PILOT-SCALE VERIFICATION TESTS FOR HANFORD GROUT

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ABSTRACT

The Grout Treatment Facility (GTF) at Hanford, Washington will process the low-level fraction of selected double-shell tank (DST) wastes on the Hanford Site, to produce a cementitious waste form. This facility, which is operated by Westinghouse Hanford Company (Westinghouse Hanford), mixes liquid wastes with cementitious materials and pumps the resulting grout slurry into large [5300 cubic meters (m^3)] concrete vaults. Once in the vault, the grout cures to produce a waste form that immobilizes radioactive and hazardous constituents through chemical reactions and/or microencapsulation. Although this disposal scheme has several advantages, pouring grout into large vaults raises concerns about how to handle the heat generated from the exothermic hydration reactions that occur as the grout cures. WHC's current strategy for addressing the problem of hydration heat is to fill the vault in stages and use forced ventilation in the airspace above the grout to speed heat removal.

The varying composition of Hanford tank waste requires that each tank be processed in a separate campaign using a grout formulation specifically designed for that waste. The next tank scheduled for treatment is DST 241-AN-106. A four-phase grout formulation development is used to assure that the formulation will meet various processing and waste form requirements. These phases are: 1) laboratory formulation development studies and modeling with simulated wastes, 2) laboratory variability studies with simulated waste, 3) pilot-scale verification tests with simulated wastes, and 4) laboratory verification tests with actual waste.

This paper presents an overview of the pilot-scale verification tests conducted as part of the grout formulation development for the 241-AN-106 tank waste. The paper specifically discusses results dealing with 1) the grout slurry critical flow rate and 2) the ability to handle grout hydration heat with forced ventilation and by pouring in lifts.

INTRODUCTION

Disposal of the low-level fraction of liquid, radioactive wastes stored in DSTs on the Hanford Site is scheduled to begin in the 1990s. Disposal will consist of mixing the liquid wastes with cementitious grout-forming solids. The resulting grout slurry will be pumped into reinforced, 5300-m^3 concrete vaults, where it will harden into a cementitious mass. The vaults will be equipped with internal and external liner systems with a leachate collection tank to meet Resource Conservation and Recovery Act (RCRA) requirements for waste disposal. Each vault will be fully enclosed in a solid asphalt pavement barrier to reduce the migration of contaminants. Barriers over the top of the system will help to reduce and divert moisture infiltration to the soil from precipitation. This engineered system will constitute final disposal of the wastes. At Hanford, Westinghouse Hanford manages the Grout Disposal Program for the U.S. Department of Energy (DOE). Pacific Northwest Laboratory (PNL)* provides technical support to the program through pilot-scale tests, performance assessments, waste form characterization, and other verification work.

An important part of this disposal scheme is to develop a grout formulation that will meet all production and final waste form requirements. The formulation development strategy starts by specifying the criteria necessary to assure that 1) the grout can be processed in the production equipment and 2) the final waste form requirements are met. The next step is to characterize the waste that will be processed in a campaign. Once these two steps are accomplished, a four-phase formulation development process is used to initially investigate a large number of possible tormulations and dry-blend ingredients and then ensur that the final formulation choses will give the desired properties when produced in the production equipment. These phases are: 1) laboratory formulation development studies and modeling with simulated wastes, 2) laboratory variability studies with simulated wastes, 3) pilot-scale verification tests with simulated wastes, and 4) laboratory verification tests with actual waste.

The first phase in the formulation development process used statistically designed mixture studies to generate empirical models. These models were used to study the advantages and disadvantages of several possible formulations. The resulting projected properties allowed Westinghouse Hanford to select one formulation for the verification studies. The final formulation selected for further verification work was 20 wt% (1.74 lb/gal) type II-LA *(moderate heat of hydration)* Portland cement, 66 wt% (5.74 lb/gal) Class F fly ash, and 14 wt% (1.22 lb/gal) Attapulgite 150 drilling clay.

The other three phases in the formulation development process help confirm that the selected formulation will work as desired in the production environment. The formulation variability study determines if the baseline formulation will produce an acceptable product over the expected range of process variability in the production equipment. The pilot-scale tests confirms that the formulation can be processed in

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production-like equipment and that the grout produced with this equipment, and cast in a large mold, has properties similar to those of the laboratory samples. The third verification step is the hot cell work, in which grouts are mixed with samples of the tank waste to confirm that the actual wastes yield properties similar to those obtained with the simulated waste.

Several important issues were addressed in the pilot-scale tests for the 241-AN-106 tank wastes. This paper reports on two of those issues: 1) the grout slurry critical flow rate and 2) the ability to handle grout hydration heat with forced ventilation and by pouring in lifts. These two issues were chosen for discussion here to show the importance of pilot-scale tests in the formulation development process and illustrate how the pilot-scale tests can be used to address other large-scale concerns, such as how to handle grout hydration heat.

BACKGROUND

Radioactive and hazardous wastes have been generated at the Hanford Site since the mid-1940s from the production of weapons-grade plutonium. These liquid wastes were originally stored in underground single-shell tanks (SSTs). Beginning in 1969, twenty-eight 3,800-m^3 DSTs were constructed to receive waste transferred from the SSTs as well as newly generated waste from ongoing site operations. The inventory of DST waste will continue to grow during the next several years as the final quantities of liquid are pumped from SSTs, and the military plutonium production mission comes to an end.

Much of the DST waste has been classified as low-level waste. These low-level wastes are radioactive, concentrated salt solutions, classified as "hazardous" by the U.S. Environmental Protection Agency (EPA) and "dangerous" by the Washington State Department of Ecology (WDOE). These wastes are approximately 73 wt% water with major chemical constituents of sodium nitrate, sodium hydroxide, sodium nitrite, sodium aluminate, sodium phosphate, and sodium chloride. The variation in composition from tank to tank, however, is great, so each tank will be processed in a separate campaign with a grout formulation specifically designed for that waste. The first tank of nonhazardous waste was processed in 1988-89. The second tank of hazardous waste scheduled for treatment is Tank 241-AN-106. Many radionuclides are present in the wastes, but Cs-137 and Sr-90 contribute more than 99% of the 0.3 Ci/L activity. From a long-term performance assessment standpoint, nitrate, Tc-99, and I-129 are the primary contaminants of concern.

The balance of the tank waste must be pretreated to separate the material into high-level and low-level fractions. Beginning in 1999, the high-level waste will be processed to form a borosilicate glass for eventual disposal in the Nation's high-level waste repository. The current inventory of low-level waste and the low-level fraction from the pretreatment process will be pumped to the GTF, where the waste will be processed to form a cement-based grout for onsite disposal in large, near-surface concrete vaults (1).

GROUT TREATMENT FACILITY

The GTF includes four components: 1) the Dry Materials Facility (DMF), 2) two 3,800-m^3 feed tanks, 3) the Grout Processing Facility (GPF), and 4) the final disposal system.

The $3.8 million DMF receives and blends the dry materials (Portland cement, fly ash, and attapulgite clay) to form a single dry component that can be combined with the liquid waste at the GPF. After blending, the dry materials are transported by truck, 22,600 kilograms at a time, to the processing plant.

Two of the Hanford Site's 28 DSTs will be modified for possible use as a feed tank for the grouting process. At least three months before treatment, 3,800-m^3 of mixed waste is transferred to one of the feed tanks. In the feed tank, the waste is homogenized and sampled to verify that its composition is within the formulation envelope. Samples of the waste are also taken for use in processing and regulatory confirmation tests. During a 3,800-m^3 grout campaign, waste is pumped via an underground encased pipeline from the tank to the processing plant at approximately 190 L/min [50 gallons/min (gpm)].

The GPF mixes the dry materials and liquid waste to produce a grout slurry that is pumped via an underground pipeline to the disposal vaults. The main components of the GPF that constrain the rheological properties of the grout slurry are the mixer, the pump, and the pipeline to the vaults. The capabilities of these three components are simulated in a pilot-scale facility located at PNL.

The disposal system is comprised of three major elements: 1) a 38-m-long, 15-m-wide, and 10-m-high reinforced concrete vault and catch basin which serve as a double-liner/leachate collection system, 2) an asphaltic concrete diffusion barrier to control long- term contaminant release, and 3) a multilayered cover system to prevent water infiltration. The disposal system 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.

The disposal system design is somewhat different than that suggested by the MTG because of the 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 asphaltic concrete diffusion barrier surrounding the waste, and a multilayered cover system.

A 100,000-m^2 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 a dilute waste high in phosphate/sulfate in 1988-89 as a full-scale demonstration of the grout disposal system.

The current treatment and disposal scheme for the Hanford DST waste has several advantages. The volume and weight increase that results when grouting these wastes is not a great concern since the final waste form does not have to be transported to an offsite disposal facility. The large disposal vaults also eliminate the additional wastes that would be generated if the grout were placed in small containers that could be shipped. However, one disadvantage of pouring grout into a large vault is that the heat generated when the cementitious materials hydrate to form a solid waste form is not readily dissipated, and high grout temperatures can result. These high temperatures can significantly reduce the leach resistance of the final waste form. To address this heat generation problem, Westinghouse Hanford has proposed pouring the vaults in stages and introducing forced ventilation of the grout surface as a method to remove hydration heat and control grout temperatures. Each stage is referred to as a lift.

PILOT-SCALE TESTS WITH 241-AN-106 TANK WASTE

For the pilot-scale tests with the 241-AN-106 tank waste, 13,000 L [3500 gallons (gal)] of simulated 241-AN-106 tank waste (see Table I) were mixed in an insulated 15,000 L (4000-gal) tank and heated to approximately 45°C before processing. The dry-blend (see Table II) was mixed at the DMF and delivered to the pilot-scale facility at PNL in trucks.

The simulated waste and dry-blend were mixed in a 5-in. (1/4-scale) Teledyne Readco Twin-Shaft Continuous Processor. This mixer is the same brand and type of mixer used in the GPF. The mixed grout fell into an agitated, conical surge tank which fed a Roper two-stage progressing cavity pump. Both the surge tank and pump are 1/4-scale versions of the equipment used in the GPF. The pump transferred the mixed grout through 30-41 m (100-135 ft) of 3/4-in. schedule 40 carbon steel pipe to one of two molds. A schematic of the pilot-scale system is shown in Fig. 1. The grout production rate was approximately 38 L/min [10 gpm].

The first mold was 2.44-m (8-ft) dia X 2.2-m (7.5-ft) high with plate coils on its outer surface. Water was circulated through these plate coils to produce a temperature gradient in the mold. Core samples obtained from different locations in the mold will be used to determine the effects of curing conditions on other grout properties (results are not yet available).

The second mold was used to study the effects from pouring in lifts and is called the lift mold. The dimensions of the lift mold were .91-m (3-ft) wide X 2.29-m (7.5-ft) long X 3.05-m (10-ft) high. The length and width were scaled to match the length/width ratio on the production vault. The lift mold was insulated to reduce nonventilation-related heat losses and was equipped to introduce a controlled 386 standard L/min [(13 standard cubic feet per minute (scfm)] air flow through the mold. This air flow was determined by maintaining the air flow/cooling surface area ratio the same for the lift mold as is planned for the production vault. The mold was instrumented to measure the inlet and outlet air temperature and humidity to allow heat loss calculations resulting from the air flow. The lift mold was instrumented with thermocouples to measure the grout temperatures. This mold was filled in four 0.61-m (2-ft) lifts with one week between each lift. A schematic of the experimental setup is shown in Fig. 2. The temperature and heat removal information obtained from the lift mold was used to determine the effectiveness of increased air flows for controlling the grout temperatures when pouring in lifts.

TABLE I
Simulated 106-AN Waste Composition

Species	M/l	g/l
NO_3	130	71.50
OH	0.497	8.44
Al	0.341	9.21
PO_4	0.196	18.60
NO_2	0.534	24.60
CO_3	0.341	20.50
Na	3.974	91.36
K	0.0246	0.963
Cl	0.0675	2.39
Citrate	0.00851	1.61
B	0.0026	0.0281
Cr	0.0105	0.544
SO_4	0.0273	2.63
Ni	0.00104	0.061
Ca	0.00186	0.0746
Si	0.00158	0.0444
Mg	0.000107	0.0026
EDTA	0.00340	0.980
HEDTA	0.0136	3.74
Glycolate	0.00851	0.638

TABLE II
Dry Blend Formulations

Component	Baseline Formulation Weight% (Lbs/Gal)	Modified Formulation Weight% (Lbs/Gal)
Class F Fly Ash	66.0 (5.74)	68.3 (5.74)
Type II Portland Cement	20.0 (1.74)	20.7 (1.74)
Attapulgite-150 Clay	14.0 (1.22)	11.0 (0.92)

Grout used in pilot-scale tests was produced in four different runs. The first run provided enough grout to fill the gradient mold and the first lift in the lift mold. Grout slurry samples were obtained every 30 minutes during this run. The second, third, and fourth runs were short production runs which produced enough grout to complete the second, third,

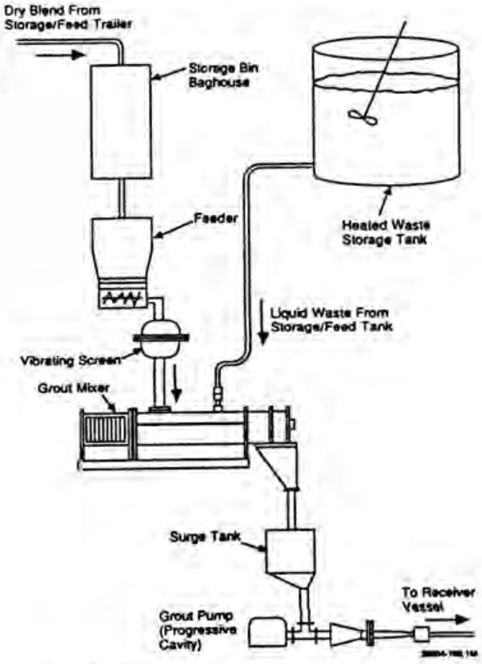


Fig. 1. Pilot-scale process schematic.

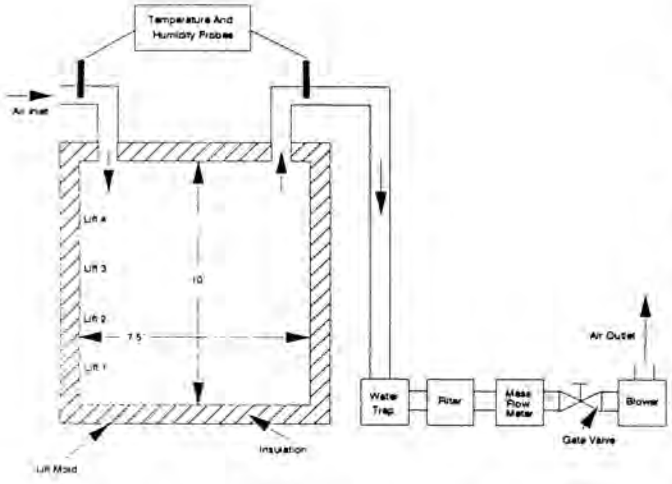


Fig. 2. Lift mold schematic.

and fourth lifts in the lift mold. One to four slurry samples were taken during each of these lift pours.

CRITICAL FLOW RATES

An important part of the formulation verification process is to determine if the grout formulation, developed in laboratory studies, yields the desired properties when processed in a manner similar to that used in the GTF. In the production processing scheme, the grout is pumped to the disposal vault through several hundred feet of pipe. The flow through this pipe must be turbulent to assure that settling of the solids in the grout slurry does not restrict the flow of grout. The minimum flow rate that will produce turbulent flow is known as the critical flow rate. The maximum allowable critical flow rate for a grout formulation that will be processed in the GTF is 227 L/min (60 gpm) (2). The critical flow rate is calculated using the equation shown below:

$$CFR = 39.62\,((2830\,K'(46.4^{n'}))/p)^{1\backslash(2-n')}$$

Where:

CFR = critical flow rate, L/min

K' = fluid consistency index, Newtons/m^3

n' = flow behavior index, dimensionless

p = slurry density, kg/m^3

This equation assumes that a Reynolds number of 2100 is the transition point from laminar to turbulent flow for grout slurries (3). The grout slurry samples obtained during the main grout pour and the lift pours were used to determine the densities and rheological properties necessary for the above calculation.

Table III shows the critical flow rates determined from samples taken during pilot-scale testing. Rheological information obtained from samples taken at the surge tank indicated that the grout formulation with 14 wt% attapulgite clay had a critical flow rate of less than 150 L/min (40 gpm). This value was well below the 227 L/min (60 gpm) criteria value and only slightly above the 118 L/min (31.3 gpm) value predicted by the laboratory-scale formulation study. These values are also fairly close to the values obtained from laboratory samples prepared with the pilot-scale materials. However, the samples at the pipe discharge yielded critical flow values which were above 227 L/min (60 gpm). This effect, known as shear thickening, was also seen in a prior phosphate/sulfate waste pilot-scale run when attapulgite clay was part of the formulation (4). The amount of shear thickening observed did not change significantly for different pumping speeds or minor variations in the mix ratio.

Additional slurry samples were obtained while pouring the second and third lifts. These lifts used the dry-blend with 14 wt% clay blended for the main run. As a result, the times between blending and grout production were longer for the second and third lift. The thickening effect of attapulgite clay has been shown to be reduced as the storage time of the mixed dry-blend increases when ingredients are sealed (5). The reduced thickening effect for both surge tank and discharge samples can be seen in Table III.

The results of the critical flow rate tests for the main pour and the first two lift pours did not conclusively determine that the dry-blend formulation with 14 wt% attapulgite clay would always exceed the 227 L/min (60 gpm) criteria value for the production equipment. However, the results do show the many variables which can affect the performance of the attapulgite clay and that high critical flow rates are possible with the 14 wt% attapulgite clay formulation. In addition, the main purpose of the clay is to control free liquid generation, but the grout in the gradient mold showed no free liquids. Therefore, reducing the amount of attapulgite clay would reduce the possibility of exceeding the 227 L/min (60 gpm) criteria value without jeopardizing other grout properties.

A slightly modified dry-blend was prepared by the DMF for the fourth lift (see Table II). This formulation reduced the attapulgite content from 14 to 11 wt% while keeping the fly ash/cement ratio constant. The critical flow rates for this adjusted formulation still showed a shear thickening effect, but the highest critical flow rate obtained for the 5 samples taken was 144 L/min (38 gpm). Two 55-gal drums of this formulation poured while completing the fourth lift had no free liquids. Therefore, the adjusted formulation with 11 wt% attapulgite clay adequately controlled the free liquid and had critical flow rates well below the criterion value even after significant shear thickening. If the adjusted formulation meets other performance criteria, it will be recommended for the tank 241-AN-106 campaign.

HEAT REMOVAL AND TEMPERATURE PROFILES IN LIFT MOLD

By pouring in lifts and increasing the air flow over the surface of the grout, WHC hopes to keep the maximum temperature of the grout below 90°C (2). With some grouts, temperatures above 90°C are thought to negatively affect the leach resistance of the grout. When pouring in lifts, two conditions develop that can create high temperatures. The first condition develops shortly after the pour, when the initial hydration heat is released so rapidly that the surface cooling does not adequately control the maximum temperatures. Presently, the existing information about this grout formulation is insufficient to know if short-duration, high-temperature peaks early in the curing cycle will adversely affect the final grout properties. To keep temperatures from

TABLE III
Calculated Critical Flow Rates

					Calculated GTF Critical Flow Rates liters/min (gpm)	
Pour	Wt% Clay in Dry-Blend	Mix Ratio Kg/liter (Lbs/Gal)	Pumping Rate Liters/min (gpm)	Dry Blend Age (Days)	Surge Tank Sample	Discharge Sample
Lab 1*	14	1.04 (8.70)	N/A	6	149 (39.4)	
Lab 2*	14	1.04 (8.70)	N/A	6	142 (37.5)	
Main**	14	1.01 (8.45)	49 (13)	7	109 (28.2)	232 (61.3)
Main	14	1.04 (8.70)	38 (10)	9	124 (32.8)	216 (57.1)
Main	14	1.04 (8.70)	38 (10)	9	139 (36.8)	234 (61.9)
Main	14	1.04 (8.70)	38 (10)	9	127 (33.6)	220 (58.1)
Main	14	1.04 (8.70)	57 (15)	9	140 (36.9)	231 (61.0)
Main	14	1.04 (8.70)	38 (10)	9	132 (35.1)	217 (57.5)
Main	14	1.07 (8.95)	38 (10)	9	147 (38.9)	239 (63.1)
Main	14	1.07 (8.95)	57 (15)	9	145 (38.4)	235 (62.0)
Lift 2	14	1.04 (8.70)	38 (10)	16	109 (28.7)	184 (48.6)
Lift 2	14	1.04 (8.70)	38 (10)	16	102 (27.1)	158 (41.7)
Lift 3	14	1.04 (8.70)	38 (10)	23	89 (23.6)	127 (33.5)
Lift 4	11	1.00 (8.40)	38 (10)	2	91 (24.1)	126 (33.3)
Lift 4	11	1.00 (8.40)	38 (10)	2	92 (24.2)	127 (33.4)
Lift 4	11	1.00 (8.40)	57 (15)	2	105 (27.8)	144 (38.0)
Lift 4	11	1.00 (8.40)	38 (10)	2	91 (24.0)	106 (28.0)

* Grout sample produced with pilot-scale materials.

** Grout sample taken during aborted main run attempt 2 days prior to main run.

rising above 90°C, the lift must be thin enough to allow the effects of surface cooling to control this early temperature peak. The second condition develops after a lift has been covered by several other lifts. In this case, increased cooling of the surface has little effect. To address this problem, enough heat must be removed from each lift of grout to assure that the temperature will not exceed 90°C as the grout continues to cure.

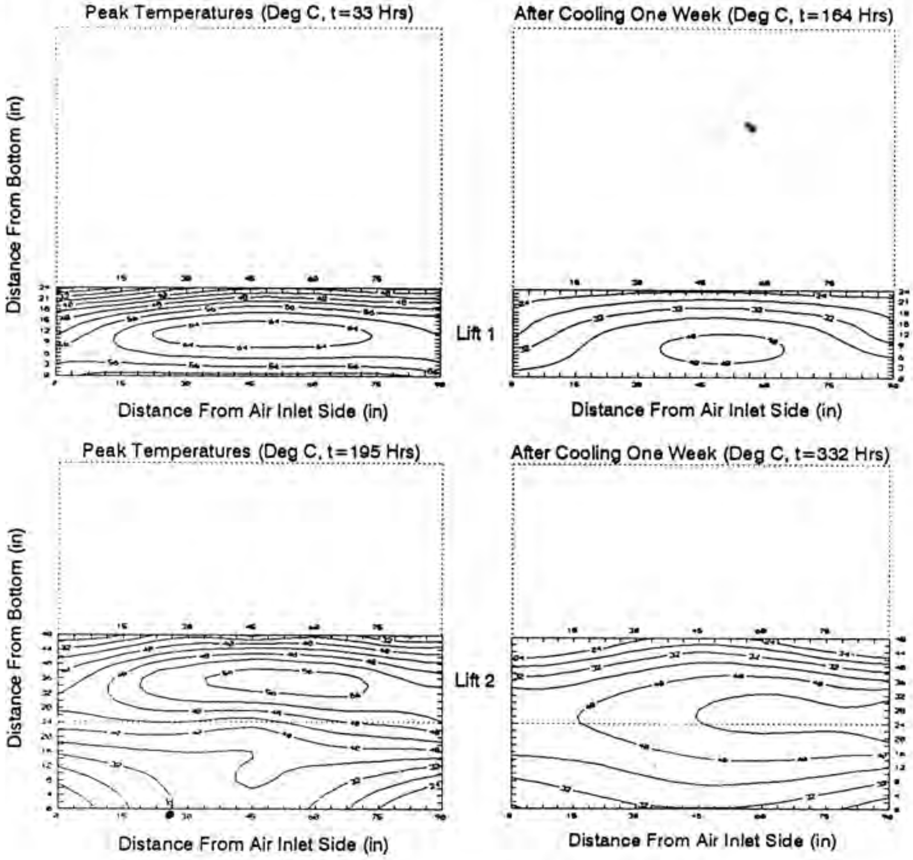
The temperature profiles observed in the lift mold are shown in Figs. 3 and 4. These profiles show the side view centerline [i.e. 0.46-m (1.5-ft) from the front and back inner surfaces of the mold] temperatures of the grout. In the following discussions, the center of a lift refers to the area 0.31-m (1-ft) below the surface of the grout block at the completion of the 0.61-m (2-ft) lift. Two profiles were taken for each of the four lifts placed in the mold. One profile was taken when the center of each new lift was at its peak temperature (about 33 hours after completion of the lift pour) and the second profile was taken one week after completion of the lift pour (just prior to pouring the next lift). Table IV shows the highest mold temperatures recorded after a 1-week cooling period for each lift, and the maximum lift temperatures. The total amount of heat removed with the 386 L/min (13 scfm) air flow and the resulting average temperature reduction of each lift are shown in Table V.

Peak temperature gradients in the first lift show that the heat loss from the grout is primarily through the top surface with some heat loss through the bottom. Heat loss through the insulated side surfaces is relatively small. The warmest areas are just below the center of the lift with a maximum observed temperature of 66°C. After one week of cooling, the warmest temperature in the mold is 42°C, located slightly below the center of the lift.

Peak thermal profiles in the second lift are typical of the remaining lifts and show that the warmest area is near or below the center of the lift and shifted slightly towards the cooling air outlet side of the mold. Heat from the second lift is primarily lost to the cooling air at the surface, and is conducted to the cooler first lift.

After each lift underwent a 1-week cooling period, the thermal profiles showed that the first two lifts, and all subsequent lifts, could no longer be distinguished by their thermal profiles. These profiles also show that the maximum temperature in the lift mold steadily increased with each subsequent lift.

Examining the thermal data for all four lifts shows that the temperature of the grout never exceeded 70°C. This indicates that pouring in 0.61-m (2-ft) lifts with an air flow of 386 L/min (13 scfm) is sufficient to control the initial hydration heat and maintain grout temperatures below 90°C. The lift mold data also point out two other general effects. The first effect results from the method used to simulate the bottom of the grout vault in the lift mold. The lift mold simulated the insulating capabilities of the bottom of the concrete vault, but did not simulate the mass. Initially, only a small amount of heat was lost from the first lift to the mass of the mold bottom,

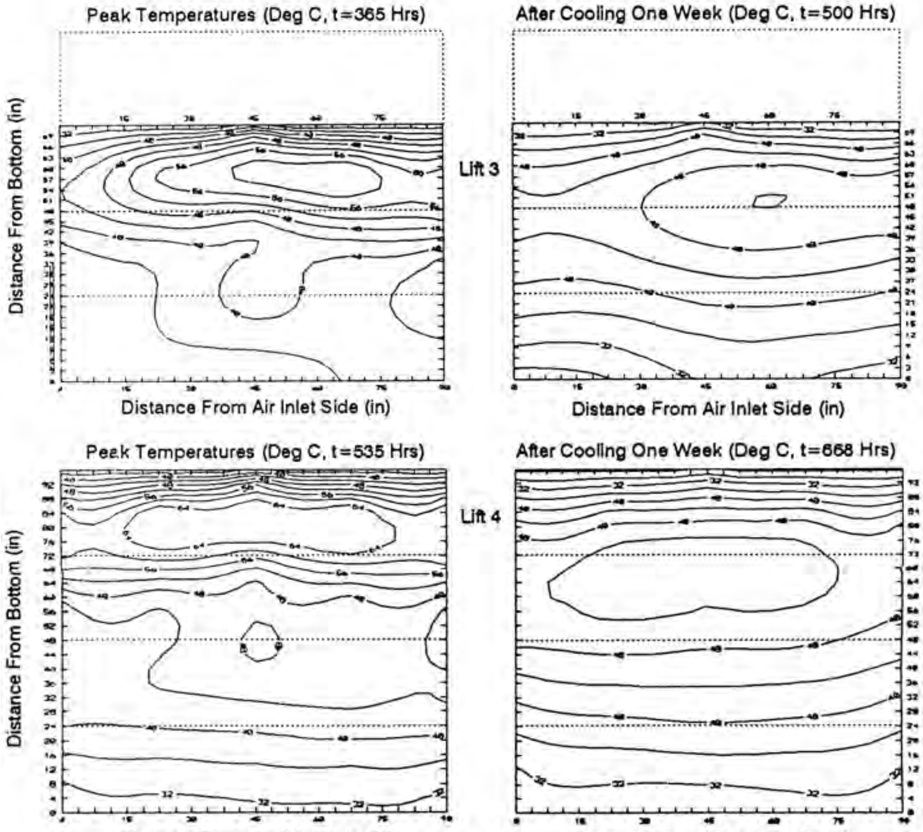

Peak Temperatures (Deg C, t=33 Hrs)

After Cooling One Week (Deg C, t=164 Hrs)

Peak Temperatures (Deg C, t=195 Hrs)

After Cooling One Week (Deg C, t=332 Hrs)

Fig. 3. Lift mold temperatures for lifts 1 and 2.


Peak Temperatures (Deg C, t=365 Hrs)

After Cooling One Week (Deg C, t=500 Hrs)

Peak Temperatures (Deg C, t=535 Hrs)

After Cooling One Week (Deg C, t=668 Hrs)

Fig. 4. Lift mold temperatures for lifts 3 and 4.

TABLE IV
Observed Lift Temperature Variations

Lift Number	Max Temperatures After One Week (°C)	Maximum Lift Temperature (°C)
1	42	66
2	46	58
3	50	62
4	54	69

TABLE V
Total Heat Removed With Convective/Evaporative Cooling

Lift Number	Total Heat Removed (Joules)	Lift Temperature Reduction (°C)
1	84,300,000	19.3
2	74,700,000	17.2
3	81,900,000	18.8
4	104,700,000	24.0

which was low-density insulation board. The low heat loss to the insulation board was not sufficient to lower short-term hydration temperatures as much as the grout vault concrete would. Since there was no large mass for energy to be transferred to in the first lift, a higher peak temperature was obtained. This higher peak temperature resulted in better heat removal by the ventilation system (84,300,000 joules). When the second lift was poured, some of the initial hydration heat from the second lift went into reheating the grout mass in the first lift, reducing the peak temperature. Therefore, the removal of ventilation heat for the second lift (74,700,000 joules) was lower than that from the first lift. Enhanced cooling of the first few lifts in the vault are expected because of the heat transfer to the large mass of the concrete vault.

The second effect is a gradual increase in the peak temperatures for lifts 2 through 4 and a gradual increase in the grout mass temperature at the end of each 1-week cooling period. This gradual buildup in temperature is accompanied by an increase in the amount of heat removed (lifts 2-4) with the forced air flow. It appears that higher grout temperatures produce a steeper thermal gradient that conducts more heat to the surface where it is removed by the air flow. Therefore, as the additional lifts are added, a balance between higher temperatures and improved heat removal will tend to limit the extent of this temperature increase.

Averaging the results from all four lifts shows that the 386 L/min (13 scfm) air flow removed enough heat to reduce the grout temperature by about 20°C. To determine if the heat removed was sufficient to keep the long-term grout temperatures below 90°C, an accurate measurement of the total adiabatic temperature rise is required. Work is currently being conducted to measure this value. If the total heat removed is not sufficient, time between lifts would be lengthened to allow more time for heat removal.

The information obtained from the lift mold data shows that the short-term temperatures are effectively handled by pouring 0.61-m (2-ft) lifts one week apart and increasing the air flow. However, experimental limitations, such as those imposed by the heat loss through the sides of the mold, make it difficult to confirm that long-term temperatures will be below 90°C. Also, the 0.61-m (2-ft) lift scenario may not be the optimum (i.e., fastest) scenario for controlling short-term grout temperatures. Therefore, Westinghouse Hanford plans to conduct modeling to determine the optimum pour schedule for controlling both long- and short-term grout temperatures. The lift mold data will give Westinghouse Hanford modelers experimental data to help benchmark their grout heat removal models.

CONCLUSIONS

- These results show the importance of pilot-scale tests in the overall grout formulation development process and illustrate how the pilot-scale tests can be used to address other large-scale concerns.
- The grout produced with a dry-blend formulation consisting of 14 wt% attapulgite clay, 20 wt% cement and 66 wt% class F fly ash showed significant shear thickening and had calculated critical flow rates at the pipe discharge that were above the criterion value of 227 L/min (60 gpm). Slight modification of the dry-blend formulation to 11 wt% attapulgite, 20.7 wt% cement, and 68.3 wt% class F fly ash reduced the critical flow rate to below 150 L/min (40 gpm). This modified formulation was recommended for further verification testing.
- Grout temperatures in the lift mold never exceeded 70°C. This indicates that pouring in 0.61-m (2-ft) lifts with a 1-week cooling period while using an air flow of 386 L/min (13 scfm) is sufficient to control the initial hydration heat. The 386 L/min (13 scfm) air flow removed enough heat to reduce the temperature of the grout by about 20°C. These tests demonstrate that a reasonable pour scenario can be developed to control grout temperatures.

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