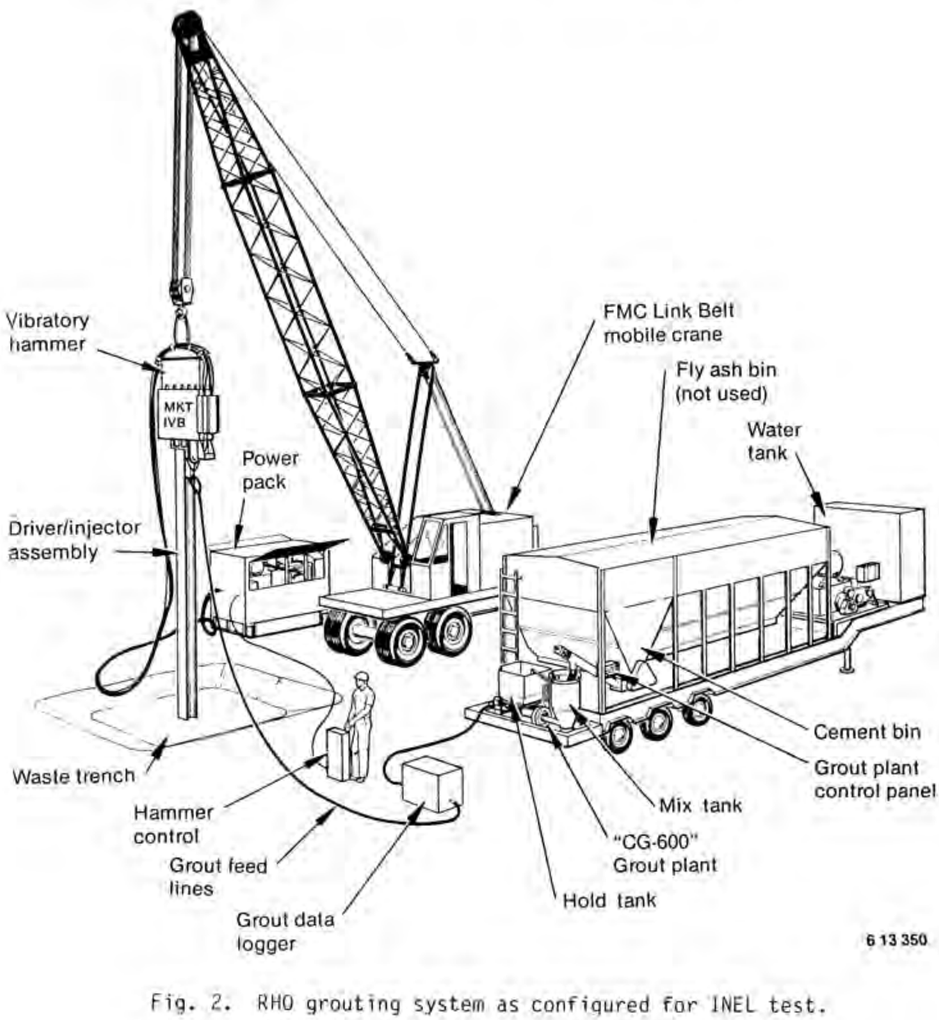

Fig. 2. RHO grouting system as configured for INEL test.

- Grout holes tended to be slanted rather than truly vertical, because of obstructions encountered by the grout injector.

Post Grouting Results

Post grouting hydraulic assessment and systematic destructive examination of the test trench were performed 6 weeks after grouting operations were completed. Results of post grouting testing and examination are as follows:

- The grouting operation reduced the saturated hydraulic conductivity of the simulated TRU test trench by approximately two orders of magnitude. The grouting operation decreased the hydraulic conductivity of the test trench from 5.9×10^{-3} cm/s before grouting to 6.05×10^{-5} cm/s after grouting, a factor of 98 or approximately 2 orders of magnitude. This decrease probably resulted primarily from the plugging action of the cement grout on channels within the waste and soil as well as soil compaction because of: (a) the vibratory action of the system, and (b) to the displacement and consequent compaction of the soil resulting from the penetration of the RHO system into the soil.
- Destructive examination of the test trench indicates that the grout has not penetrated the fine-grained soil. This resulted in columns of grout in a soil matrix.
- Fractures and accessible voids connected to grout columns by channels were entirely grouted.
- Waste materials were displaced from the drums by grouting operations.
- Generally, the drums were not totally encapsulated by grout, even though the drums were penetrated by the grout injector.
- Pockets of soil and waste within the grout columns were ungrouted.
- Soil within the plywood boxes was ungrouted.
- Use of the RHO dynamic-compaction/grouting system resulted in the displacement of approximately 4.9 m^3 of voids which were filled by grout. This resulted in soil and waste compaction of approximately 5% by volume.

CONCLUSIONS

In situ grouting using particulate cements is not a viable long-term management technique for INEL buried TRU wastes. Grouting did achieve stabilization of the test trench. However, hydrological isolation of the trench from transient water fluxes was not achieved. Hydrological isolation is desirable to ensure migration of TRU radionuclides does not occur. The RHO dynamic-compaction/ grouting system does provide significant void fill and consolidation of the waste. Utilization of this technique at other sites may be beneficial.

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