IMMOBILIZATION OF SELECTED LOW-LEVEL HANFORD WASTES IN GROUT

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ABSTRACT

The U.S. Department of Energy and Rockwell Hanford Operations are preparing for the construction of a Transportable Grout Facility to immobilize selected radioactive liquid waste stored on the Hanford Site. The immobilization process solidifies low-level liquid wastes by mixing them with a cementitious dry solids blend that consists primarily of cement, fly ash and clay. This paper presents a brief description of the grout formulation development, the Transportable Grout Facility and near-surface disposal site, and the performance assessment and verification work being performed in conjunction with a planned 1986 startup.

INTRODUCTION

During 1983, Rockwell Hanford Operations (Rockwell) evaluated several options for the immobilization and near-surface disposal of low-level liquid radioactive waste in a cost effective and environmentally sound manner. These options included solidification in organic polymer, urea-formaldehyde, ceramics, bitumen, and concrete; and drying with induction heat, alternating current (AC) heat and microwave heat. Many of these options were eliminated due to their need for additional development (e.g. SYNROC ceramic, induction drying, and AC drying), their high operating costs (e.g. organic polymer, urea formaldehyde, and bitumen), or their high capital costs. The most promising alternatives involved variations of two basic processes, grout solidification and radiofrequency drying. Grout solidification by means of transportable equipment was selected for application at Hanford based on cost, flexibility, and engineering requirements.

Grouting of selected low-level liquid waste is an integral part of the overall waste management strategy developed for Hanford.[1] This technology will be applied to waste derived from a variety of sources. Candidate feeds are: the waste produced from reactor containment decontamination and spent fuel storage pool filtration systems; the low-level portion of wastes produced from cladding and fuel dissolution; concentrated non-complexed wastes; and other small volume, low-level wastes from the facilities located on the Hanford Site. The waste volumes are given in Table I.

TABLE I

Grout Feed Volumes

Source	Volume (Expressed in Thousand of Units)
Decontamination and Filtration Waste	8,000 gal (30,300 L)
Cladding Removal Waste	17,000 gal (64,300 L)
Neutralized Current Acid Waste	2,000 gal (7,600 L)
Concentrated Noncomplexed Waste	33,000 gal (124,900 L)
Other Low-Level Waste	21,000 gal (79,500 L)
TOTAL	81,000 gal (306,600 L)

The application of grout to radioactive liquid waste disposal is not new technology. Oak Ridge National Laboratory (ORNL) has mixed radioactive liquid waste with a cementitious formulation and injected the resulting slurry into a fractured shale formation several hundred feet underground. Oak Ridge National Laboratory is providing an applicable grout formulation for Hanford wastes. Battelle Memorial Institute's Pacific Northwest Laboratory (PNL) is performing a variety of support studies on the grout system including verifying system operability and assessing long-term performance.

The mixing of low-level liquid radioactive waste with cementitious materials to form grout will free existing double-shell tank space for interim storage of new waste; reduce, and even possibly eliminate construction of new tanks; and dispose of the waste in an environmentally sound and safe manner.

GROUT FORMULATION

Grout is a mixture of cementitious material and water (or other liquid), without aggregate, proportioned to be pourable without segregation of the constituents.

The cementitious material used at Hanford will primarily consist of Portland Cement as the binder; American Society for Testing Materials (ASTM) Class F fly ash for retaining radioactive strontium and extending the cement; and Attapulgite-150 drilling clay as a suspending agent. Indian Red Pottery Clay may be used in some mixes as an ion exchange material for radioactive cesium retention. The dry materials will be blended to produce a homogenous mix within the ranges identified in Table II.

Table II

Dry Materials

Constituent	Percent By Weight
Portland Cement	20-50
Fly Ash	30-80
Attapulgite Drilling Clay	0-20
Indian Red Pottery Clay	0-10

Distinctive dry solids formulations will be developed for each of the liquid waste streams identified in Table I. However, the objective of the formulations will be the same. Each formula will be tailored to maximize the waste loading while minimizing cost, to use commercially available raw materials, and to accommodate moderate variability of the wastes.

The formulations must also produce grouts with the following characteristics:

1. A pressure loss of less than 8 lb/in^2 (56 kPa) per 100 ft (30 m) of pipe.

2. A gel strength of less than 100 $lb_f/100\ ft^2$ (48 Pa) after 10 minutes.

3. No freestanding water on the grout surface 28 days after completing placement.

4. A compressive strength of at least 50 lb/in^2 (350 kPa) after 28 days.

5. A temperature of less than 250°F (394K) at any time.

6. An American Nuclear Society leachability index of 6 or greater.[2]

Pressure loss is being regulated to be compatible with the grout pump and a potential pumping distance of 3,000 feet (915 m). The gel strength is being minimized to assure that stagnant grout can be moved after a short shutdown of the pumping equipment. The grouts are being tailored to limit freestanding water to ensure that all liquid waste is disposed of in a solid form without unduly delaying or complicating post-emplacement operations. The 50 lb/in^2 (350 kPa) minimum compressive strength will support the weight of a soil and rock overburden which will be placed over the grout monolith. The temperature limit assures that moisture in the pore spaces of the grout monolith is not heated to temperatures that produce vapors (ie., steam). Leaching is being controlled to enhance long-term performance. Additionally, the grouts are to possess flow properties that limit the grout angle-of-repose and ensure that the disposal site volume is effectively utilized.

Grouts with these characteristics can be expected to allow safe, efficient operations and provide long term isolation of the immobilized radionuclides.

GROUT PROCESSING FACILITIES

The grout production and disposal system consists of three major components: a 1 million-gallon (3.8 ML) feed tank; a Dry Materials Receiving and Handling Facility (DMRHF), and the Transportable Grout Equipment (TGE); and a near-surface disposal site. The DMRHF and TGE are collectively called the Transportable Grout Facility (TGF) and comprise the "heart" of the grout disposal system.

Low-level liquid radioactive waste will be staged in 1 million-gallon (3.8 ML) batches in a double-shell tank which is currently under construction as part of another project. The waste will then be pumped to the TGE where it is mixed with the blended dry solids (prepared at the DMRHF) and pumped to the near-surface disposal site. After the grout monolith has cured to the desired state of hardness, it will be covered with a thick layer of backfill. The disposal concept is described in more detail in the succeeding paragraphs. A diagram depicting the entire disposal process is provided in Fig. 1.

The DMRHF will primarily consist of railcar and truck unloading hoppers, four dry materials storage bins, a dry materials blender, and a blended materials storage bin. The capacities of the various storage bins are provided in Fig. 2. These bins have been sized to support a continuous seven days per week, 24 hours per day grouting operation. The DMRHF will be capable of producing between 15,000 and 30,000 lb/h (6,820 and 13,640 kg/h) of dry blended solids.

The dry materials will be delivered to the Hanford Site in covered hopper railcars and in bulk material transport trucks. Capabilities will be provided at the DMRHF for gravity flow unloading of the delivery vehicle and pneumatically transferring the bulk dry solids to the storage bins. Unloading is to be accomplished at a rate of no less than 5,000 lb/min (2,270 kg/min) for railcars and 2,000 lb/min (910 kg/min) for trucks.

The dry solids will be pneumatically conveyed to a ribbon blender. The blender will be designed and operated to produce a homogeneous blend. Each constituent in any one pound (.45 kg) sample of the homogenized dry material will be within ±5 % of their specified weight. The blended dry solids will be discharged from the blender to the blended materials storage bin by gravity flow.

The dry blended materials storage bin will be designed to assure that the blended material does not segregate beyond the desired ±5 wt% accuracy. Material from this bin will be gravimetrically fed to

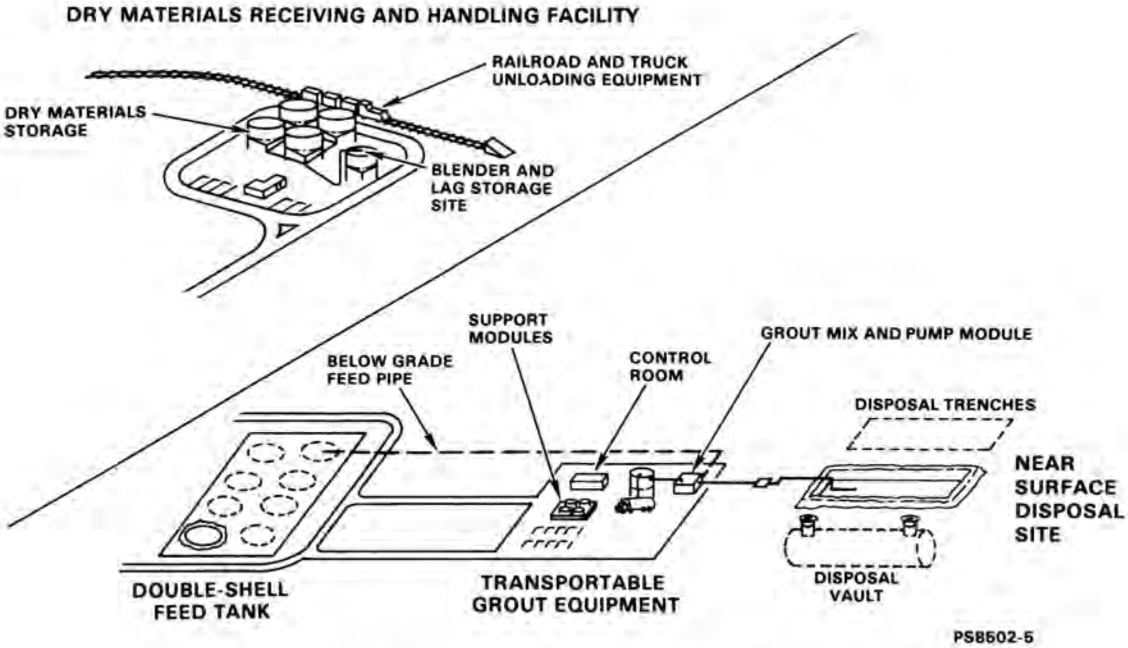

Fig. 1. Grouting and Disposal of Low-Level Liquid Radioactive Waste.

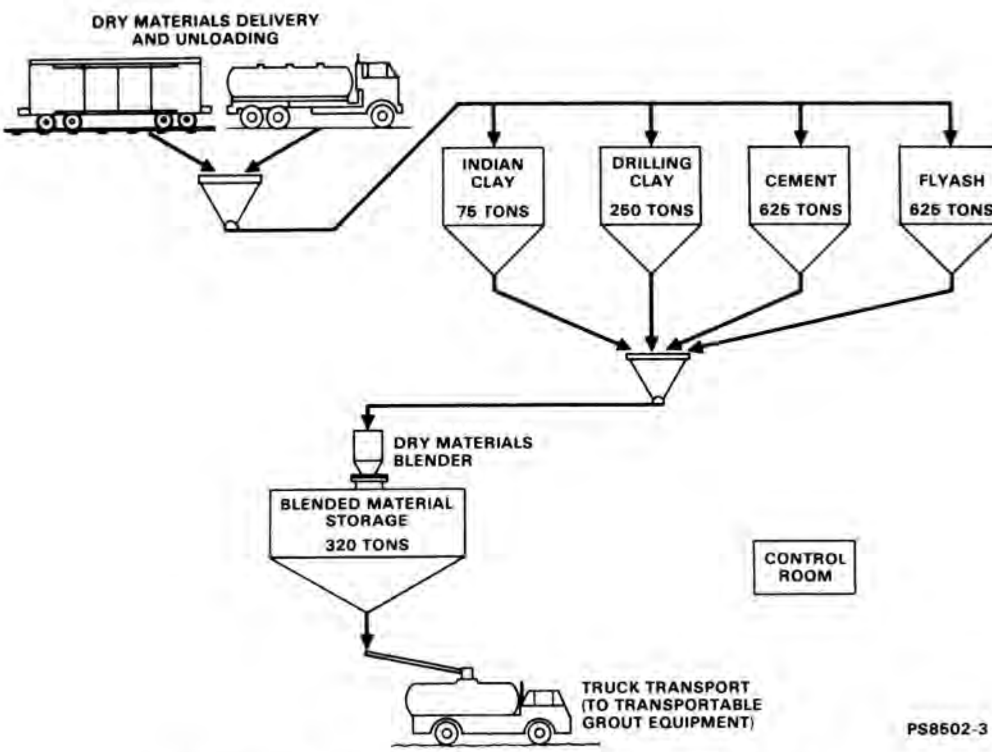

Fig. 2. Dry Materials Receiv' ı and Handling Facility.

27-ton (24,500 kg) bulk material transport trucks for delivery to the Transportable Grout Equipment (TGE) site, about one mile (1.67 km) away.

The TGE will consist of seven integrated modules performing the following functions: (1) dry blended material receiving, storage and feeding; (2) process additives storage and dispensing; (3) blended materials/liquid waste mixing and pumping; (4) decontamination solution storage; (5) process ventilation; (6) decontamination solution and flush water collection; and (7) process control. A schematic showing how the modules are integrated is given in Fig. 3.

Dry blended materials delivered to the TGE will be pneumatically unloaded and transferred to a 35-ton (31,800 kg) dry storage bin. The solids will be automatically fed to the grout mixer/pump system at selected rates varying between 100 and 600 lb/min (45 and 273 kg/min). Radioactive liquid waste will be fed to this module at 25 to 50 gal/min (95 to 190 L/min). No more than 200 gal (750 L) of radioactive liquid will be contained in mixer and pump module at any time. The system will produce and pump grout slurries made by mixing solids and liquids at a ratio of 4 to 12 lb (2 to 6 kg) of dry blended solids to 1 gal of waste. The grout slurry will be discharged from the pump at selected rates between 30 and 70 gal (113 and 265 L/min).

It is anticipated that additives will occasionally be required to adjust viscosity, reduce air entrainment, or to regulate the set time. A module for storing and dispensing the additives is included in the TGE design. The module will provide for automatic additive metering into the mixer.

The decontamination module will store and supply sodium hydroxide and a phosphate-based cleaning solution. These solutions will be used for routine decontamination after completion of each campaign and in the event of a process upset. Normal equipment decontamination will start by mixing and pumping nonradioactive grout through the system to scour the internal surfaces. Subsequent to the scouring, the surfaces will be chemically decontaminated using a 25 wt% sodium hydroxide solution followed by a diluted solution of the phosphate based cleaner. Decontamination solutions will be routed to the liquid collection module.

The liquid collection module will be capable of containing 500 gal (1890 L) of spent decontamination solutions. The module will also collect and store liquid accumulated from the exhauster drain system. The tank will be equipped with a transfer pump, feed pump, agitator, density indicators and level indicators. Collected effluent will be routed to the mixer/pumping module for conversion to grout.

The ventilation module will consist of a dual high-efficiency particulate air (HEPA) filter system which will allow filter changeout during routine operations. The module will maintain a 1-in water gauge (250 kPa) negative pressure on the mixing/pumping module. A continuous radioactive gaseous effluent sampler and recording system will be included.

The TGE control room module will be the center of process control activities. From this location, all operations will be automatically monitored and adjusted.

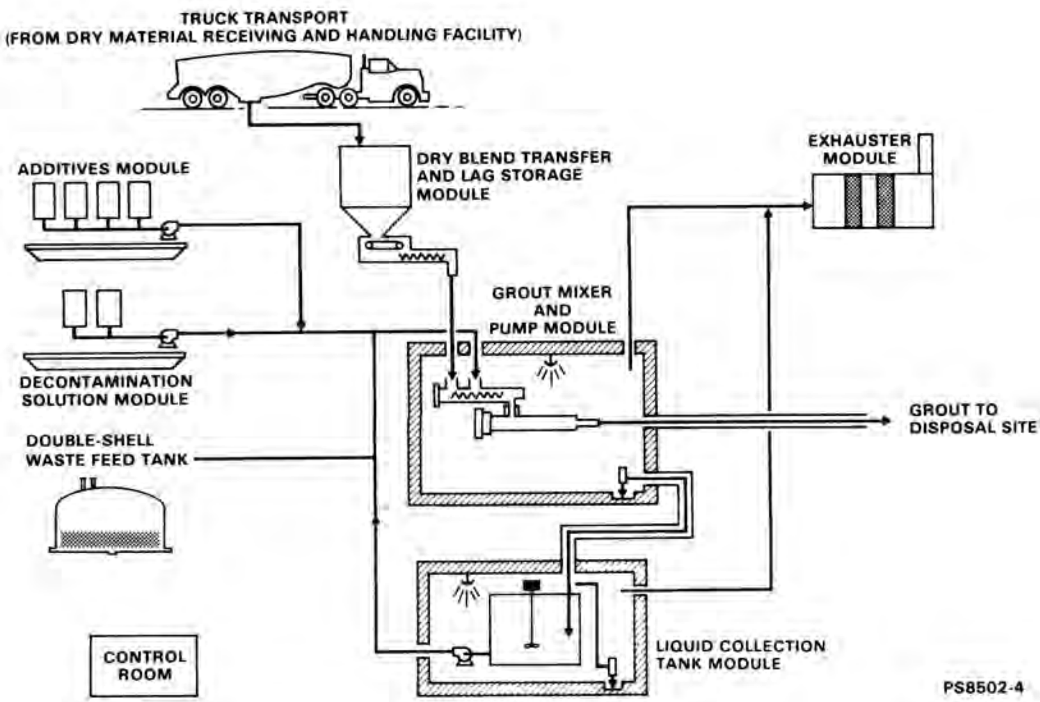

Fig. 3. Transportable Grout Equipment.

The near-surface disposal site will encompass approximately 80 acres (4050 m^2) and be enclosed by an 8-ft (2.5-m) chain link fence. The site is over 200 ft (60 m) above the groundwater table and well above any postulated flood zone. The geology of the Hanford Site is very stable.

Disposal of the liquid radioactive waste at the site will be accomplished by discharging the radioactive grout slurry to a preconstructed trench or subsurface vault. Trenches will be used for the disposal of very low-level waste which is primarily generated by reactor decontamination, storage pool water filtering backwashes, and ion exchange resin regeneration. The trenches will be sized to accommodate 1.3 million gal (5 ML) of grout slurry. Each trench will be lined with plastic sheeting to prevent water loss to the surrounding soils during the curing process. Additionally, the trenches will be covered to reduce evaporation and deposition of small windblown debris. The vaults will be used for the disposal of wastes with radionuclide concentrations great enough to warrant additional shielding. These vaults will be constructed about 26 ft (8 m) below grade. Corrugated metal culverts that are 10 ft (3 m) in diameter and 130 ft (40 m) in length, have been proposed as a grout receivers. The vaults will be equipped with exhaust vents and liquid level indicators.

Grout disposal in trenches will be completed by backfilling to grade with clean soil removed during the trench excavation. Grout disposal in vaults will be completed by backfilling to grade with layered rock and soil. This configuration enhances the long-term performance of the vault disposal system. Typical completed grout disposal trenches and vaults are illustrated in Figs. 4 and 5. The protective barrier and marker system is expected to effectively deter infiltration, biotic intrusion, erosion, and human intrusion until the waste is decayed to harmless levels. Optimization studies on protective barrier design including the trench edge overlap are being performed. This disposal concept will immobilize the radionuclides for extended periods of time; allowing them to decay to levels that do not pose a health hazard to future generations.

The TGF is scheduled to begin operation in 1986 and will operate on a campaign basis. A campaign will consist of grouting one million gal of low-level liquid waste during a three to five week period. An average 4 to 6 million gal (15 to 23 ML) of waste are expected to be disposed of per year.

PERFORMANCE ASSESSMENT AND VERIFICATION

The performance of grout in immobilizing radioactivity for extended periods of time is being

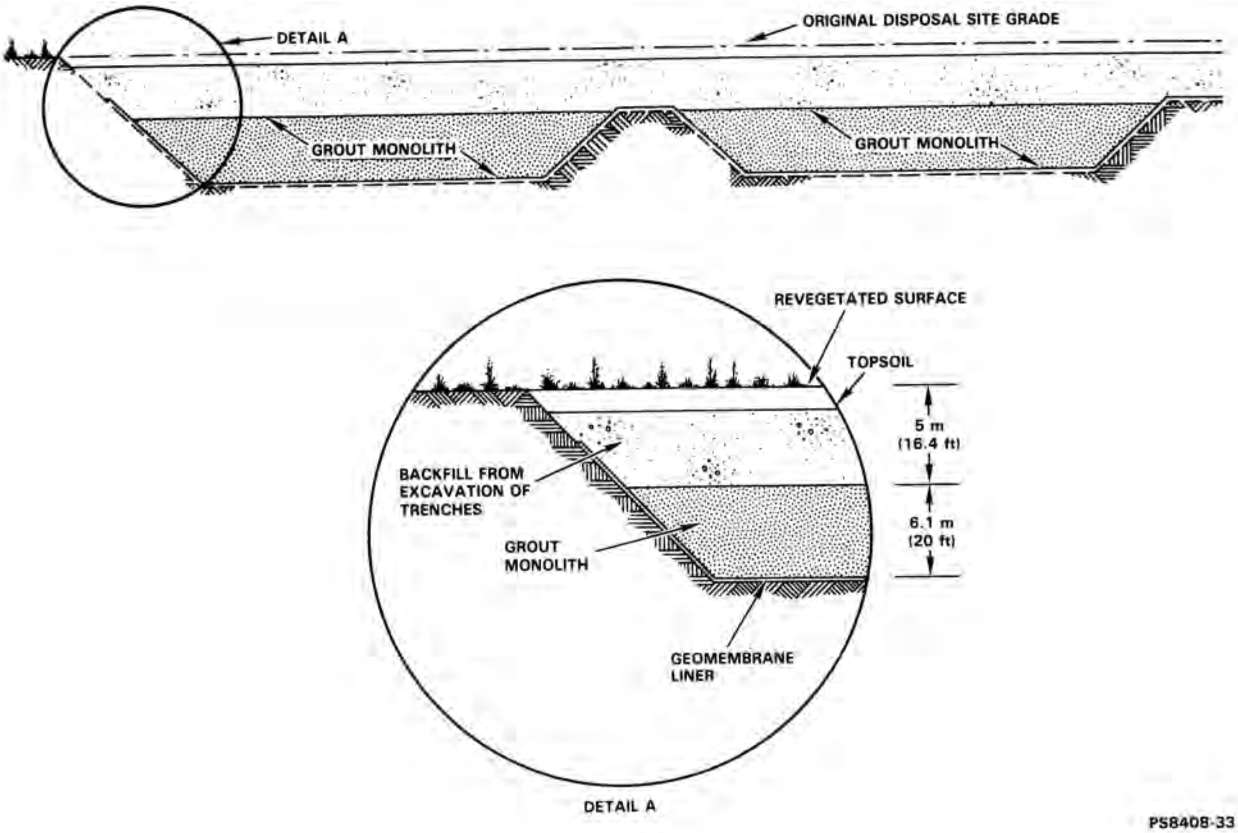

Fig. 4. Completed Grout Disposal Trenches.

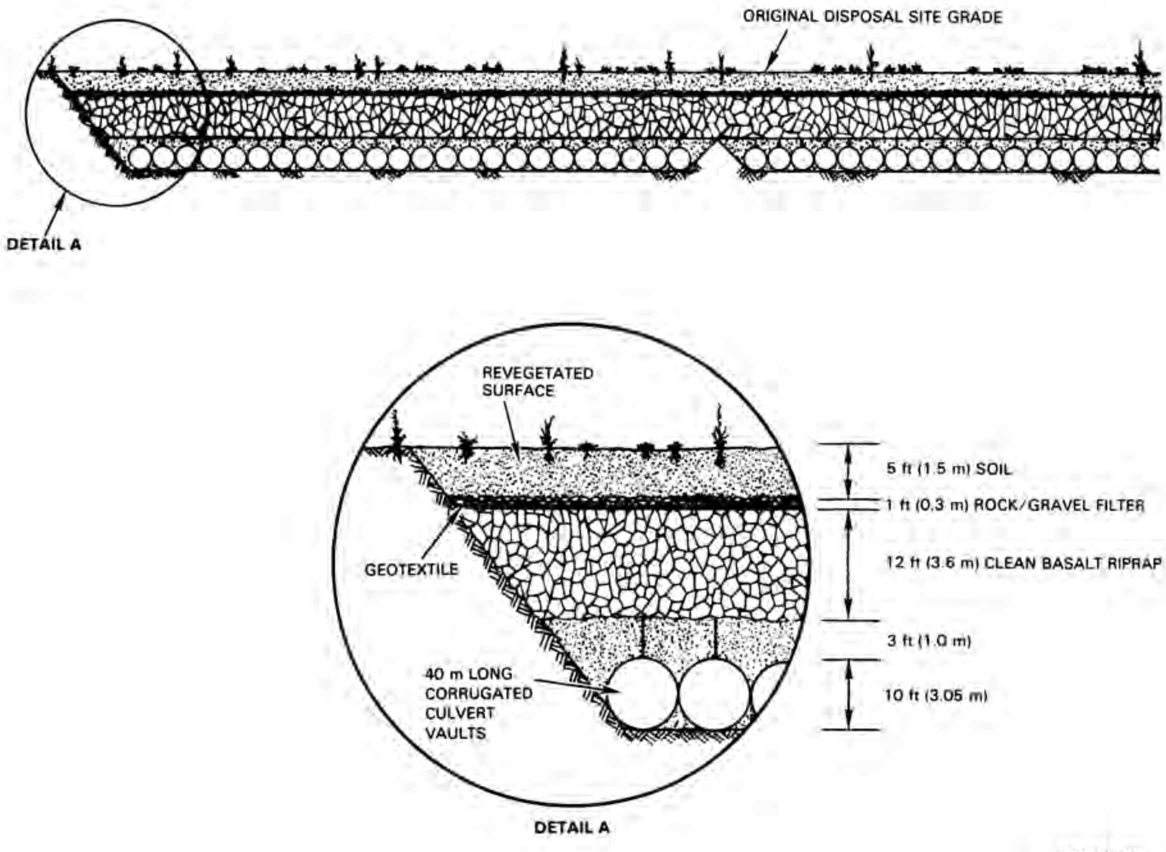

Fig. 5. Completed Grout Disposal Vaults.

assessed using the allowable residual contamination level (ARCL) method and Hanford specific exposure scenarios, pathway-to-man models, and dosimetry models. Data gathered from lysimeter and laboratory testing will also be used in the models. The analyses being performed focus on the potential natural, human-induced, and disposal-induced events that may result in human exposure. Natural events included climatic changes, seismic activity, biotic transport, and wind erosion. Human-induced events include well drilling, excavation, and irrigation over a buried grout monolith. Disposal-induced events include structural failure of the monolith from thermal or pressure excursions.

Preliminary results show that bulk grouted decontamination and fuel storage basin filter solution, and cladding removal waste can be expected to perform adequately over the long term. Penetration of the waste zone by plants and burrowing animals would be essentially precluded by the soil and rock cover over the grout. Well drillers or excavating personnel would receive small radiation doses. Small doses would also occur to inhabitants living in the immediate vicinity of the waste material brought to the surface. Groundwater contamination would result in doses that are 30 million times lower than the average annual dose due to exposure to naturally occurring radiation. In no case would acute radiation effects on human health occur. Over the long term, no fatal cancers would be expected.

GROUT SYSTEM COST

The costs associated with implementing low-level liquid radioactive waste disposal by producing grout are given in Table III.

TABLE III

Grout Disposal System Costs

Equipment	Cost
Dry Materials Receiving and Handling Facility	$ 3.8 Million
Transportable Grout Equipment	$ 4.0 Million
Near-Surface Disposal Site	$ 3.4 Million
Miscellaneous Capital Expenditures (in-tank mixer, blended dry solids delivery trucks, etc.)	$ 1.0 Million
Expense Funded	$15.0 Million
TOTAL	$27.2 Million

The expense costs include engineering, formulation development, performance assessment, analytical capability development, and construction of the first disposal trench.

CONCLUSIONS

The immobilization by grouting of selected low-level wastes at the Hanford Site is a cost effective and environmentally sound alternative to present waste storage operations. In 1986, the U.S. Department of Energy will have state-of-the-art facilities for mixing low-level liquid radioactive waste with cementitious materials to form a grout. The hardened grout will isolate the radionuclides from the environment until natural decay can reduce their activity to acceptable levels.

REFERENCES

1. "Hanford Waste Management Plan", U.S. Department of Energy-Richland Operations Office (December 1984).

2. American Nuclear Society, proposed standard ANS-16.1, "Measurement of the Leachability of Solidified Low-Level Radioactive Wastes," (June 20, 1984).