GROUT DISPOSAL SYSTEM FOR HANFORD SITE MIXED WASTE

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ABSTRACT

The Grout Treatment Facility has been constructed at Hanford for processing liquid radioactive and hazardous tank wastes into a cement-based solid for disposal in near-surface concrete vaults. A unique disposal system design has been developed to satisfy hazardous waste regulations and U.S. Department of Energy long-term performance criteria. This design will be used in the construction of 43 vaults for the disposal of 227,000 cubic meters of grouted mixed waste.

INTRODUCTION

The Grout Treatment Facility (GTF) completed processing and disposal of an initial 3,800 cubic meters of radioactive waste from Hanford's double-shell tanks on July 11, 1989. For the first time in the Hanford Site's 46-year history, tank wastes were moved out of liquid storage and converted into a solid for environmentally safe disposal. This first campaign, which started on August 30, 1988, marked the beginning of a massive cleanup effort described in the "Hanford Defense Waste-Environmental Impact Statement" and represents a key element of the "Hanford Federal Facility and Consent Order" (Tri-Party Agreement) controlling site cleanup signed by the U.S. Environmental Protection Agency (EPA), Washington State Department of Ecology, and the U.S. Department of Energy (DOE) in May 1989 (1,2). In addition to the 3,800 cubic meters of nonhazardous, low-level waste processed in 1988 and 1989, approximately 163,000 cubic meters of mixed waste will be treated for disposal between 1991 and 2013.

This paper presents an overview of the Grout Disposal Program and a detailed discussion of the design of concrete vaults for mixed waste disposal. Waste streams destined for solidification and near-surface disposal will be defined, followed by a brief explanation of the treatment process and the facilities constructed to perform the liquid-to-solid transformation. The bulk of the paper will be devoted to a feature-by-feature discussion of the mixed waste vault design.

WASTE TO BE PROCESSED

Radioactive and hazardous wastes have been generated at the Hanford Site since the mid-1940s as a result of weapons-grade plutonium production. These liquid wastes were originally stored in underground single-shell tanks. Beginning in 1971, 3,800 cubic meter double-shell tanks were constructed to receive waste transferred from the single-shell tanks as well as newly generated waste from ongoing site operations.

Today, 28 double-shell tanks (DST) contain the majority of mixed waste planned for processing through the GTF and disposal in near-surface concrete vaults. The inventory of DST waste will continue to grow during the next several years as the final quantities of liquid are pumped from single-shell tanks, and the military plutonium production mission comes to an end.

Much of the DST waste has been classified as low-level waste and is suitable for solidification and near-surface disposal. However, some of the tank liquids must receive pretreatment to separate the material into high-level and low-level fractions. Beginning in 1999, the high-level waste will be processed into a borosilicate glass for eventual disposal in the Nation's high-level waste repository. The low-level waste will be pumped to the GTF for processing into a cement-based grout for onsite disposal in large underground concrete vaults.

These low-level wastes are radioactive, concentrated salt solutions, classified as "hazardous" by EPA and "dangerous" by the Washington State Department of Ecology. As feed for the grouting process they contain approximately 11 percent sodium nitrate, 6 percent sodium hydroxide, 5 percent sodium nitrite, 3 percent sodium aluminate, 1 percent sodium phosphate, 0.5 percent sodium chloride, and 73 percent water. Many radionuclides are present, although CS-137 contributes more than 99 percent of the 0.3 curies/liter activity. From a long-term performance assessment standpoint, nitrate, Tc-99, and I-129 are the primary contaminants of concern.

GROUTING PROCESS

The GTF includes four components (see Fig. 1): (1) a Dry Materials Facility, (2) a 3,800 cubic meter feed tank, (3) a grout processing plant, and (4) disposal vaults. The $3.8 million Dry Materials Facility receives and blends cementitious materials (blast furnace slag, flyash, limestone, and Portland cement) to be combined with the liquid waste at the grout processing plant. After blending, the dry materials are transported by truck, 22,600 kilograms at a time, to the processing plant.

One of the Hanford Site's 28 DSTs serves as a feed tank for the grouting process. At least 3 months before treatment, 3,800 cubic meters of mixed waste is transferred to the tank. In the feed tank, the waste is sampled to verify that its composition is within the formulation envelope. Samples are also taken to make grout in a site laboratory for processing and regulatory confirmation tests. During a 3,800 cubic meter grout campaign, waste is pumped via an underground

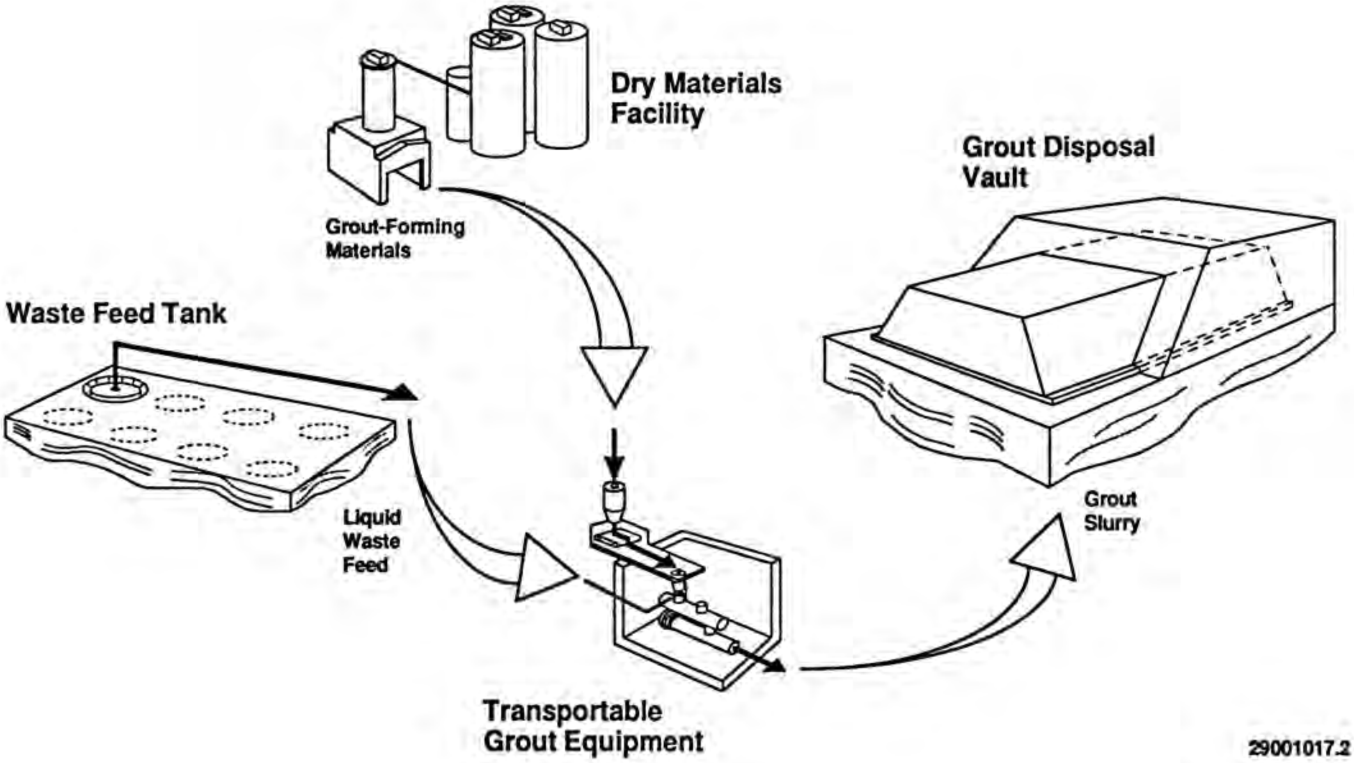

Fig. 1. Grout Treatment Facility.

encased pipeline from the tank to the processing plant at approximately 190 liters/minute.

The grout processing plant, called the Transportable Grout Equipment, mixes the dry materials and liquid waste to produce a grout slurry which is pumped via an underground encased pipeline to the disposal vaults. The major components of the processing plant are the mixer module, dry blend feed system, ventilation system, liquid additives/decontamination module, and control room. This $9 million facility is designed for remote operation and maintenance to minimize exposure to personnel. During a campaign, essentially all operation and monitoring functions are performed from the control room. A programmable logic controller allows a single Nuclear Operator to control and monitor plant production.

A 100,000 square meter site adjacent to the processing plant will accommodate the planned 43 mixed waste disposal vaults and the single existing nonhazardous vault. The existing vault was filled with phosphate/sulfate waste as a full-scale demonstration run in 1988 and 1989. This reinforced concrete vault is approximately 38 meters long, 15 meters wide, and 10 meters high.

A double-liner/leachate collection system was installed in the vault to demonstrate compliance capability with state and federal hazardous and dangerous waste regulations. Before operation, a concrete roof was placed over the vault, and the structure was backfilled for radiation shielding purposes. Processing the 3,800 cubic meters of phosphate/sulfate waste resulted in a vault filled with 5,300 cubic meters of solidified waste.

Lessons learned in design, construction, and operation of the first vault were considered during the subsequent mixed-waste vault design. Also impacting the new design were elevated temperatures (90 degrees centigrade) expected from hydration of the mixed waste formulation and performance assessment requirements for a diffusion controlled disposal system. A detailed description of the mixed waste vault design is presented below.

DISPOSAL SYSTEM DESIGN

The disposal system is comprised of four major elements (see Fig. 2):

(1) the solidified waste, (2) the vault and catch basin which serve as a double-liner/leachate collection system, (3) an asphalt-coated gravel diffusion barrier to control

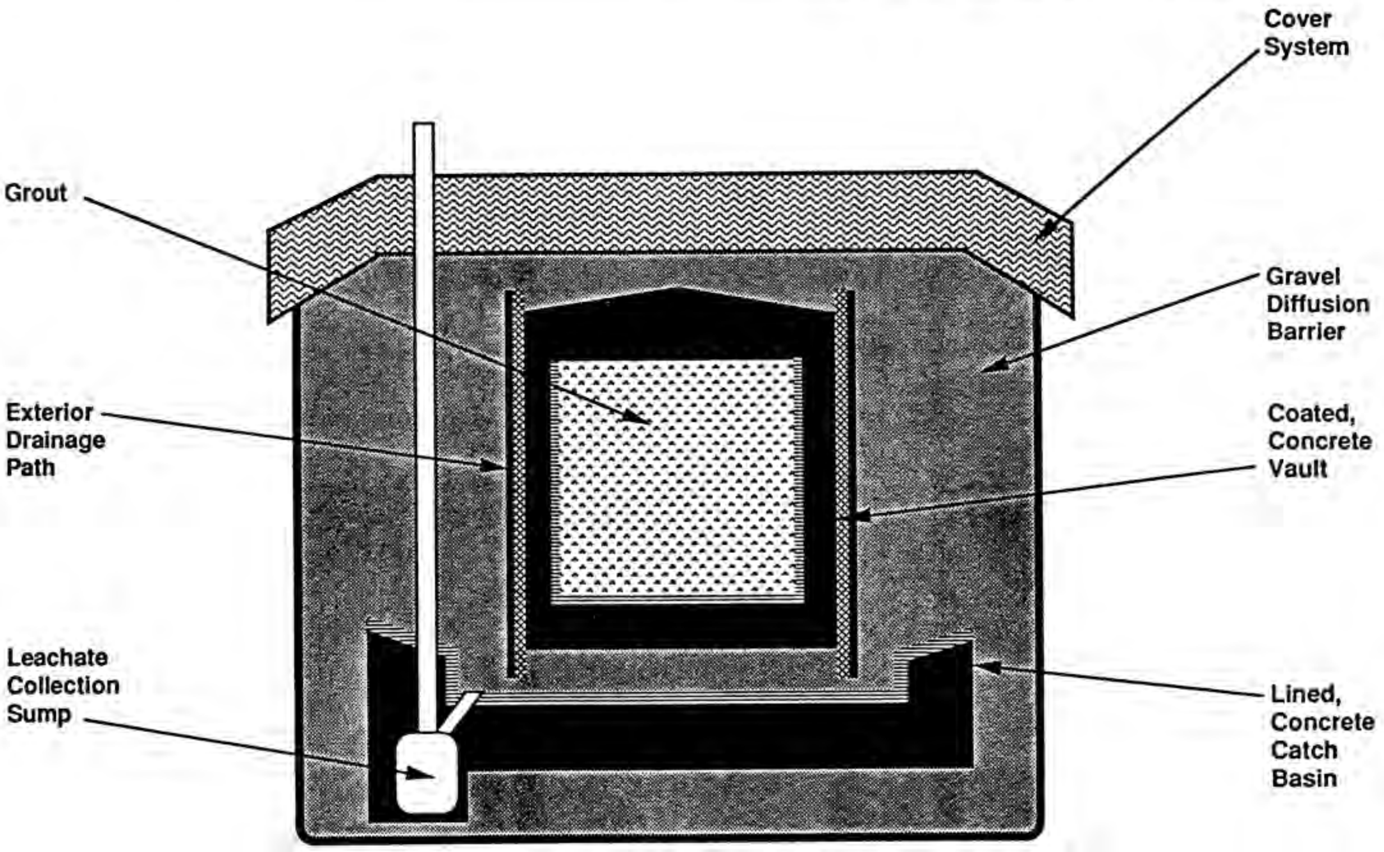

Fig. 2. DST Waste Disposal System.

contaminant release during thousands of years, and (4) a multilayered cover system to prevent water from reaching the grouted waste. Each vault, with its auxiliary components, is designed to satisfy Resource Conservation and Recovery Act (RCRA) Minimum Technology Guidance (MTG) for hazardous waste landfills and the DOE objective to protect the public and environment from release of radioactive and hazardous constituents for a minimum of 1,000 years.

The disposal system design is somewhat different than suggested by the MTG due to more stringent DOE long-term performance criteria and the unique nature of the grouted waste: a liquid during placement and a solid after curing. Thus, each vault will be opened as a surface impoundment receiving liquid waste, but will be closed as a landfill containing a solid waste. The MTG containment criteria for surface impoundments will be satisfied by a primary composite liner, a secondary composite liner, and a leachate detection, collection, and removal system. The DOE performance criteria will be met using the above, a solidified waste form, an asphalt-coated gravel diffusion barrier surrounding the waste, and a multilayered cover system.

At the center of the disposal system is the solid, grouted waste. The formulation for treating DST waste requires the addition of approximately 1.1 kilograms of dry material to each liter of liquid waste feed. The dry material "recipe" is 40 percent limestone, 28 percent blast furnace slag, 28 percent flyash, and 4 percent Portland cement. Laboratory-scale and pilot-scale tests on an earlier variation of this formulation resulted in compressive strengths of 14 to 140 kilograms/square centimeter, Extraction Procedure Toxicity well below regulatory limits, and ANS 16.1 leach indices of 9 for Cs-137 and 14 for Sr-90. After placement and solidification of the grouted waste, any remaining fluids are pumped from the disposal vault and returned to the DST tank system. The void space left in the vault is completely filled with a nonshrink Portland cement grout.

The concrete vault shell, the next environmental protection component in the system design, surrounds the grout. Interior vault shell dimensions are 37.6 meters long, 15.4 meters wide, and 10.4 meters high. The structure is constructed of 4,500 pounds/square inch reinforced concrete and designed to meet the requirements of the American Concrete Institute (ACI) 301, 318, 349, 350R and DOE Order 6430.1A, "General Design Criteria."(3) Various loads were considered, including thermal loading from 90 degrees centigrade grout, and a Safe Shutdown Earthquake with a maximum free-field horizontal ground acceleration of 0.25 g. Structural design verification was done using a nonlinear, inelastic analysis which included the effects of the concrete cracking and the redistribution of moments and shears.

Long walls of the vault shell are tapered from 1.4 meters thick at the base to 0.6 meter thick at the top. These walls are reinforced on both faces with vertical No. 11 steel bars at 0.1 meter centers and with horizontal No. 10 bars at 0.1 meter centers. The end walls are 0.8 meter thick and reinforced with vertical and horizontal No. 10 bars at 0.1 meter centers on each face. The foundation slab is 1.4 meters thick and reinforced with No. 10 and No. 11 bars at the top and bottom edges, and No. 7 and No. 9 bars in the center. Shear steel is also in the foundation slab where required. The roof planks are 0.7 meters thick, 1.2 meters wide, precast, prestressed solid concrete panels spanning between the long walls of the vault shell. A concrete topping is poured over the planks.

The vault shell and roof panels serve two major functions: (1) a contain-ment vessel while the grout is in a liquid state and (2) a support for shielding backfill. Before operation, the structure is backfilled on all sides, including a minimum of 1.2 meters of shielding material on top of the vault roof. To ensure containment of the grout slurry, interior surfaces of the vault shell are coated with a 0.13 to 0.2 centimeter thickness of elastomeric-asphalt urethane. The composite asphalt/concrete liner system is hydrostatically tested to prove its water tightness. The following tests were performed to confirm adequacy of the vault shell/asphalt composite liner design: Asphalt coating waste compatibility

- Asphalt coating waste compatibility
- Asphalt coating water vapor transmission
- Asphalt coating bond stability
- Asphalt coating crack spanning.

Exterior to the four vault shell walls is a drainage path which will provide positive movement of unlikely leakage from the vault shell to the leachate collection system for the few months free liquids are present in the vault. This drainage path consists of a 60 mil High Density Polyethylene (HDPE) Flexible Membrane Liner (FML) and a drainage net. All liquids entering this system are drained to the catch basin discussed below.

Below the vault shell is a HDPE-lined, reinforced concrete structure referred to as a catch basin. The basin extends 0.23 meter beyond the vault shell walls constructed above it. As the name implies, its function is to collect any leachate from the upper liner or coated concrete vault shell. This composite liner consists of a cast-in-place basin 40 meters long and 19 meters wide with walls 1.1 meters high. The basin floor is 0.6 meter thick and reinforced with No. 7 steel bars at 0.2 meter centers, top and bottom, both ways. The catch basin floor slopes at 2 percent towards a trench in the center which will direct liquid flow to a leachate collection sump. The catch basin is fully lined with a 60 mil FML installed to rigorous quality assurance requirements. A layer of pea gravel is placed between the composite secondary liner and the vault shell to ensure that any leachate is quickly transmitted to the catch basin where it can be detected, collected, and removed.

The 60 mil catch basin liner was selected after conducting compatibility tests with simulated waste using EPA's Method 9090 on various available liner materials. The testing was done at 90 degrees centigrade, which is the maximum temperature expected at the vault concrete during operation. Also taken into account was the radiation dose that is expected during the facility life. The HDPE was found to be resistant to the simulated leachate and the radiation exposure at 90 degrees centigrade. During construction of the catch basin liner, destructive and nondestructive testing of liner welds is performed to verify acceptable installation.

As mentioned above, a layer of gravel serving as part of the leachate collection system is placed over the lower composite liner. A 4-inch perforated steel pipe lies on the sloped bottom of the catch basin. Leachate entering this pipe is carried to a 4-inch HDPE pipe buried within the concrete catch basin. The HDPE pipe conveys the leachate to a collection sump. This sump is formed by a carbon steel sump liner embedded in 0.6 meter of concrete. Leachate is removed from the sump through a steel standpipe with a leachate pump, and transferred back to the 3,800 cubic meter feed tank. An impressed-current cathodic protection system is installed on the leachate sump and standpipe.

The following tests were performed to confirm adequacy of composite catch basin/HDPE liner construction materials:

- HDPE liner 9090 compatibility
- HDPE liner creep
- HDPE liner compression/tensile
- Drainage gravel compatibility
- Drainage gravel compression
- Liner seam compatibility
- Liner seam bond strength
- Liner seam peel adhesion.

Release from low-level waste disposal sites are traditionally assumed to occur from leaching of the waste as precipitation enters the soil, "flows" past the emplaced waste, and then carries contaminants to the groundwater. Originally, it was planned to place the Hanford Site grout mixture in concrete vaults in contact with the soil. This arrangement would have left the grouted waste vulnerable to leaching once the vault shell lost its structural integrity after several hundred years. Early estimates of the long-term impacts to the groundwater resulting from grout disposal of DST waste indicated additional retardation of contaminant release was required. As a result, a diffusion/hydraulic barrier completely surrounding each vault is incorporated into the disposal system design.

The diffusion/hydraulic barrier (commonly called a cocoon) consists of asphalt-coated gravel. In addition, solid asphalt pavement material is under consideration to serve as a vapor barrier. The thickness of the barrier is a minimum of approximately 1 meter. The gravel is crushed river rock. The addition of the asphalt coating to the gravel creates a hydrophobic surface that greatly reduces the effective diffusivity by preventing the formation of continuous water films on the rock particles. Laboratory measurements of diffusivity, using a unique electrical conductivity method, consistently produced results below the detection limit of 2.5 E-11 centimeters squared/second.

To address the impact on the effective diffusivity of the cocoon resulting from the introduction of uncoated gravel and fines during the construction process, a series of diffusion measurements were made on mixtures of various levels of uncoated gravel and fines in coated gravel. The results showed coated gravel containing 10 weight percent or less uncoated gravel, 3 weight percent uncoated sand, or up to 1 weight percent uncoated fines maintained the diffusion coefficient at detection limits. The likelihood of cold flow over long periods of time was also discounted by subjecting asphalt-coated gravel samples to 10,000 g centrifugal acceleration for 12 hours at 90 degrees Centigrade without any significant flow of asphalt from the gravel particles. An experimental investigation of the potential for migration of sand and fine particles into the gravel cocoon resulting from seismic activity was performed in the Soil Dynamics and Earthquake Engineering Laboratory at the University of Washington. The experiments performed in the study subjected large-scale models of the gravel diffusion barrier and native backfill sands to levels of simulated earthquake activity far in excess of that which could reasonably be expected at the GTF site. Migration into the cocoon gravel was observed to be quite small and well within design limits.

Above the vault, the cocoon gravel is sloped to ensure that advecting water is diverted along the fine soil instead of entering the diffusion/hydraulic barrier. The difference in hydraulic conductivity at the expected moisture content will keep water from advecting into the barrier. By preventing water from contacting the vault and grout, the diffusion of contaminants across the barrier will be very slow, providing the required reduction in contaminant migration.

The fourth and final major element of the disposal system is the multi-layered cover system. Moving from the center of the system outward, the cover system includes a RCRA closure cover, including a sand wicking layer and the Hanford Site protective barrier. Working together, these components inhibit precipitation, plants, animals, and man from coming in contact with the solidified waste. After construction of the cover system, the distance from the ground surface to the treated waste is a minimum of 5 meters.

The first component of the cover system to be constructed above the 10-percent sloped gravel cocoon is a 0.3 meter thick layer of filter sand which prevents migration of particles from the soil-bentonite layer above to the gravel diffusion barrier below. A 0.6 meter thick layer of soil-bentonite mix with a minimum hydraulic conductivity of 1.0 E-7 centimeters/second is placed on the filter sand to impede the downward movement of precipitation. A 60-mil geomembrane is laid over the soil-bentonite layer to act as a barrier to water infiltration. A 0.3 meter thick, sloped, sandy soil drainage layer is subsequently placed to effectively transport infiltration to the edges of the cover where it is transferred to the soil and around the vault. In the near-term, 0 to 30 years, a minimum 1.1 meters thickness of top soil is placed as the final layer of the RCRA closure cover. This top soil supports planted grasses, prevents roots from reaching the low permeability layer, and prevents freeze-thaw damage of the lower layers.

The grout vaults eventually will be covered with a protective barrier and marker system that is currently under development. The barrier will reduce the likelihood of wind erosion; water infiltration; and plant, animal, and human intrusion. Conceptually, this barrier will include layers of riprap, filter sands, sandy loam topsoil, and vegetation. Vegetation on the topsoil will inhibit wind erosion and recycle water to the atmosphere. The riprap will reduce the potential for plant roots and animals to penetrate the barrier. Soils above the riprap will store water for use by vegetation, and the capillary suction of these soils will prevent water from entering the riprap. A marker system consisting of rock monoliths and ceramic discs with inscribed warnings will be designed to deter human intrusion into the disposal site.

SUMMARY

The Nation's first large-scale disposal of defense tank waste in an engineered structure has been demonstrated at the Grout Treatment Facility. While the initial 3,800 cubic meter campaign processed a relatively low-activity, nonhazardous waste, 43 future campaigns are planned for the treatment and disposal of higher activity, mixed waste from the Hanford Site's double-shell tanks. The grouting process combines cementitious materials with liquid waste to form grout slurry which is pumped to large, underground, concrete vaults for solidification and final disposal.

Design of the mixed waste disposal system incorporates lessons learned from the first grout campaign, the need to handle higher wasteform temperatures, hazardous waste regulations, and DOE long-term performance criteria. The disposal system design includes the solidified waste, two composite liners, leachate collection system, diffusion barrier, and multilayered cover system.

The Grout Treatment Facility disposal system design is a unique concept for meeting both hazardous and low-level waste disposal criteria.

REFERENCES

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