LOW-LEVEL WASTE DISPOSAL - GROUT ISSUE AND ALTERNATIVE WASTE FORM TECHNOLOGY

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ABSTRACT

Based on the Record of Decision (1) for the Hanford Defense Waste Environmental Impact Statement (HDW-EIS) (2), the U.S. Department of Energy (DOE) is planning to dispose of the low-level fraction of double-shell tank (DST) waste by solidifying the liquid waste as a cement-based grout placed in near-surface, reinforced, lined concrete vaults at the Hanford Site.

In 1989, the Hanford Grout Disposal Program (HGDP) completed a full-scale demonstration campaign by successfully grouting 3,800 cubic meters (1 million gallons) of low radioactivity, nonhazardous, phosphate/sulfate waste (PSW), mainly decontamination solution from N Reactor.

The HGDP is now preparing for restart of the facility to grout a higher level activity, mixed waste double-shell slurry feed (DSSF). This greater radionuclide and hazardous waste content has resulted in a number of issues confronting the disposal system and the program.

This paper will present a brief summary of the Grout Treatment Facility's components and features and will provide a status of the HGDP, concentrating on the major issues and challenges resulting from the higher radionuclide and hazardous content of the waste. The following major issues will be discussed:

- Formulation (cementitious mix) development;
- The Performance Assessment (PA) (3) to show compliance of the disposal system to long-term environmental protection objectives;
- The impacts of grouting on waste volume projections and tank space needs.

While some issues, especially the PA, have delayed the next grout campaign from the original schedule, important schedule drivers, including the benefit grout provides for tank space requirements, emphasize the need to move ahead. The current Hanford Waste Tank Volume Projections and the impact of a delay in the Grout Program schedule on tank space needs will be examined.

Plans to increase the waste form robustness for future low-level waste disposal will also be addressed. The activities summarized in this paper form part of the Tank Waste Remediation System (TWRS) decision bases.

DISCUSSION

Grout Systems Background

Disposal of Hanford Site low-level tank waste using grout is accomplished in the Grout Treatment Facility by mixing a blend of cementitious products (typically Portland cement, fly ash, attapulgite clay, and blast furnace slag) with liquid DST waste. The resulting grout slurry is pumped to large underground concrete vaults to cure. The DST wastes are disposed of in batch sizes (campaigns) of about 3,800 cubic meters (1 million gallons). The total grout volume when dry solids are mixed with 3,800 cubic meters of liquid waste is about 5,300 cubic meters (1.4 million gallons). Each vault is designed to contain the 5,300-cubic meter volume required to complete a campaign.

Four main subsystems comprise the Grout Treatment Facility: the Dry Material Facility, the Grout Processing Facility, the Grout Disposal Facility, and the Feed Transfer System, which is composed of two designated (grout liquid waste) feed tanks in tank farms and the underground encased transfer line to the Grout Processing Facility (refer to Fig. 1).

The Dry Material Facility, which is centrally located in the 200 East Area of the Hanford Site, receives dry cementitious materials by truck or rail car for storage and subsequent blending. The blend proportions are established as a specific grout formulation for a specific waste feed. After testing for proper proportions, the dry material blend is trucked to the Grout Processing Facility and loaded into a storage day bin.

The Grout Processing Facility, which is the heart of the Grout Treatment Facility, includes the control room for the remote processing operation and the belowgrade, isolated, covered mixer module. Waste feed from one of the two feed tanks is transferred to the mixer module via an underground encased line. In the mixer module, the waste is mixed with dry material blend to form a grout slurry. The slurry is pumped

Fig. 1. Grout treatment facility.

through underground encased lines to the Grout Disposal Facility vault(s), where the slurry cures to form a solidified grout mass.

The Grout Disposal Facility is composed of large underground near-surface, reinforced, lined concrete vaults with an approximate volume of 6,000 cubic meters (refer to Fig. 2). The inside dimensions of the concrete vault are approximately 37.6 meters (123 feet) long, 15.4 meters (50 feet) wide, and 10.4 meters (34 feet) high. The Grout Disposal Facility includes associated grout slurry transfer lines; excess water return lines; a lined leachate collection basin; a leachate collection sump; a portable instrument house for sensing grout temperature, grout level, and sound transmission properties; and a vault exhauster for maintaining negative vault pressure and for cooling grout during vault fill and cure operations. An approximate 1-meter (40-inch)-minimum thick asphalt barrier surrounds and seals each vault and limits ionic diffusion out of the vault and vapor diffusion returning to the vault.

Issues Background

The HDW-EIS decision to directly grout the double-shell slurry (DSS) and DSSF has resulted in a number of issues confronting the Grout Program. DSS/DSSF is non-high level waste (HLW), but, nonetheless, a waste with a fairly high level of radionuclide inventory (equivalent to 10 *Code of Federal Regulations* [CFR] 61 Class C or less concentrations) (4). See Fig. 3 comparing the waste for the first DSSF grout campaign to 10 CFR 61 limits.

The Nuclear Regulatory Commission (NRC), in reviewing the HDW-EIS in 1988, considered that the DSS/DSSF planned for grouting without further pretreatment may meet the definition of HLW and be subject to NRC licensing. After a series of meetings between the NRC and DOE in 1988 and 1989, the NRC determined the DST waste was non-HLW, or incidental waste. A subsequent petition to the NRC by the States of Washington and Oregon questioned this decision. This petition has not yet been responded to by the NRC. This unanswered and unresolved petition to the NRC and the associated high-activity level of radionuclides in the DSS/DSSF constitute major stumbling blocks for proceeding with grout. A petition to the NRC by the Yakima Indian Nation on the definition of disposed wastes at the Hanford Site raises similar concerns.

Nearly 99 percent of the activity in DSS/DSSF is due to ^{137}Cs, a relativity short half-life and relatively immobile isotope. The Grout Treatment Facility Safety Analysis Report (in the approval stage) documents satisfactory occupational doses, emissions, and accident analysis doses for grout operations (refer to Figs. 4 and 5). The Grout PA documents satisfactory 500-year intruder doses with effectively no environmental impact from ^{137}Cs. After 500 years, little ^{137}Cs concentration has migrated from the grout waste form into the concrete vault (refer to Fig. 6). The environmental risk from grouting is due to more mobile radionuclides with long half-lives (e.g., ^{99}Tc and ^{129}I); however, in perspective, the risks are not large risks to future populations. The PA evaluates the disposal system against performance objectives (25 mR/yr effective dose equivalent [EDE]) - all pathways and 4 mR/yr EDE - drinking water) (5). Any radionuclide reaching the river (and potentially reaching large populations) is not an issue because nuclide concentrations are orders of magnitude

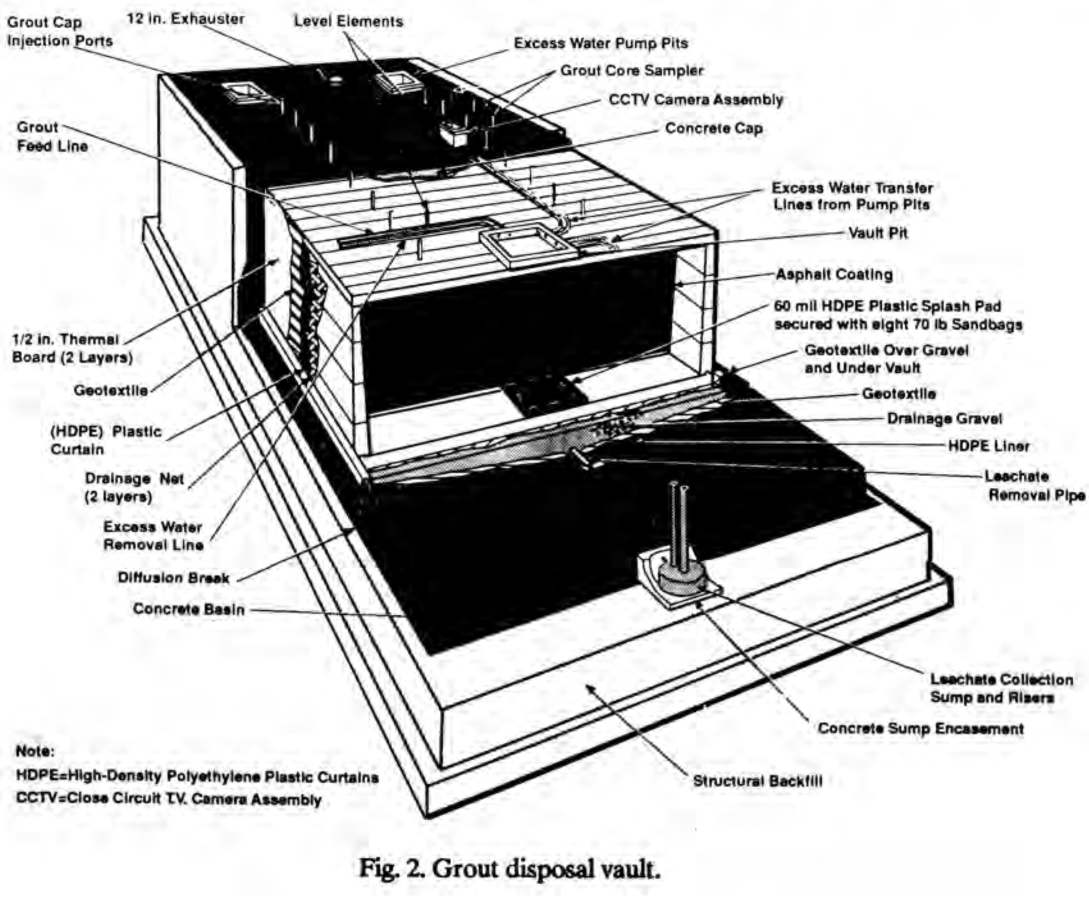

Fig. 2. Grout disposal vault.

Comparison of Radionuclide Concentration
Tank 241-AN-106 to 10 CFR §61.55.

Nuclide	Concentration (Ci/m^3 grout)*	Waste Class Limits (Tables 1 and 2)			Overall Waste Class
		A	B	C	
H-3	1.9 E-03	40	--	--	C
C-14	2.3 E-04	0.8	--	8	
Co-60	3.6 E-02	700	--	--	
Sr-90	1.4 E+00	0.04	150	7000	
Tc-99	4.8 E-02	0.3	--	3	
I-129	< 5.2 E-05	0.008	--	0.08	
Cs-137	129.4	1	44	4600	
TRU (nCi/g)	2.3	10	--	100	

*Grouted concentrations are 1/1.43 times waste concentration. TRU value not corrected for grouting. Concentrations are mean concentrations decayed to October 31, 1993.

Fig. 3. Comparison of radionuclide concentration.

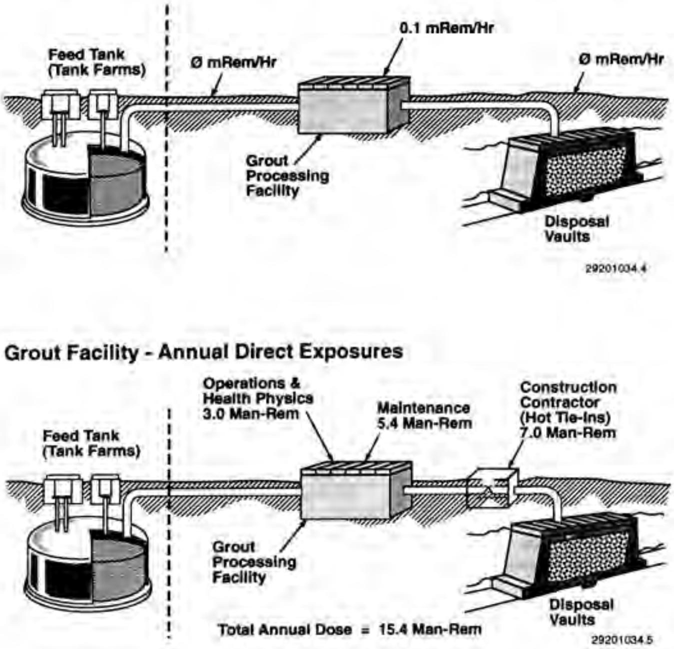

Fig. 4. Doses during normal grouting operations.

Final Safety Analysis Report

Effective Dose Equivalent Consequences for a Release from a Gasket Failure in a Jumper Pit (maximum consequence accident identified).

Location	Inhalation (Rem)	Annual Probability	WHC Limit (Rem) Probability Range of 10^{-4} to 10^{-6}
Onsite (100m)	3.4	10^{-4} - 10^{-6}	10 - 25
Offsite (15.9km)	7.8×10^{-3}	10^{-4} - 10^{-6}	4 - 25

Offsite Fifty Year Dose Consequences From One Year GTF Operation From Emissions.

Offsite Receptor	Effective Dose Equivalent (Rem)	WHC Guidelines (Rem/Yr)	DOE Limits[1] (Rem/yr)
Maximally exposed offsite individual	4.7×10^{-7}	.01	.01
Integrated population (16 sectors)	1.1×10^{-1} (person-rem)	N/A	N/A

[1] Most restrictive limits
(EPA 40 CFR 61, Subpart H = 25 mRem/yr)
(DOE 5400.5 = 10 mRem/yr)

Fig. 5. Final safety analysis report.

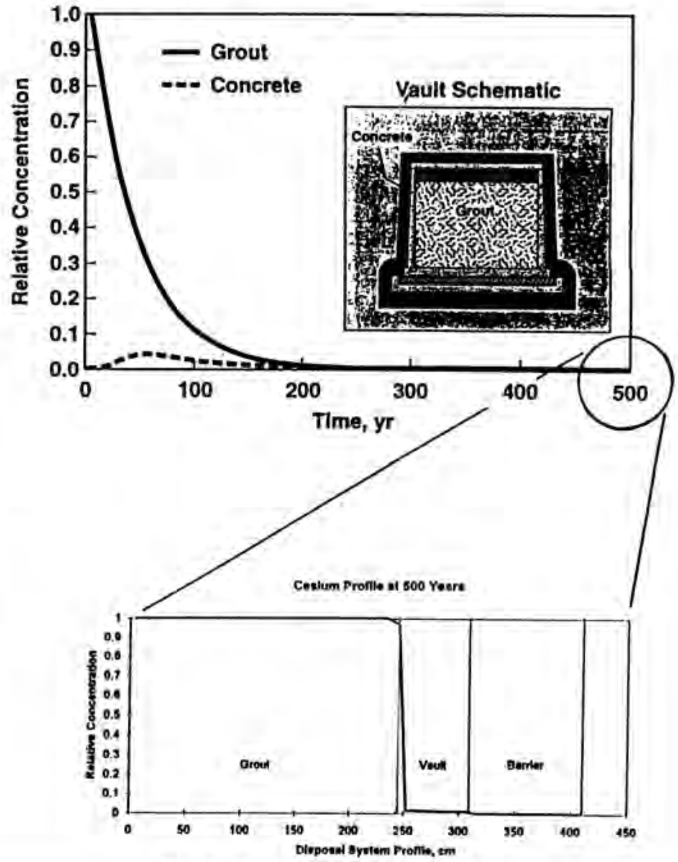

Fig. 6. Cs-137 in grout/concrete.

below limits. Dose limits are reached in only those scenarios in which a well is drilled on the Hanford Site which conservatively captures the migrated nuclides in groundwater. These cases involve few individuals (approximately 25 in any generation). The engineered disposal system contains the wastes such that no activity reaches the groundwater for thousands of years and peak groundwater concentrations are not reached for thousands of years thereafter. Moreover, by providing tank space, grout offsets increased risk to the environment from incremental tank leakage (radionuclides are more mobile in the soil column than in an engineered disposal system) and potential tank safety issues (risk associated with unmitigated tank safety issues versus risks associated with grouting).

However, a number of major issues stem from the radionuclide level in the waste, including the impact on grout formulation. The concern is whether the grout will *fail to set* up due to synergistic (e.g., radioactivity, organic) effects and whether retrieval of a large solidified mass of the slurry would be required. Another major issue associated with the Grout PA, which examines long-term performance objectives of the grout disposal system, is associated with the long-lived mobile species, ^{99}Tc and ^{129}I, and the projection of their peak dose out in the 7-100 thousand year time frame, depending on the rate and extent of degradation of the engineered system. Taking essentially no credit for the engineered system results in peak doses in 7,000 years. More realistic projections result in peak doses beyond 10,000 years. Activities addressing these major issues to safely and acceptably use grout for moving ahead with waste disposal include the intensive efforts going on to produce and test a successful grout formulation and the significant rewrite and documentation effort on the Grout Facilities PA.

Major drivers that favor proceeding with grout as presently planned include the considerable benefit of visibly proceeding with a major disposal action, progressing on the required "Hanford Federal Facility Agreement and Consent Order" (Tri-Party Agreement) (6) disposal objectives, and freeing much needed tank space.

The HDW-EIS, as well as the agreement with the NRC, detailed the considerable impact on schedule, cost, and additional waste produced to delay grouting to pretreat the DSS/DSSF waste. A number of years (5 to 7 estimated) is required to implement a pretreatment process to remove the ^{137}Cs from DSS/DSSF waste. During this period, mitigation of tank leakage and tank safety issues would be impacted due to tank space shortage. Grout is projected to relieve tank space shortage and is more environmentally sound than continued storage of liquid tank waste with the potential tank leakage to the soil column. Also, it should be recognized that while this pretreatment would reduce the initial radionuclide level in grout, this reduction would not solve the longer term PA dose issue which results from the more mobile, long half-life isotopes (e.g., ^{99}Tc and ^{129}I).

The strategy of TWRS is to proceed with grouting the first few DSSF tanks while simultaneously expediting the earliest introduction of pretreatment of DSSF intended for grout and accelerating the development of a more robust waste form with greater leach resistance. This strategy addresses the various issues, including the NRC petition and the concern associated with the level of radionuclides, while at the same time recognizing the need for tank space and that the impact of doing nothing is of greater potential impact that the impact of grouting.

DETAILED DISCUSSION OF MAJOR ACTIVITIES

The following items will be presented in greater detail:

- Grout formulation effort;
- Grout PA revision;
- Waste tank volume projection;
- Accelerated alternate waste form development.

GROUT FORMULATION

The HGDP has performed extensive formulation work to ensure that an acceptable grout will be produced as well as to prevent difficulties encountered by other grouting programs. The HGDP employs several Hanford Site and national laboratories in this effort. Laboratory-to-laboratory comparisons are made to confirm grout quality and to identify issues.

Grout formulation development and verification begin at the point where the wastes in the tank to be grouted are sufficiently characterized to develop a simulated waste for laboratory testing. A formulation of dry materials is then tailored for that waste such that the resulting grout product will meet defined performance criteria. The grout formulation is then verified in laboratory and pilot-scale tests as needed. A final confirmation of the formulation is made with actual wastes before production is authorized. During production, nondestructive techniques will be used to verify the grout quality. The details of this formulation development and verification are described below.

Laboratory Studies

Laboratory studies begin by the sampling and characterizing of candidate waste feed tanks. The candidate tank is sampled according to a statistically designed test plan. Simulants are prepared based on analytical results. The simulant contains virtually all of the inorganic and organic constituents of the waste, but no radionuclides. For example, the simulant used during laboratory and pilot-plant testing of the grout formulation for the next grout campaign was made up of all inorganic ions present above detection limits except regulated heavy metals. The heavy metals were excluded to avoid generating regulated waste. The organics included in the simulant comprise over 99.7 percent of the organics in the waste.

A statistically designed matrix of formulations is tested using potential dry materials, including cement, flyash, slag, and clays. The most promising formulation candidates are then subjected to an extensive battery of tests, including product properties (leachability, compressive strength, thermal conductivity, toxicity, hazard class, and free-standing liquid), processibility (frictional pressure drop, 10-minute gel strength, critical flow rate), and other parameters (heat of hydration/temperature rise).

The outcome of this testing is the selection of an acceptable "reference" formulation. This reference formulation then undergoes further laboratory testing to verify that the formulation can accommodate waste and dry material variability.

Leach testing of simulated waste grouts spiked with specific organic or radioactive species may be conducted to determine the leaching behavior of potential "problem" constituents. Laboratory samples are tested that include the regulated heavy metals, to ensure there is no adverse effect.

Pilot Plant Testing

Pilot plant testing is conducted on new formulations. Three major pilot plant tests have been conducted to date. In the latest, more than 11,000 liters of simulated waste were processed through the approximately 1/4 scale equipment (see Bagaasen and Powell (7) in this proceedings). Dry materials are blended in the Dry Materials Facility (the same facility used during full-scale campaign runs). Simulated waste is used. The pilot-scale testing provides process data on the grout slurry and the opportunity to monitor the behavior of a larger scale grout pour. The rate and extent of heat generation and dissipation in the receiver vessel are monitored and property data are obtained for the cured grout.

Radioactive Verification Testing

Actual samples of waste from candidate tanks are mixed with a reference dry blend in the hot cell. Compressive strength, leach, toxic characteristic leach procedure (TCLP), drainable liquid, and rheological tests are conducted to ensure that the grout will solidify and meet criteria.

Waste samples are taken from the grout feed tank for characterization prior to grouting. Composites of these samples are mixed with the reference dry material formulation. Compressive strength, leach, drainable liquid, and rheological tests are conducted to ensure that the grout will solidify and meet performance criteria. The compressive strength, leach, and TCLP data are required to be submitted to Washington State Department of Ecology prior to operation.

A hot "pilot" test using a container placed in a vault may be included in the HGDP to address any remaining uncertainty with planned grouting of the higher curie mixed waste.

It is considered that the HGDP's testing is adequate to ensure acceptable grout. A cold pilot-scale run is adequate for determining potential processing problems because the radionuclides are very minor constituents of the waste (on a concentration basis). Expected organic species are included in the laboratory and pilot-scale testing to ensure that their impacts are included in the evaluation and selection process. The hot waste samples grouted in the lab hot cells verify that the hot waste can be successfully solidified.

Full-Scale Processing

After the above steps are satisfactorily completed, the waste is acceptable for grouting.

This process was used when the facility was started up in 1988 for the successful grouting of 3,800 cubic meters (1 million gallons) of PSW. Several tests have been conducted to ensure that results are consistent with prior laboratory and pilot-scale work.

In production, two nondestructive data collection methods can be used to ensure that the grout is solidified: temperature monitoring and ultrasonic testing. Four thermocouple trees are located inside the vault. The thermocouples are positioned at 0.6-meter (2-foot) vertical intervals. The grout slurry begins hydration immediately upon mixing, and a temperature rise will be noticeable within hours. Temperatures can be monitored to provide assurance that hydration is proceeding. Ultrasonic pulse velocity testing to detect solidification has proven successful in laboratory, pilot plant, and full-scale tests. These monitoring techniques can provide assurance that hydration reactions are proceeding and solidification has been achieved.

Final verification of the actual grout product can be achieved through core drilling and nondestructive testing of the grout within the vaults. Core drill samples of the PSW grout produced in 1988-1989 were taken in 1992 and are being characterized. The PSW grout is meeting the performance criteria established for those wastes. It is also planned to core drill the next vault to be filled as a final verification of that grout product.

PERFORMANCE ASSESSMENT

DOE Order 5820.2A, "Radioactive Waste Management," (5) requires the DOE field sites to prepare and maintain a site-specific radiological PA for any low-level waste (LLW) disposal facility on DOE field sites. The PA must provide reasonable assurance that the facility design and method of disposal will comply with performance objectives of the Order and the long-term radiological impacts on the environment and public due to the disposal action have been assessed. The Order also requires compliance with Federal, State, and local groundwater protection requirements, but does not speak to time of compliance for either radiological or hazardous waste.

A PA prepared for the HGDP was submitted to the DOE-Headquarters Peer Review Panel (PRP) for review and approval. The results of that PA indicated that the grout disposal system, functioning as designed, will achieve the defined performance goals for 10,000 years. The PRP returned the PA for revision, requesting dose analyses to time of maximum impact ($>$ 100,000 years), *additional* analyses of degradation of the engineered system, sensitivity analyses of exposure scenarios, analysis of groundwater protection, and an integration and interpretation of results. Revisions to the PA based on these comments are nearing completion.

Flow and transport modeling shows that the maximum long-term dose contributions can be attributed largely to ^{129}I and ^{99}Tc. These radionuclides have long half-lives (1.6×10^7 and 2.13×10^5 years respectively) and are among the most mobile in the grout and in the unsaturated soil column beneath the grout vaults. Other long half-life radionuclides (e.g., ^{237}Np, ^{126}Sn, ^{135}Cs and ^{79}Se) are absorbed on the Hanford soils and therefore reach the groundwater thousands of years after the ^{129}I and ^{99}Tc and have maximum dose contributions less than the more mobile radionuclides.

Nearly 99 percent of the radioactivity in DSS/DSSF for disposal in grout is from ^{137}Cs. This radionuclide has a relatively short half-life (30 years), is better contained in the grout, and is highly sorbed on Hanford soils relative to ^{129}I and ^{99}Tc. After less than 500 years, the ^{137}Cs has decayed to inconsequential levels. In the interim, little of this radionuclide has migrated into the concrete vault surrounding the grout (refer to Fig. 6). Should the engineered system be breached for some reason during that 500-year period, the ^{137}Cs would be sorbed on the Hanford soils and would not reach the groundwater beneath the disposal site. Therefore, the environmental risk resulting from including ^{137}Cs in grout is very small. Furthermore, the grout disposal system includes barriers and markers to deter inadvertent intruders, and the Hanford Site will be under institutional control for at least 100 years.

Savannah River uses large vaults and grout (saltstone) to dispose of their decontaminated salt waste, similar to the Hanford Site. Saltstone is a lower total activity waste comparable to 10 CFR 61 Class A concentration. Concerning long-lived isotopes, Hanford Site grout and Savannah River saltstone will contain very similar quantities of ^{129}I and ^{99}Tc, yet the Hanford Site has a much more elaborate disposal system than Savannah River. Because performance criteria are based on concentration-derived parameters (groundwater concentration, dose) and because the water advecting past an arid disposal site is much less than that advecting past a high-recharge site, the HGDP must rely on a more robust engineered system to achieve the same groundwater concentrations as a high-recharge disposal site such as Savannah River. This presents a challenge to the program to demonstrate the long-term performance of the engineered system. The regulatory community needs to recognize this difficulty and establish time-of-compliance requirements for LLW disposal and/or establish more reasonable long-term performance objectives. These long-term performance objectives might include a population dose basis, fractional release per year, higher dose limits, and/or a cutoff time for analysis.

WASTE VOLUME PROJECTIONS

In disposing of DST waste, grout processing frees up tank space. An available reserve of tank space is needed to address leaking tanks; mitigate tank safety issues; receive waste from facility operations; and provide required space for retrieval, pretreatment, and Hanford Waste Vitrification Plant (HWVP) operations. Tank space is critically short at the Hanford Site; therefore, grout processing is extremely important to providing much needed tank space. To maximize tank space availability, careful tracking and controls on tank space are maintained.

The purpose of the Waste Volume Projections at the Hanford Site is to maintain an up-to-date picture of all current and future tank usage and the resulting changes in waste volume and tank space. Waste Volume Projections monitor and project tank transfers, evaporations, and tank retrieval requirements to predict available tank space and impacts on tank farm operations and to assist site integration activities.

Waste from facilities is initially received into DSTs in dilute concentrations. When operating, an evaporator concentrates the waste by several factors, thereby reducing storage space and freeing up tank space. However, the Hanford Site tank farms 242 Evaporator has been shut down for several years and is just currently preparing for start-up. Until the evaporator is operational, considerable tank space is occupied with dilute waste, and available space is minimal.

At the same time, some DST space is reserved as spare space for emergency leaks and safety mitigation actions; some space is set aside for maintaining different types of waste segregated (e.g., complexed from non-complexed); and some space is reserved for ongoing processing and restoration activities, including single-shell tank (SST) stabilization and evaporator start-up. It is vital for tank waste management to maintain these reserve requirements.

Waste Volume Projections periodically update assumptions from all the facilities and programs involved with using or occupying and relieving tank space. The assumptions include all the pertinent parameters of the facilities and programs which have an impact on tank space, plus or minus, and include: start-up dates and operational schedules of the various facilities and programs, concentration efficiencies, volumes retrieved, volume of space required for operations, and volume of waste disposed of or concentrated. The entire set of tank space available data, reserve requirements, and assumptions are analyzed in a program to monitor and project tank space needs.

The overall projection is a set of scenarios, or what-if cases. Alternatives to reduce DST space requirements provide these scenario assumptions, as well as provide alternative actions for planning. Two scenarios: Without A Delay in Grout and One Grout Vault Only are shown in Fig. 7. The impacts of not grouting or not continuing to grout are evident. This figure clearly shows the benefit of grout in providing DST space for other needs. Delaying or deferring grout (i.e., to wait on pretreatment or to first develop an alternate waste form) could impact availability of tank space for resolving safety

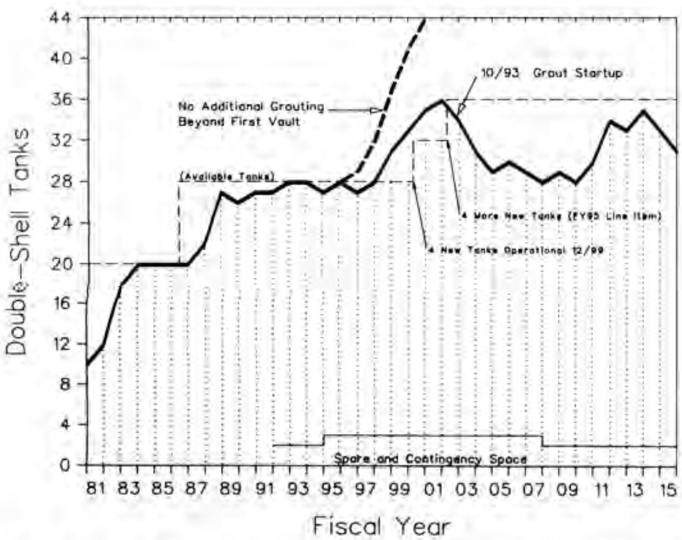

Fig. 7. Available tank storage space with and without grout operations.

issues, thus increasing incremental risk. It may also impact needed tank space capacity for pretreatment and HWVP, potentially affecting other Tri-Party Agreement milestones.

ALTERNATE WASTE FORM DEVELOPMENT

Alternate waste forms have been examined (preliminary studies) to compare with grout for LLW onsite disposal. Grouts are widely used in the nuclear and hazardous waste industry for the solidification of radioactive LLW and toxic waste. However, the level of radionuclides and hazardous constituents in DST waste, coupled with the low recharge rate of groundwater on the Hanford Site, result in an elaborate engineered disposal system for grout, which is depended on for long periods after disposal. Alternate waste forms offer higher leach resistance and hazardous waste constituents (organics and NO_2/NO_3) destruction, thereby reducing dependence on the engineered disposal system. Also, the recent decision to address retrieval and disposal of all tank wastes, SST as well as DST, has significantly increased the volume of LLW to be disposed.

Whereas the current grout waste form may be appropriate to initiate DST grout campaigns, an improved waste form may be more appropriate for SST LLW disposal, considering the much larger SST LLW volume and the requisite number of grout vaults for that volume. Furthermore, once developed and available (7-10 years estimated), the new waste form could be substituted for grout if DST LLW disposal is still ongoing at that point, thereby benefitting from any enhanced waste form advantages.

A number of possible waste forms for onsite LLW disposal have been evaluated and compared over a range of factors. The following waste forms were considered:

- Salt grout--Current grout form could include enhancements.
- Polyethylene encapsulated waste--Waste slurry will be dried to a powder that is mixed into molten polyethylene. The polyethylene waste mix will then be cast into containers that are buried onsite.
- Mineral grout--In this process, the waste will first be thermally denitrated and quenched, producing sodium hydroxide (NaOH). The caustic solution will be mixed with bentonite clay and solidification additives. The mix will then be pumped to a bulk disposal site where the mix solidifies into a massive monolith. Bentonite reacts with the caustic at ambient temperatures to form analcite, which binds up the sodium.
- Containerized Glass--The waste will be incorporated into borosilicate or lead phosphate glass, which is then cast in large containers that are buried onsite.
- Soil Melt Slurry Injection--Soil Melt Slurry Injection technology will be used to create a pool of molten soil to which the waste is added. The waste and molten soil cool to form a glass waste form.
- Glass in sulfur concrete--The waste will be incorporated into borosilicate or lead phosphate glass, which is then quenched to form cullet. The cullet will be added to molten sulfur, which is pumped to a bulk disposal site.
- Ceramic in grout--The waste will be calcined with kaolinite clay at 800°C (1472°F) to form nepheline, a sodium aluminosilicate mineral. The nepheline,

which functions as an aggregate, will be mixed with water and Portland cement to form a grout that is pumped to a bulk disposal site.

Figure 8 indicates how the alternatives compared against major properties in the evaluation. As shown, glass in sulfur and containerized glass offer excellent leach characteristics and are technically feasible to implement within a reasonable time frame.

The Hanford Site is continuing to evaluate grout and glass forms (i.e., glass in sulfur and containerized glass), leading to development of the most favorable alternative, while proceeding with the first few grout campaigns.

Major Properties Evaluated

Alternate Waste Form	Land commitment (acres)	Leach index	Waste volume (km^3)	Technical feasibility	Life-cycle cost ($M)
Salt grout	115	7.6	1277	High	605
Salt polyethelene	408	9.7	580	High	980
Mineral grout	208	11.3	2320	Low	995
Containerized glass (in cans)	190	17.0	220	Medium	1340
Salt melt slurry	11	11.6	336	Low	296
Glass in sulfur	27	17.0	297	High	1260
Ceramic in grout	67	11.1	753	Low	1120

Fig. 8. Major properties evaluated.

CONCLUSION

While the total amount of radionuclides planned for Hanford Site grout is considerably higher than other similar programs (e.g., Savannah River saltstone), the specific isotopes making up the difference in quantities must be considered. Nearly 99 percent of the curie content in DSS/DSSF for disposal in grout is ^{137}Cs. This isotope is retained within the grout and is highly sorbed on Hanford soils. Additionally, ^{137}Cs has a relativity short half-life, 30 years. After 500 years, the ^{137}Cs has decayed to an insignificant level, and only a minor concentration has migrated into the concrete vault structure surrounding the grout waste form. Therefore, the increased environmental risk resulting from the increased curies planned for disposal in grout is very small.

On the other hand, considering mobile species with long half-lives (e.g., ^{199}Tc and ^{129}I), Hanford Site grout has a very similar though somewhat smaller quantity of radionuclides compared to other disposal programs (e.g., Savannah River). The HGDP PA indicates that performance objective doses are not reached for thousands of years.

Rather than comparing just the difference in the absolute amount of curies, it is more appropriate to compare different inventories by considering impact on the environment (degree of mobility, half-life and biological toxicity). This examination would indicate that the long half-life mobile species (<1 percent of total activity) dominates the highly retained, short half-life ^{137}Cs (nearly 99 percent of total DSS/DSSF activity) in grout. Essentially, the higher curie content of Hanford Site grout does not present any significantly greater risk from an environmental impact point-of-view.

Concerning the ability to produce grout successfully, the HGDP has done extensive formulation work to address both the higher Hanford Site curie content and chemical/hazardous wastes as well as to prevent the difficulties encountered by other grouting programs. The HGDP has employed several Hanford Site and national laboratories in this effort.

The current HGDP has a very rigorous formulation development and verification test program to ensure a high probability of success. This includes detailed waste characterization, use of multiple laboratories, a pilot plant, hot cell tests, and actual plant operating experience. These tests and the comparison of these data sets provide a built-in quality assurance check for the success of disposing of Hanford Site tank waste via grout.

Finally, the risks associated with proceeding with grout cannot be viewed in isolation. Rather, the risks of grouting must be compared to the risks incurred if the HGDP is deferred for years to first remove radionuclides and/or to pursue an alternate waste form.

A number of years (5 to 10 estimated) is required to implement yet undeveloped and unscrutinized pretreatment and/or alternate waste form programs. During this period, mitigation of tank leakage and tank safety issues would be impacted due to tank space shortage. Grout is projected to relieve tank space shortage and is more environmentally sound than the continued storage of liquid tank waste with the potential for leakage to the soil column.

Therefore, the current strategy of TWRS is to introduce pretreatment to remove ^{137}Cs as quickly as possible and to accelerate development of an enhanced waste form, while simultaneously proceeding with the first grout vault campaigns to initiate disposal actions and relieve critical tank space needs.

REFERENCES

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