October 30, 2013

MEMORANDUM TO: Gregory Suber, Chief
Low-Level Waste Branch
Environmental Protection
and Performance Assessment Directorate
Division of Waste Management
and Environmental Protection

THRU: Christepher McKenney, Chief **/RA/**
Performance Assessment Branch
Environmental Protection
and Performance Assessment Directorate
Division of Waste Management
and Environmental Protection

FROM: Christopher Grossman, Systems Performance Analyst **/RA/**
Performance Assessment Branch
Environmental Protection
and Performance Assessment Directorate
Division of Waste Management
and Environmental Protection

SUBJECT: TECHNICAL REVIEW: U.S. DEPARTMENT OF ENERGY DOCUMENTATION RELATED TO TANKS 18F AND 19F FINAL CONFIGURATIONS WITH AN EMPHASIS ON GROUTING FROM RECOMMENDATIONS AND TESTING TO FINAL SPECIFICATIONS AND PROCEDURES (PROJECT NO. PROJ0734)

The U.S. Nuclear Regulatory Commission (NRC) staff has performed a technical review of several documents prepared by the U.S. Department of Energy (DOE) that provide information on closure of Tanks 18F and 19F with an emphasis on grout formulations, testing, placement procedures and final configurations. This technical review activity supports Monitoring Factors 3.3, “Shrinkage and Cracking”, and 3.4, “Grout Performance”, in NRC staff’s F-Tank Farm (FTF) Monitoring Plan, Rev. 0 (Available in the Agencywide Documents Access and Management System (ADAMS) Accession No. ML12212A192). The NRC staff concludes that performance requirements for grout formulations recommended and tested for Tanks 18F and 19F closure are generally consistent with bulk, initial chemical and hydraulic properties assumed in DOE’s FTF Performance Assessment (SRS-REG-2007-00002, Rev. 1). However, the NRC staff also concludes that DOE has not provided sufficient information and testing to exclude preferential flow through the tank grout monolith from its reference case. Primarily, the NRC staff expects

CONTACT: Christopher Grossman, FSME/DWMEP
(301) 415-7658

DOE to provide additional information related to the extent and performance impact of shrinkage to have reasonable assurance that the performance objectives specified in Subpart C of Part 61 of Title 10 of the Code of Federal Regulations (10 CFR Part 61, Subpart C) will be met. Further, during the review of tank grouting video, NRC staff has observed potential segregation of tank grout that could enhance the extent of shrinkage along the periphery of the Type IV tanks (i.e., along the tank walls). NRC staff also expects DOE to provide additional information on the potential for thermal cracking of the grout monolith for Tanks 18F and 19F. The NRC staff will continue to evaluate the potential for shrinkage and cracking induced preferential flow through the tank grout under Monitoring Factor 3.3, "Shrinkage and Cracking" (See ML12212A192). NRC also continues to monitor the potential for segregation of emplaced grout and its impacts on flow through the grout monolith and waste release under Monitoring Factor 3.4, "Grout Performance". NRC staff believes this information is needed for NRC to have reasonable assurance that the FTF will meet 10 CFR Part 61, Subpart C.

The NRC staff will also continue to monitor void volumes in the emplaced grout to the extent information is available (Monitoring Factor 3.4, "Grout Performance"), the importance of alkali-silica reactivity on cementitious material degradation (Monitoring Factor 3.3, "Shrinkage and Cracking") and the impact of limestone additions to the grout mix on pH buffering of water contacting the emplaced grout (Monitoring Factor 3.4, "Grout Performance"). The NRC staff believes this information would enhance DOE's demonstration that the performance objectives of 10 CFR Part 61, Subpart C are met with reasonable assurance.

Enclosure:
Technical Review of Documents Related
to Tank 18F and 19F Grout Formulations,
Operations, and Final Closure at the
F-Area Tank Farm at the Savannah River Site

DOE to provide additional information related to the extent and performance impact of shrinkage to have reasonable assurance that the performance objectives specified in Subpart C of Part 61 of Title 10 of the Code of Federal Regulations (10 CFR Part 61, Subpart C) will be met. Further, during the review of tank grouting video, NRC staff has observed potential segregation of tank grout that could enhance the extent of shrinkage along the periphery of the Type IV tanks (i.e., along the tank walls). NRC staff also expects DOE to provide additional information on the potential for thermal cracking of the grout monolith for Tanks 18F and 19F. The NRC staff will continue to evaluate the potential for shrinkage and cracking induced preferential flow through the tank grout under Monitoring Factor 3.3, "Shrinkage and Cracking" (See ML12212A192). NRC also continues to monitor the potential for segregation of emplaced grout and its impacts on flow through the grout monolith and waste release under Monitoring Factor 3.4, "Grout Performance". NRC staff believes this information is needed for NRC to have reasonable assurance that the closure of FTF tanks will meet 10 CFR Part 61, Subpart C.

The NRC staff will also continue to monitor void volumes in the emplaced grout to the extent information is available (Monitoring Factor 3.4, "Grout Performance"), the importance of alkali-silica reactivity on cementitious material degradation (Monitoring Factor 3.3, "Shrinkage and Cracking") and the impact of limestone additions to the grout mix on pH buffering of water contacting the emplaced grout (Monitoring Factor 3.4, "Grout Performance"). The NRC staff believes this information would enhance DOE's demonstration that the performance objectives of 10 CFR Part 61, Subpart C are met with reasonable assurance.

Enclosure:
Technical Review of Documents Related
to Tank 18F and 19F Grout Formulations,
Operations, and Final Closure at the
F-Area Tank Farm at the Savannah River Site

DISTRIBUTION (w/Enclosure): CBarr GAlexander LParks MFuhrmann
DPickett, CNWRA WIR Service List DOE SRS Email List

ML13269A365

OFC	DWMEP:TR	DWMEP:LA	DWMEP:PM	DWMEP:BC	DWMEP:TR
NAME	CGrossman	TMoon	HFelsher	CMKenney	CGrossman
DATE	09/30/13	10/1/13	10/3/13	10/30/13	10/30/13

OFFICIAL RECORD COPY

Technical Review of Documents Related to Tank 18F and 19F Grout Formulations, Operations, and Final Closure at the F-Area Tank Farm at the Savannah River Site

Date: September 30, 2013

Reviewers:

Roberto Pabalan, Center for Nuclear Waste Regulatory Analyses
Cynthia Dinwiddie, Southwest Research Institute®
Gary Walter, Southwest Research Institute®
Christopher Grossman, U.S. Nuclear Regulatory Commission (NRC)

Documents:

Alexander, O. "Placement of Grout Tank 18 Center Riser." Work Order No. 01087939–16, Revision 03. March 29, 2012.

C-DCF-F-01524. Ganguly, A. "Revise Tanks 18F & 19F Closure Grout Specification." Aiken, South Carolina: Savannah River Remediation, LLC. February, 28, 2012.

C-DCF-F-01527, Forty, R.W. "Revise Tanks 18F & 19F Closure Grout Specification for Testing Samples." Aiken, South Carolina: Savannah River Remediation, LLC. March 29, 2012.

C-SPP-F-00055, Forty, R.W. "Furnishing and Delivery of Tank Closure Grout." Revision 2. Aiken, South Carolina: Savannah River Remediation, LLC. August 25, 2011.

C-TRT-F-00005, Ganguly, A. "Technical Summary Report for Tanks 18F and 19F Closure — Initial Trial Batching (U)." Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. April 17, 2012.

Isherwood, A. "Placement of Grout Tank 18 Various Equipment Locations." Work Order No. 01087939–17, Revision 1. March 1, 2012.

Patton, G. "Placement of Grout Tank 19 Various Equipment Locations." Work Order No. 01087938–16, Revision 1. March 1, 2012.

Patton, G. "Placement of Grout Tank 19 Center Riser." Work Order No. 01087938–15, Revision 04. April 23, 2012.

SRNL-L3100-2011-00180, Langton, C. A. and D.B. Stefanko. "Bulk Fill Grout Recommendations for Tanks 18-F and 19-F." Memorandum to F.M. Pennebaker and R.C. Jolly Jr. Aiken, SC: Savannah River National Laboratory. August 31, 2011.

SRNL-RP-2011-00977, Stefanko, D.B. and C.A. Langton. "Tanks 18-F and 19-F Grout Fill Engineering and Performance Requirements." Revision 0. Aiken, South Carolina: Savannah River National Laboratory. August, 2011.

Enclosure

SRNL-STI-2011-00551, Stefanko, D.B. and C.A. Langton. "Tanks 18 and 19-F Structural Flowable Grout Fill Material Evaluation and Recommendations." Revision 0. Aiken, South Carolina: Savannah River National Laboratory. September, 2011.

SRNL-STI-2011-00564, Stefanko, D.B. and C.A. Langton. "Tank 18 and 19-F Tier 1A Equipment Fill Mock Up Test Summary." Revision 0. Aiken, South Carolina: Savannah River National Laboratory. September, 2011.

SRNL-STI-2011-00592, Stefanko, D.B. and C.A. Langton. "Tanks 18 and 19-F Equipment Grout Fill Material Evaluation and Recommendations." Revision 0. Aiken, South Carolina: Savannah River National Laboratory. November 2011.

SRNL-STI-2011-00749, Stefanko, D.B. and C.A. Langton. "Tank 18-F and 19-F Tank Fill Grout Scale Up Test Summary." Revision 0. Aiken, South Carolina: Savannah River National Laboratory. December, 2011.

SRR-CWDA-2012-00170, Martin, B. "Tanks 18 and 19 Final Configuration Report for F-Tank Farm at the Savannah River Site." Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. June, 2013.

SRR-CWDA-2012-00172. Ross, S. R. Memorandum to J. Shaffner Transmitting Tank 18F Grout Pour Videos. August 17, 2012.

SRR-LWE-2012-00036, Thaxton, G.D. "Tank 18F and 19F Closure Assurance Plan." Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. March 28, 2012.

SRR-LWE-2012-00217, Frazier, S.L. "Tanks 18 and 19 Final Configuration Report Inputs." Revision 1. Aiken, South Carolina: Savannah River Remediation, LLC. January 16, 2013.

SRR-LWP-2012-00034, Guilherme, J.B. "SRR Subcontractor Surveillance Plan Furnishing and Delivery of Tank Closure Grout (TK 18/19)." Aiken, South Carolina: Savannah River Remediation, LLC. May 9, 2012.

Summaries of Technical Reports:

SRNL-RP-2011-00977, Stefanko and Langton (2011), *Tanks 18-F and 19-F Grout Fill Engineering and Performance Requirements,* Rev. 0.

The report provides the physical property requirements for the tank closure grout. An abbreviated list of requirements provided by Savannah River Remediation (SRR) F-Area Tank Farm (FTF) Engineering was used for evaluating candidate grout formulations and as screening criteria for designing improved formulations. The list of requirements was expanded as grout formulation work progressed. Included in this report are brief explanations of selected tests used to support and/or parameterize the FTF Performance Assessment (SRS-REG-2007-00002, Rev. 1) and the bases for the requirements.

The physical property requirements include those for fresh grout and for cured grout. Fresh grout properties include slump-flow, static flow, air content, set time, bleed water, maximum temperature during curing, and slurry pH. Cured grout properties include alkalinity, reducing capacity, compressive strength, effective porosity, dry bulk density, and particle density. The required pH and E_h are ≥12.4 and ~–200 to –400 mV, respectively. No specific requirements for effective porosity, dry bulk density, and particle density are given; these are to be measured or calculated for input to the FTF Performance Assessment. Dimensional stability, shrinkage, and cracks also are mentioned as important cured grout physical properties. No numerical requirements are specified for these properties, but the report acknowledges that tank closure grout with minimal cracks (as low as reasonably achievable) caused by shrinkage and/or expansion is desired. The report states that “test methods and mix designs are currently being developed to quantify shrinkage for the base case grout and to explore opportunities for reducing chemical shrinkage inherent to portland cement materials.”

Numerical requirements for transport properties of cured grout also are listed in the report. These properties include effective diffusion coefficient ($\leq 8.0\times10^{-7}$ cm^2/s [$\leq 8.6\times10^{-10}$ ft^2/s]), tortuosity (≤ 20), saturated hydraulic conductivity K_{sat} ($\leq 3.6\times10^{-8}$ cm/s [$\leq 1.2\times10^{-9}$ ft/s]), and K_ds (varies with radioelement and redox condition).

SRNL-L3100-2011-00180, Langton and Stefanko (2011), *Bulk Fill Grout Recommendations for Tanks 18-F and 19-F*.

This document is a short interoffice memorandum that summarizes the test results described more fully in SRNL-STI-2011-00551, which is discussed below. The memo recommends three grout mix formulations for filling Tanks 18F and 19F[1]. The recommended mix numbers are LP#8-16, LP#8-16C, and LP#8-20. Mix LP#8-16C is similar to LP#8-16 but has less fly ash and quartz sand and contains a shrinkage compensating component. LP#8-20 is similar to LP#8-16 but has more quartz sand and ViscoCrete® admixture and less water and Kelco-Crete® admixture.

SRNL-L3100-2011-00180 appears to predate the completion of SRNL-STI-2011-00551, which is discussed below. In contrast to SRNL-L3100-2011-00180, SRNL-STI-2011-00551

---

[1] The DOE documents cited in this report refer to Tanks 18 and 19 of the FTF with various monikers (e.g., “Tanks 18-F and 19-F”, “TK 18/19”, and “Tanks 18F and 19F”). The various monikers are synonymous.

recommends only one grout mix formulation, LP#8-16, for filling Tanks 18F and 19F. That formulation was used in a tank fill grout scale up test described in SRNL-STI-2011-00749.

SRNL-STI-2011-00551, Stefanko and Langton (2011), *Tanks 18 and 19-F Structural Flowable Grout Fill Material Evaluation and Recommendations*.

Tests were conducted to identify a single (all-in-one) grout to stabilize and isolate the residual radionuclides in Tanks 18F and 19F, provide structural stability to the closed tanks, and serve as an inadvertent intruder barrier. The use of a single grout is different from the three layer concept (stabilizing, structural, and capping grouts) used in Tanks 17F and 20F. The new grout mix designs that were tested were based on the flowable zero bleed structural fill mix that was used for the in-situ decommissioning of SRS P- and R-Reactor facilities. New admixtures for adjusting grout flow properties were also tested because the admixture products used in previous grouts are no longer available. Also, the sources of cement and fly ash have changed from previous tests and currently available portland cements contain up to 5% by weight limestone.

Table 1-2 of SRNL-STI-2011-00551 provides a link between grout attributes, physical properties, and engineering parameters. For example, to meet the grout attribute of high reducing capacity over the long term, at least 210 lb [95 kg] of slag per cubic yard of reducing grout is specified as an engineering parameter. To satisfy the attribute of low water infiltration through the in-place grout over the long term, a saturated hydraulic conductivity, K_{sat}, less than or equal to 3.66×10^{-8} cm/s [1.20×10^{-9} ft/s] is specified as an engineering parameter. Because LP#8-20 and LP#8-16 have the same quantities of cement and slag cement, Langton and Stefanko (SRNL-STI-2011-00551; Tables 3-4 and 4-1) estimate that the two mixes have identical thermal properties, i.e., adiabatic temperature rise for complete hydration of 34 °C [93 °F], specific heat of 1,080 J/kg·K [0.258 Btu/lb], and thermal conductivity of 2.5 W/m·K [1.44 Btu/hr-°F-ft]. The aforementioned thermal properties were not experimentally verified. Langton and Stefanko estimate density for the two mixes, listed in Table 3-4 of SRNL-STI-2011-00551, that may not agree with the bulk and particle densities listed in Table 3-5 for LP#8-20 and LP#8-16. When this document was published, the moisture retention function was also still under development. The only data available were volumetric water contents at pressures ranging between 0 and 15 bars [0 and 15 atm] (Table 3-6); water contents for pressures between 15 and 45 bars [15 and 44 atm] were not available.

Tests involved measurements of fresh grout properties, including slump flow, set time, bleed water, unit weight, air content, and cured grout properties, including compressive strength, saturated hydraulic conductivity, moisture retention characteristics, and heat of hydration. The tests used mix designs that contained sand only or both sand and ⅜ in [9.53 mm] granite "pea gravel" as aggregates. All mix designs tested included portland cement, blast furnace slag, and fly ash, as well as the additives ViscoCrete® and Kelco-Crete®. The report mentions that special test forms were designed and instrumented to evaluate dimensional changes (shrinkage and expansion) as a function of time, temperature, and humidity. However, the report states that tests of shrinkage and bonding to steel forms and tests of formulations with shrinkage compensating admixtures were postponed by tank closure project personnel.

Table 1. Tanks 18F and 19F Bulk Fill Material Recommendation

Mix Number	Cement Type I/II	Slag Grade 100	Fly Ash Class F	Type G Shrinkage Compensating Component	Sand Quartz	Gravel No. 8	Water	HRWR SIKA® ViscoCrete® 2100	VMA Diutan Gum Kelco-Crete® DG
	lb/yd^3						gal/yd^3	fl oz /yd^3	gram/yd^3
LP#8-16	125	210	363	0	1790	800	48.5	41	200

The tests indicate that including ⅜ in [9.53 mm] gravel, rather than using sand as the only aggregate, improved mixing and homogeneity, flow, and compressive strength. Mix formulations in the LP#8 series, which was based on the self-leveling, flowable structural fill grout used for in-situ decommissioning of SRS P- and R-Reactor facilities, were selected as candidates for fillings Tanks 18F and 19F based on fresh grout properties, compressive strength at 28 days, and water-to-cement ratio. Based on additional data on adiabatic temperature rise and hydraulic conductivity, the report recommends mix LP#8-16 for scale-up testing and inclusion in the procurement specification for furnishing and delivering tank closure grout for Tanks 18F and 19F. The LP#8-16 mix design is provided in Table 1.

A later design change documented in C-DCF-F-01524, which is discussed below, revised the amount and commercial brand of admixtures (high range water reducer and viscosity modifier) to be used in the tank grout.

SRNL-STI-2011-00564, Stefanko and Langton (2011), *Tank 18 and 19-F Tier 1A Equipment Fill Mock Up Test Summary*, Rev. 0.

The report documents the results of equipment fill mock up testing DOE conducted to evaluate placement issues related to grouting equipment that will be left in Tanks 18F and 19F. This equipment includes the Advance Design Mixer Pump (ADMP), transfer pumps, transfer jets, standard slurry mixer pumps, equipment support masts, sampling masts, dip tube assemblies, and robotic crawlers. DOE grouted the equipment in place to fill voids in the equipment and eliminate vertical fast pathways for water infiltration.

The mock up tests focused on filling the ADMP and pipes 1 in [3 cm] and larger in diameter. DOE considered these configurations to be representative and bound the majority of the equipment that will be left in the tanks. The ADMP is a particular concern because of its 55-ft [16.8-m] length, large size, and complicated flow path through its support column. Initially, for the ADMP mock up test, a 1 ft [0.3 m] × 1 ft [0.3 m] × 8 ft [2.4 m] Plexiglas scaled mock up test form was constructed, with 18 chambers to represent the ADMP internal volumes. However, because of limitations in material availability, grout batching capability, and logistics of filling an 8 ft [2.4 m] high test form, the initial form was cut in half and only the bottom 4 ft [1.2 m] test form, partitioned into 9 chambers with Plexiglas dividers/shelves, was used for the test. Pipe grouting mock up tests used 5 ft [1.5 m] long, 1 in [3 cm] and 2 in [5 cm] diameter pipes oriented vertically.

The mock up tests used two grout formulations, T1a-62.5FA and T1a-75FA, which are summarized below (see summary of SRNL-STI-2011-00592). For the ADMP mock up test, the grout was gravity fed into the test form using a funnel, with the grout level maintained at the 9 in [23 cm] mark of the funnel to keep a relatively constant fill rate. Ten batches of grout were used to fill the form. The first five batches used the T1a-62.5FA grout formulation and the second five batches used the T1a-75FA formulation. After filling, all chambers except one were observed to be completely filled with grout. The report speculates that the dividing plate between two of the chambers may not have been level. For the pipe filling tests, the pipes were filled from the top down through a funnel and also from the bottom up by discharge through a tube inserted into the pipes. In the latter case, the inserted tube was connected to a grout pump. The test results indicate that the pipes were completely filled using both fill methods.

The report documents that the grout mixes had high viscosities (honey like) and appeared sticky. The report notes that the potential for chamber flooding was apparent during the mock up test even with the ability of the staff to manually control the fill rate and to observe through the Plexiglas for possible signs of near flooded conditions. It is also reported that chamber flooding did occur at the higher flow rate used in the test and the displaced air could not vent through a flooded chamber, which resulted in overfilling and rejection (spill) of grout around the funnel and air vent. From these observations and recognizing the long and tortuous path and long fill time involved in filling the 55-ft [16.8-m] long column in the actual ADMP, the report recommended that a lower viscosity grout be considered to increase the likelihood of complete filling of the ADMP and reduce the risk of spills caused by chamber flooding.

SRNL-STI-2011-00592, Stefanko and Langton (2011), *Tanks 18 and 19-F Equipment Grout Fill Material Evaluation and Recommendation*s, Rev. 0.

Laboratory tests were conducted to identify a grout formulation for filling bulk waste and heel waste removal equipment that will remain in Tanks 18F and 19F. This equipment includes mixer pumps, transfer pumps, transfer jets, equipment support masts, sampling masts, and dip tube assemblies. The internal void spaces in the equipment were to be grouted to eliminate fast pathways and slow water infiltration to the residual waste material on the tank floor. General performance requirements for the equipment fill grout are: (1) the grout must be alkaline and chemically reducing (i.e., contain slag), (2) the grout must be sufficiently flowable to fill equipment voids and pipes ≥ 1 in [2.54 cm] in diameter, (3) the grout must form a solid material upon curing, and (4) the grout must provide a barrier to infiltrating water, i.e., minimize vertical pathways. Table 2-1 in the report lists the test methods used to characterize the properties of fresh grout slurries, including initial and static flow, air content, set time, bleed water, maximum temperature during curing, slurry pH, static working time, and dynamic working time. Table 2-2 in the report lists the test methods to characterize the cured grout properties, which include compressive strength, effective porosity, dry bulk density, pH, reducing capacity, effective diffusion coefficient, and saturated hydraulic conductivity. Tables 2-1 and 2-2 also list the target values for the grout properties and the bases for those target values.

Initial tests were conducted using a grout formulation that previously was tested (in 2008) for filling cooling coils (2-in [5-cm] schedule 40 piping) in HLW tanks. This grout is a mixture of Masterflow® cable grout, Grade 100 blast furnace slag, and water. The test results indicate that the cooling coil mix generated high temperatures (> 100 °C [> 212 °F]) due to exothermic hydration reactions and exhibited flow behavior that was more suited for pressure grouting than for gravity filling. Therefore, the cooling coil grout was modified to reduce the amount of heat generated and to increase flowability. Class F fly ash was substituted for up to 75 % by weight of the Masterflow® 816 cable grout and the water-to-cementitious material ratio was increased. Based on the additional tests, two mix formulations (referred to as T1a-62.5FA and T1a-75FA) are recommended in the report for the Advanced Design Mixer Pump (ADMP) Tier 1A equipment fill mock up test. Both mixes have lower heats of reaction than the cooling coil grout and produce cured grouts that meet or exceed the strength and saturated hydraulic conductivity requirements for Tank 18F and 19F bulk grout fill. The T1a-75FA mix generates less heat during curing than the T1a-62.5FA mix, but the latter is slightly more fluid than the former. The report states the T1a-62.5FA is the preferred formulation because the ease of filling tank equipment is more important than curing temperature, which is considered manageable using engineering controls.

SRNL-STI-2011-00749, Stefanko and Langton (2011), *Tank 18-F and 19-F Tank Fill Grout Scale Up Test Summary*, Rev. 0.

SRNL-STI-2011-00749 documents the results of a 4 yd^3 [3 m^3] bulk fill scale up test on the grout formulation that was recommended for filling Tanks 18F and 19F. The test was intended to demonstrate the proportioning, mixing, and transportation of material that was produced in a full-scale ready mix concrete batch plant. In addition, the material produced for the scale up test was characterized with respect to fresh properties, thermal properties, and compressive strength as a function of curing time.

In addition, a 1 yd^3 [0.8 m^3] insulated plywood form with an insulated lid was poured with the bulk fill grout for measuring semi-adiabatic temperature rise. The box was lined with a plastic sheet and thermocouples were installed at different locations in the box. The box was filled with grout that was discharged directly from a truck, covered with an insulated lid, and then left in place for approximately one month as temperature readings were taken.

The slump flow per ASTM International (formerly the American Society for Testing and Materials) Standard C1611 (ASTM, 2009) was 25.5 in [64.7 cm] for material measured in FTF, which is within the acceptable range in the tank fill procurement specification 24 to 28 in [61 to 71 cm] and corresponded to values measured in the laboratory. The set time was 7.5 hours, which is less than the 24 hours required to sustain next day operations and to meet the production requirement for filling the waste tanks. The average compressive strength of the samples that were cured for 28 days was 2,800 psi [19 MPa], which meets the >2,000 psi [14 MPa] engineering and FTF Performance Assessment requirement (SRS-REG-2007-00002 Rev. 1). The peak temperature in the grout occurred after 82 hours with a semi-adiabatic temperature rise of 23 °C [41 °F], which was considered to meet the objective for grout that can be mass placed.

C-SPP-F-00055, Forty (2011), *Furnishing and Delivery of Tank Closure Grout*, Rev. 2.

C-SPP-F-00055 is a detailed listing of the procurement specifications for furnishing and delivery of tank closure grout, including trial batching to demonstrate the production grout will meet the specification requirements. ASTM International (formerly the American Society of Testing and Materials) and American Concrete Institute (ACI) standards and specifications are generally specified. The three mix designs (LP#8-16, LP#8-16C, and LP#8-20) recommended in SRNL-L3100-2011-00180 are listed as the initial mix designs, although a later document (C-DCF-F-01524), which is discussed below, eliminates LP#8-16C and LP#8-20 from the list of grout mixes to be supplied. The batch plant capacity is specified as (i) sustained average capacity of 400 yd^3/day [300 m^3/day] through a five day work week and (ii) a sustained average capacity of 70 yd^3/day [50 m^3/day] for an eight hour period. The estimated duration of grout production is six months and the estimated quantity of grout is 17,064 yd^3 [13,046 m^3], based on filling Tanks 18F and 19F.

C-TRT-F-00005, Ganguly (2012), *Technical Summary Report for Tanks 18F and 19F Closure — Initial Trial Batching* (U), Rev. 0.

Tank grout trial batching of vendor supplied grout mix and its components was performed in March 2012, prior to the start of production grouting to fill Tanks 18F and 19F, to demonstrate the capability of the vendor to produce tank closure grout in compliance with the tank fill grout specification requirements. This report documents the results of trial batching and initial qualification testing. The tests demonstrate that the grout supplier can produce and deliver grout in accordance with the tank closure grout specification requirements.

The report discusses five action items that resulted from discrepancies between the vendor test data and the grout specification requirements. These discrepancies apparently were identified during two previous assessments of vendor supplied grout. The report states that additional information supplied by the vendor was satisfactory such that the grout supplier is considered able to produce and deliver grout in accordance with the specification requirements.

One deficiency identified in a previous assessment (and discussed in Appendix I of the report) pertains to the lack of 16-day test data for Potential Alkali Reactivity per ASTM Standard C1260 on coarse aggregate. To resolve this deficiency, the vendor noted that (i) 5- to 14-day Potential Alkali Reactivity test data for the coarse aggregate indicate the average length of expansion is very insignificant (0.04 percent) such that a 16-day test will have no significant adverse effect on the grout mix quality, and (ii) because the coarse aggregates came from the same quarry that was certified in 2006, no new testing on the aggregates was performed. SRS concludes that based on the additional information the vendor provided, the supplied aggregates are acceptable for use in the grout mix.

C-DCF-F-01524, Ganguly (2012), *Revise Tanks 18F & 19F Closure Grout Specification*.

This document describes the following changes to the Tanks 18F and 19F closure grout specification:

- ASTM 5971 (Standard Practice for Sampling Freshly Mixed Controlled Low-Strength Material) and ASTM 4832 [Standard Test Method for Preparation and Testing of Controlled Low-Strength Material (CLSM) Test Cylinders] were replaced with ASTM C172 (Standard Practice for Sampling Freshly Mixed Concrete) and ASTM C31 (Standard Practice for Making and Curing Concrete Test Specimens in the Field). The specified ASTM standards were replaced because the selected grout mix, which was selected after laboratory and field mock-up tests, behaves more like high flow concrete with small aggregates, instead of a controlled low-strength material.

- The previous specification included grout mix component specification for the base mix formulation LP#8-16 and alternative formulations LP#8-16C, and LP#8-20. Because only LP#8-16 was verified through field testing, the specifications for LP#8-16C and LP#8-20 were deleted from the revised grout specification document.

- The amount and commercial brand of admixtures (high range water reducer and viscosity modifier) to be used in the tank grout were changed.

C-DCF-F-01527, Forty (2012), *Revise Tanks 18F & 19F Closure Grout Specification for Testing Samples*.

This document describes a change in the required method for sampling tank grout that is delivered to the site. ASTM Standard C172 requires that samples be obtained by collecting two or more portions taken at regularly spaced intervals during discharge of the middle portion of the batch and combining them into one composite sample. In the revised procedure, only single portion samples will be taken after 0.8 yd^3 [0.6 m^3] has been discharged from the truck. Because samples will be taken at a station at the top of the hill away from the hoppers, the revised sampling procedure will facilitate traffic flow, worker safety, and ensure grout quality. The revised procedure is justified on the basis of tests comparing the compressive strength and slump flow of single portion samples and composition samples. The tests indicate that there was no variation in the slump flow between the two sample types and only a slight variation in compressive strength. The test results are included in the document.

SRR-LWP-2012-00034, Guilherme (2012), *SRR Subcontractor Surveillance Plan Furnishing and Delivery of Tank Closure Grout (TK 18/19)*.

This document lists the Quality Control (QC) surveillance and Quality Assurance (QA) assessment activities SRR Construction Quality Services will perform in its oversight of the subcontractor during furnishing and delivery of tank closure grout for Tanks 18F and 19F. QC surveillance includes: (i) inspection of production mixes, (ii) grout inspection and testing, (iii) material testing and control, (iv) verification of measuring and test equipment calibration, (v) batch procedures, and (vi) receipt inspection. QA assessment will verify conformance to the procurement specification, procedures, and applicable codes and standards.

SRR-LWE-2012-00036, Thaxton (2012), *Tank 18F and 19F Closure Assurance Plan*, Rev. 0.

This closure assurance plan identifies process and documentation requirements and provides a strategy to ensure the process requirements are met and the required documentation is generated and retained during grouting of Tanks 18F and 19F. The plan is considered to be a tool for DOE to ensure that Tanks 18F and 19F are closed successfully, while meeting all regulatory process and documentation requirements.

The plan lists the requirements and documentation for the: (i) initial trial batch qualification; (ii) surveillances required prior to production grouting; (iii) SRR point of delivery sampling and acceptance of delivery; (iv) production grout sample testing; (v) supplier certification, testing, and documentation requirements for grout components during production grouting; (vi) surveillances of grout supplier and testing laboratories during production grouting; (vii) in-tank surveillance of production grouting; and (viii) in-tank surveillance of grouting of abandoned equipment. Attachment 1 of the document provides a crosswalk between the closure assurance requirements and the FTF Performance Assessment requirements.

Alexander (2012), *Placement of Grout Tank 18 Center Riser*, Work Order No. 01087939–16 and Patton (2012), *Placement of Grout Tank 19 Center Riser*, Work Order No. 01087938–15.

These work orders provide detailed lists of activities to be performed during grouting of Tanks 18F and 19F through the center risers. The work orders estimate that it would have taken approximately eight lifts to the tank spring line for a total of approximately 7,200 yd^3

[5,500 m^3] of grout, then the dome would be filled with an additional ~1,140 yd^3 [~871 m^3] of grout, for a tank fill total of approximately ~8,340 yd^3 [~6380 m^3]. The work orders include safety precautions and limitations that were to be followed (including radiation control procedures) during grouting.

Isherwood (2012), *Placement of Grout Tank 18 Various Equipment Locations*, Work Order No. 01087939–17 and Patton (2012), *Placement of Grout Tank 19 Various Equipment Locations*, Work Order No. 01087938–16.

These work orders provide detailed lists of activities that were to be performed during grouting of equipment and risers for Tanks 18F and 19F. For Tank 18F, the risers include East Riser, West Riser, Northeast Riser, Northwest Riser, Southeast Riser, Southwest Riser, Center Riser, and Mechanical Cleaning Riser. For Tank 19F, the risers include East Riser, West Riser, Northeast Riser, Waste Transfer Containment Enclosure (near northeast riser), Northwest Riser, Southeast Riser, and Southwest Riser. The work orders include safety precautions and limitations that were to be followed (including radiation control procedures) during grouting.

SRR-CWDA-2012-00127, Ross (2012), Memorandum Regarding Tank 18F Grouting Operation Videos

This memorandum transmitted to NRC video recording of Tanks 18F grout pours and an in-tank daily inspection in response to an action item identified during the onsite observation visit that occurred on June 12, 2012 (The onsite observation report is available in ADAMS at Accession No. ML12191A210). The approximately 35 hours of video footage that was transmitted captures 12 days of grouting operations for Tank 18F from April 12, 2012 through June 28, 2012. The document identifies whether the initial four hours or the last four hours of grout pouring operations were video recorded for each specified day.

SRR-LWE-2012-00217, Frazier (2013), *Tanks 18 and 19 Final Configuration Report Inputs*, Rev. 1

This report documents data from the grouting of Tanks 18F and 19F for future reference and includes deviations from the configuration described in the Closure Module (SRR-CWDA-2010-00003). The data include important dates in which grouting began and ended, average compressive strength test results, bulk fill and equipment fill grout volume estimates, and differences in the final configurations of Tanks 18F and 19F from those that are spelled out in the Closure Module (SRR-CWDA-2010-00003). DOE reports average compressive strength test results from a total of 1,161 test cylinders. The average of the results for the compressive strength tests that were performed after a 28-day cure is 2,880 psi [19.86 MPa] which exceeded the design compressive strength of 2,000 psi [14 MPa]. The average of the 90-day compressive strength test results is 4,680 psi [32.3 MPa]. DOE also reports that the volume of bulk fill grout was estimated at 8,343 yd^3 [6,379 m^3] per tank while actual bulk fill volumes are 8,094.5 yd^3 [6,188.7 m^3] and 8,090 yd^3 [6,185 m^3] for Tank 18F and 19F respectively.

SRR-CWDA-2012-00170, Martin (2013), *Tanks 18 and 19 Final Configuration Report for F-Tank Farm at the Savannah River Site*, Rev. 0.

This report documents completion of operational closure of Tanks 18F and 19F and the final as-built configuration of the closed waste tanks and any field conditions that differ from those described in the Closure Module (SRR-CWDA-2010-00003). The document summarizes isolation and grouting activities that have been completed and monitoring that will occur during the interim period between operational closure of Tanks 18F and 19F and the final closure of FTF. In terms of grouting, this report summarizes bulk tank fills, equipment fills, and modifications to waste tank tops to accommodate riser grouting. Details on grouting of Tanks 18F and 19F are provided in Work Orders No. 01087939 and 01087938, respectively.

For final bulk grout fill conditions, the report compares actual grout volumes to an estimated volume of 8,343 yd^3. [6,379 m^3]. The actual volumes were estimated from the number of grout trucks and an assumption of 8 yd^3 [6 m^3] of grout per truck, which was not verified for each truck. For Tanks 18F and 19F, as first reported in SRR-LWE-2012-00217, the actual grout bulk fill volume is approximately 8,094 yd^3 [6,188 m^3] and 8,090 yd^3 [6,185 m^3] respectively. This report states that quality control of the grout production was implemented in accordance with C-SPP-F-00055. During grouting of both tanks, over 900 grout test cylinders were collected. The average 90-day compressive strength of the grout cylinders, as first reported in SRR-LWE-2012-00217, is 4,680 psi [32.3 MPa], which is greater than the 2,000 psi [14 MPa] described in the Closure Module (SRR-CWDA-2010-00003). The report documents one bulk fill deviation for actual conditions from the Closure Module, namely that the Tank 18F ventilation cross-tie is a 6-in [15-cm] diameter pipe with no jacket rather than a 4-in [10-cm] diameter pipe in a 6-in [15-cm] diameter jacket as described in the Closure Module.

For final equipment grout fill conditions, the report compares estimated grout fill volumes to actual grout fill volumes for in-tank equipment. The report cautions that estimated fill volumes rely on assumptions about internal void space and potential grout flow paths. Certain equipment contained long, narrow, tortuous flow paths that debris may have potentially blocked resulting in less grout fill than estimated, such as is posited for the grout fill volume in the standard mixer slurry pump in the Tank 18F East Riser that is lower (approximately 37%) than estimated. The report also documents four equipment fill deviations for actual conditions from the Closure Module (SRR-CWDA-2010-00003):

1. Two 2-in [5-cm] diameter vertical stainless steel pipes in the center riser of Tank 18F that were not previously identified were found to extend from above the tank top to near the tank floor, approximately 44 ft [13.4 m] below the tank top. The pipes were filled with 5 gallons [19 L] and 8 gallons [30 L] respectively compared to an estimated 8.7 gallons [32.9 L] of fill based on an assumed 50-ft [15-m] length.

2. The Tank 19F Northeast Riser thermowell, which is listed in Table 7.2-2 of the Closure Module (SRR-CWDA-2010-00003), was removed prior to grouting.

3. Bubbler tubes and a pipe containing a conductivity probe were identified in the Tank 19F Northwest Riser, but are not listed in Table 7.2-2 of the Closure Module (SRR-CWDA-2010-00003). The tubes and pipe were grouted when the riser was filled with grout.

4. Two 1.5-in [3.8-cm] diameter, approximately 5-ft [1.5-m] long stainless steel pipes associated with spray wash equipment were identified in the Tank 19 Northeast Riser, but are not listed in Table 7.2-2 of the Closure Module (SRR-CWDA-2010-00003). One pipe was filled with 4 gallons [15 L] and the other with 1/3 gallon [1-1/3 L] of grout.

NRC Evaluation:

Grout Formulation:

With regard to the final grout formulation (LP#8-16) selected for Tanks 18F and 19F, the following table compares the recommended grout mix formulation (SRNL-STI-2011-00551) with that assumed in Denham's (WSRC-STI-2007-00544) conceptual model of waste release (and E_h and pH transitions assumed in the FTF Performance Assessment [SRS-REG-2007-00002, Rev. 1]).

Table 2 shows that the amount of slag in LP#8-16 is the same as the value Denham used in his calculations. The LP#8-16 portland cement amount is higher than Denham's, which would result in higher pH buffering capacity (fly ash is approximately the same). The water-to-cementitious materials ratio in LP#8-16 is lower than in Denham's, which would result in lower porosity and hydraulic conductivity. The measured effective porosity of the LP#8-16 grout reported in Table 3-5 of SRNL-STI-2011-00551 is 0.21, versus 0.266 used in the FTF Performance Assessment (SRS-REG-2007-00002, Rev. 1). Also, the measured K_{sat} of the LP#8-16 specimens ranged from 3.1×10^{-10} to 2.1×10^{-9} cm/s [1.0×10^{-11} to 6.9×10^{-11} ft/s], lower than the requirement of 3.6×10^{-8} cm/s [1.2×10^{-9} ft/s]. Thus, the initial chemical and expected hydraulic properties of the LP#8-16 formulation used to fill Tanks 18F and 19F are generally consistent with FTF Performance Assessment assumptions.[2] However, the measurements are on short-term properties of the grout and do not address the physical and chemical evolution of the tank grout over time. Additionally, FTF Performance Assessment conceptual model assumptions like matrix versus fracture flow in waste release modeling that affect chemical transition times and potential for tank grout by-pass are not explicitly addressed in the DOE grout specifications. The distinction between flow through cracks in the grout monolith versus flow through the grout monolith matrix is important to performance because DOE assumes in its reference case (i.e., Case A) that infiltrating groundwater reacts with the tank grout and is chemically altered by those interactions. In the FTF Performance

Table 2. Comparison of Assumed Versus Final Specifications for Tanks 18F and 19F Fill Grout

Grout component	Reducing grout mix formula†	Recommended LP#8-16 all-in-one grout mix formula
Portland cement	75 lb/yd^3	125 lb/yd^3
Fly ash	375 lb/yd^3	363 lb/yd^3
Slag	210 lb/yd^3	210 lb/yd^3
Sand	2,300 lb/yd^3	1,790 lb/yd^3
Gravel (No. 8; 3/8")	0	800 lb/yd^3
Water	501 lb/yd^3	405 lb/yd^3 [48.5 gal/yd^3]
Additives	NA	ViscoCrete®: 41 fl.oz/yd^3 Kelco-Crete®: 200 gram/yd^3
Calculated w/c ratio	0.759	0.580

† WSRC-STI-2007-00544

[2] A subsequent report by Denham (SRNL-STI-2012-00087) used a grout formulation consistent with the LP#8-16 formulation used in Tanks 18F and 19F.

Assessment (SRS-REG-2007-00002, Rev. 1), the chemistry of the conditioned groundwater flowing through the tank grout helps maintain the low solubility and release of key radionuclides from the residual waste. If flow were primarily through cracks that by-pass the tank grout, the release rates of key radionuclides could be significantly greater and could occur much earlier in time than assumed in DOE's FTF Performance Assessment (SRS-REG-2007-00002, Rev. 1).

Stefanko and Langton (SRNL-STI-2011-00551) acknowledged shrinkage could provide fast flow pathways and listed minimizing the potential for cracking as a grout selection criterion. However, no testing of shrinkage or cracking of the recommended grout mixture was performed. The recommended grout mixture had a lower K_{sat} than assumed in the FTF Performance Assessment (SRS-REG-2007-00002, Rev. 1). While a lower K_{sat} is beneficial with respect to bulk matrix flow, grouts with lower hydraulic conductivity will tend to have less water flow through the matrix and greater potential flow through cracks, annuli, and voids, if present. Stefanko and Langton (SRNL-RP-2011-00551) recommended that final development and testing of shrinkage compensating all-in-one mix design should be conducted to help mitigate the inherent potential for fast pathways. NRC conducted onsite observations on June 12, 2012 (ML12191A210) to observe Tanks 18F and 19F grouting and on September 26-27, 2012 (ML12299A190) to follow-up on items related to Tank 18F and 19F grouting that arose from the June observation. When questioned by NRC staff regarding plans for additional testing, DOE indicated that its plans for shrinkage testing would become clearer in the Liquid Waste Performance Assessment Maintenance Plan, which DOE indicated was planned for March 2013. NRC reviewed the Performance Assessment Maintenance Plan (SRR-CWDA-2013-00049, Rev. 1), but was unable to gain additional information regarding plans for testing and development of new formulations to address tank grout shrinkage. During an onsite observation to observe grouting of Tanks 5F and 6F, which was conducted on August 27-28, 2013 (The onsite observation report is in preparation and will be issued later this year.), NRC inquired about plans for testing of new formulations to address tank grout shrinkage. DOE indicated that it currently does not have plans to conduct shrinkage testing, but may pursue tests in the future. NRC staff concur with Stefanko and Langton's recommendations for testing of admixtures and implementation of measures to help mitigate tank grout shrinkage and will continue to evaluate this technical issue in future onsite observations.

In C-TRT-F-00005, Ganguly mentions that alkali-silica reaction will have no significant adverse effect on grout mix quality based on short-term tests (≤ 16 days) of alkali-silica reactivity (ASR). ASR is a process whereby reactive aggregates break down under exposure to the highly alkaline pore solution in concrete, which can result in significant expansion and, in some cases, cause cracking of concrete. At the June 12, 2012, onsite observation (ML12191A210), NRC staff communicated its concern with the potential formation of cracks in the tank grout due to ASR. This concern arose because the grout being used to fill Tanks 18F and 19F included ⅜-in [9.53-mm] granite "pea gravel" as aggregates, instead of using only sand aggregate as described in the DOE's FTF Performance Assessment document (SRS-REG-2007-00002, Rev. 1), and because of recent observations of concrete cracking at the Seabrook nuclear power plant in Seabrook, New Hampshire. In that facility, granite aggregates also were used in the concrete mix. ASR is a slow process and its occurrence at Seabrook became evident only decades after the plant was constructed. The Tanks 18F and 19F grout fill mix contain less Portland cement than the concrete mix used at Seabrook and likely would be less susceptible to ASR. Nevertheless, NRC staff is concerned that DOE's criterion for acceptance of vendor supplied granite aggregate relies on short-term alkali reactivity tests (ASTM Standard C1260), which is unlikely to predict the occurrence of ASR over the very long period of performance for compliance with the performance objective specified at 10 CFR 61.41. NRC staff recommends that DOE consider conducting tests to evaluate potential ASR in tank grouts and its potential effect on long-term performance of the engineered barrier system.

Furthermore, Stefanko and Langton (SRNL-STI-2011-00551) indicated that sources of cement and fly ash have changed from previous tests and currently available portland cements contain up to 5 % by weight limestone. Substitution of up to 5 % by weight limestone in commercially available portland cement could vary the minerals that form upon cement hydration and the pH buffering capacity of the grout from the grout mix considered in DOE's FTF Performance Assessment (SRS-REG-2007-00002, Rev. 1). At the June 12, 2012 onsite observation, NRC staff communicated its concern that a reduction in the amount of portland cement in the grout mix would lower the pH buffering capacity of the grout and could affect the timing of release of key radionuclides (ML12191A210). NRC staff recommends that DOE evaluate the effect of limestone substitution in portland cement on the pH buffering capacity of the grout and the release of key radionuclides.

NRC staff was initially concerned that the slump flow specification of 24 to 28 in [61 to 71 cm] provided in SRNL-RP-2011-00977 was not sufficient to enable the grout to completely fill the tanks and seal around the internal tank fixtures. This concern arose from observations of an intermediate-scale grout monolith specimen constructed by the Center for Nuclear Waste Regulatory Analyses (CNWRA) using a previously proposed SRS tank grout formulation (Walter et al., 2010) with a slump flow specification of 28 to 30 in [71 to 76 cm]. The thinner CNWRA-prepared grout specimen was not self-leveling and the grout surface had a slope ranging from 4 to 8 percent with a 3 m [10 ft] radius and 0.76 m [2.5 ft] fill thickness.

Furthermore, the CNWRA grout specimen was also characterized by the presence of "lobes"[3], which were accentuated by the limited ability of the tank grout to self-level and which were due to the incomplete lateral delivery of tank grout from a centrally located placement point outwards toward the specimen walls. In addition to concerns regarding the ability for DOE to fill the tanks with reducing grout, NRC was also concerned with the presence of grout mounds and flow lobes such as these because Dinwiddie, et al. (2011; 2012) indicated that the lobe interfaces, as well as interfaces between successive lifts, are subject to shrinkage and could form high hydraulic conductivity zones through the monolith.

Following observations of potential grout segregation, which is discussed in detail below, NRC staff is less concerned about the ability to fill tanks and the creation of higher hydraulic conductivity zones, which may be associated with lobe interfaces, through the monolith. Rather, NRC staff is now more concerned with the potential for segregation and lower quality grout to be delivered to the periphery of Type IV tanks enhancing shrinkage along the tank wall and focused flow around the reducing grout leading to less conditioning of infiltrating water than if water flowed primarily through the grout.

During the June 12, 2012, onsite observation, NRC staff inquired about the extent of mounding at the center of the tanks and the ability to completely grout the tank at its periphery (ML12191A210). DOE indicated that additional access points may be created to ensure that the tanks are completely filled; however, no additional access points were created. NRC staff also observed the appearance of grout lobes in DOE-supplied video that documents the grouting of

---

[3] A grout flow lobe is a fan-shaped mass of grout that forms on a slope by the changing direction of flow.

Tanks 18F and 19F and expressed concerns about the potential for flow paths to be created between grout lobes and successive lifts. NRC requested DOE to provide a video record of tank filling that would be beneficial to NRC staff understanding of (i) the evolution of grout mounding and lobe formation over time and (ii) the potential for lower quality grout to form near the tank walls due to the use of process water (and resultant higher water-to-cement ratios of grout in contact with collected water at the tank walls) at the start of each day of grouting or segregation of grout components as the grout flows toward the periphery of the tanks. As part of their ongoing presence at the site, officials from the State of South Carolina's Department of Health and Environmental Control indicated a willingness to share information related to these grout features observed during their future inspections. South Carolina's Department of Health and Environmental Control provided video footage obtained from grouting of Tank 19F to NRC staff during the September 27-28, 2012, onsite observation visit (ML12299A190)

On August 17, 2012, DOE provided NRC a video record of tank filling (SRR-CWDA-2012-00127). Subsequently, NRC and DOE conducted a teleconference (ML13127A291) to discuss NRC observations from the video. Video footage of grout emplacement in Tank 18F suggests that the zero-bleed grout formulation may have been handled in such a way during grouting that water segregation occurred. NRC staff in reviewing the video footage from Tanks 18F (SRR-CWDA-2012-00127) and 19F, which was provided by the South Carolina Department of Health and Environmental Control (ML12299A190), made the following observations to DOE in a teleconference on May 1, 2013 (ML13127A291):

- Material tested to be zero-bleed may later be handled in such a way that excessive water segregation occurs and this excessive water segregation is believed to have been observed in grouting videos.

- Vibration during transport and dropping concrete from height during placing is known to exacerbate the production of segregation water.

- Excess water that segregates from grout is more flowable than grout and was observed to preferentially flow to the tank perimeter.

- Excess water was recognized in grouting video by its low albedo (i.e., dark color) and flowability.

- Segregated water was not tremie flushwater (i.e., clear, uncolored)

- Grout matrix porosity and permeability may increase radially due to shedding of segregated water to zones near tank perimeter.

- Shrinkage gaps at the tank perimeter may be significant.

- Grout mounded high in the tank center will hydrate in a relatively dry microclimate, whereas, grout submerged under standing water at tank perimeter will hydrate in a much wetter microclimate; because of this, grout properties are not likely to be uniform along the tank radius.

As a follow-on action from the teleconference, NRC provided DOE these main points from reviewing the video footage. Also, as a follow-on action, DOE agreed to respond to NRC at a later date, either in writing or via teleconference.

With respect to equipment grouting, DOE provided information during the June 12, 2012, onsite observation (ML12191A210) regarding its process for equipment grouting, as well as the implementation of its equipment grouting plans during grouting of Tanks 18F and 19F. During the September 26-27, 2012, onsite observation (ML12299A190), NRC staff requested documentation of DOE's equipment fill mock-up test report (SRNL-STI-2011-00564). The mock-up test focused on the ADMP because of its large size and complexity of the flow path in it. The ADMP has a 55-ft [16.8-m] long shaft, but the mock-up test utilized a 4-ft [1.2-m] long test form. The test results indicated potential problems with chamber flooding, which could result in incomplete filling of the void spaces in the ADMP. NRC staff is concerned the ADMP mock-up test provided insufficient data to support a conclusion that the ADMP void spaces could be completely filled with the T1a-62.5FA or T1a-75FA grout and eliminate a potential vertical flow path through the grouted tank. NRC will continue to monitor the equipment grouting and testing of the recommended equipment grout fill formulation for future tanks. The NRC staff will also continue to evaluate the potential for annuli to form around internal tank fixtures such as grouted abandoned equipment and cooling coils that may lead to preferential or by-passing flow around or through the tank grout.

In SRNL-STI-2011-00551, the density estimate of 2.21 g/cm^3 [138 lb/ft^3] listed in Table 3-4 for LP#8-16 is not consistent with the values of measured dry bulk density and calculated particle density listed in Table 3-5. NRC staff will follow-up with DOE regarding this discrepancy. The NRC staff also will follow-up with DOE in regard to the characteristics of the final and completed moisture retention function (i.e., volumetric water contents at pressures ranging between 15 and 45 bars [15 and 44 atm]).

Thermal Evaluation:

Stefanko and Langton (SRNL-STI-2011-00749) concluded that the adiabatic temperature rise of 23 °C [41 °F] observed in the 1 yd^3 [0.8 m^3] grout scale up test meets the objective for grout that can be mass placed. The NRC staff believes this conclusion lacks sufficient technical basis. The amount of grout that is emplaced in SRS tanks is much larger than 1 yd^3 [0.8 m^3], which would result in a much higher temperature rise than was observed in the grout scale up test. In addition, tank grouting involves sequential grout pours that would generate multiple and overlapping heat pulses. A more detailed thermal analysis that considers the specific grout pour sequence and geometry to determine the potential for thermal cracking of the tank grout would provide additional model support.

DOE did not measure the thermal properties of the selected grout mix, LP#8-16, to validate the adiabatic temperature rise for complete hydration that Stefanko and Langton (SRNL-STI-2011-00551) estimated. Measuring the adiabatic temperature rise and thermal properties of the LP#8-16 mix would ensure a complete documentary record.

QA Evaluation:

The DOE quality assurance plan, as described in SRR-LWE-2012-00036, is clear and, if implemented properly, should ensure that Tanks 18F and 19F are closed according to plan, while meeting all regulatory process and documentation requirements. As part of NRC monitoring activities, the NRC staff will continue to evaluate during its onsite observation visits whether the DOE quality assurance plan is being implemented effectively.

Final Configuration:

The final configuration of Tanks 18F and 19F, as described in SRR-CWDA-2012-00170, and the reported deviations from the Closure Module (SRR-CWDA-2010-00003) are clear. The actual grout bulk fill volumes for each tank were each approximately 3% less than initially estimated for Tanks 18F and 19F. While the volumes are generally in good agreement on a percentage basis, DOE does not document for the record expected causes for the bulk fill grout deviations to mitigate potential concern over the formation of preferential pathways. This information could also be used to improve future volume estimates. Compressive strength testing indicated that the strength of the emplaced bulk fill grout exceeds the compressive strength assumed in the FTF Performance Assessment (SRS-REG-2007-00002, Rev. 1). In contrast to bulk grout fill, the Final Configuration report (SRR-CWDA-2012-00170) does provide documentation regarding potential causes of significant deviations in equipment grout fill volumes in the Final Configuration Report, however, estimates of remaining void volumes are not provided.

Teleconference or Meeting:

NRC staff plans to discuss further with DOE the observations of apparent segregation during grouting of Tanks 18F and 19F. In a teleconference on May 1, 2013, NRC staff presented key points regarding its review of video footage during grouting of Tanks 18F and 19F (ML13127A291). As a follow-on action, NRC provided DOE its main points from reviewing the video footage. Also, as a follow-on action, DOE agreed to respond to NRC at a later date, either in writing or via teleconference.

Follow-up Actions:

At a May 1, 2013, teleconference (ML13127A291), DOE agreed to respond to NRC staff's main points from its review of the Tank 18F and 19F grouting video footage.

NRC staff will continue to monitor DOE's grout formulations under Monitoring Factors 3.3, "Shrinkage and Cracking", and 3.4, "Grout Performance" listed in NRC staff's FTF Monitoring Plan (ML12212A192) focusing on the technical concerns listed in this review report.

Open Issues:

No open issues result from this technical review. However, insufficient information is provided to address the likelihood for preferential pathways to form through the grout monolith including those from shrinkage, cracking, grout seams, and voids. DOE testing of and efforts to mitigate grout shrinkage have been postponed. NRC will continue to follow-up on this technical issue under Monitoring Factor 3.3, "Shrinkage and Cracking" (See ML12212A192).

Conclusions:

The NRC staff concludes that performance requirements for grout formulations recommended and tested for Tanks 18F and 19F closure are generally consistent with bulk, initial properties assumed in DOE's FTF Performance Assessment (SRS-REG-2007-00002, Rev. 1). However, the NRC staff also concludes that DOE has not provided sufficient information and testing to adequately invalidate alternative conceptual models reflecting preferential flow through the tank grout monolith that might result from grout shrinkage and cracking.

Thus, NRC considers the following conclusion more significant for providing reasonable assurance that that the 10 CFR Part 61 performance objectives will be met. DOE indicated that it currently does not have plans to conduct shrinkage testing, but may pursue tests in the future. The NRC staff concur with Stefanko and Langton's recommendations for testing of admixtures and implementation of measures to help mitigate tank grout shrinkage and will continue to evaluate this technical issue in future onsite observations as part of Monitoring Factor 3.3, "Shrinkage and Cracking" (ML12212A192).

The NRC staff also considers the following five conclusions to be of lesser importance at this time than the aforementioned conclusion regarding shrinkage to providing reasonable assurance the performance objectives of 10 CFR Part 61 will be met. NRC believes that the following five conclusions are less significant at this time because they are related to features or processes that tend to promote or involve water flow through the grout leading to more chemical conditioning of the water than would likely occur should the water be focused along the tank wall.

First, the NRC staff believes DOE's conclusion that the temperature rise was sufficiently low for bulk grouting of Tanks 18F and 19F based on a 1 yd^3 [0.8 m^3] bulk scale-up test and will continue to evaluate this technical issue in future onsite observations. A more detailed thermal analysis that considers the specific grout pour sequence and geometry to determine the potential for thermal cracking of the tank grout would improve model support. The NRC staff will continue to monitor DOE efforts to assess the potential for thermal cracking of the tank grout as part of Monitoring Factor 3.3, Shrinkage and Cracking" (ML12212A192).

Second, DOE did not document in the Final Configuration Report (SRR-CWDA-2012-00170) expected causes for the bulk fill grout deviations to mitigate potential concern over the formation of preferential pathways. The Final Configuration Report does provide documentation regarding potential causes of significant deviations in equipment grout fill volumes, however, estimates of remaining void volumes are not provided (e.g., ADMP). This information could also be used to improve future volume estimates. NRC staff will continue to monitor DOE estimates of void volumes including whether there is additional information that would support a conclusion that the ADMP void spaces were completely filled as part of Monitoring Factor 3.3, "Shrinkage and Cracking" (ML12212A192).

Third, the NRC staff will also continue to monitor void volumes in the emplaced grout to the extent information is available, the importance of alkali-silica reactivity on cementitious material degradation and the impact of limestone additions to the grout mix on pH buffering of water contacting the emplaced grout. This information would enhance DOE's demonstration that the Part 61 performance objectives are met with reasonable assurance.

Fourth, the NRC staff communicated its concern with the potential formation of cracks in the tank grout due to ASR. The NRC staff is concerned that DOE's criterion for acceptance of vendor supplied granite aggregate relies on short-term alkali reactivity tests (ASTM Standard C1260), which is unlikely to predict the occurrence of ASR over the very long period of performance for compliance with the performance objective specified at 10 CFR 61.41. Evaluating potential ASR in tank grouts and its potential effect on long-term performance of the engineered barrier system would improve model support for the performance of the grout and understanding of the potential for cracking of the grout. The NRC staff will continue to monitor DOE efforts to evaluate potential ASR and its potential effect on long-term performance under Monitoring Factor 3.3, "Shrinkage and Cracking" (ML12212A192).

Finally, the NRC staff is concerned that the use of commercially-available portland cements in Tanks 18F and 19F that differ from the grout mix considered in the FTF Performance Assessment (SRS-REG-2007-00002, Rev. 1) because of substitution of up to 5% by weight limestone would lower the pH buffering capacity of the grout and could affect the timing of release of key radionuclides. Evaluating the effect of limestone substitution in portland cement on the pH buffering capacity of the grout and the release of key radionuclides improves model support for the modeling of chemical states and transitions of water contacting the residual waste. The NRC staff will continue to monitor DOE efforts to evaluate limestone substitution and its potential effect on long-term performance under Monitoring Factor 6.2, "Model and Parameter Support" (ML12212A192).

References:

ASTM Standard 4832, 2010. "Standard Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders." West Conshohocken, Pennsylvania: ASTM International. 2010.

ASTM Standard 5971, 2007. " Standard Practice for Sampling Freshly Mixed Controlled Low-Strength Material" West Conshohocken, Pennsylvania: ASTM International. 2007.

ASTM Standard C31, 2012. "Standard Practice for Making and Curing Concrete Test Specimens in the Field." West Conshohocken, Pennsylvania: ASTM International. 2012.

ASTM Standard C172, 2010. "Standard Practice for Sampling Freshly Mixed Concrete." West Conshohocken, Pennsylvania: ASTM International. 2010.

ASTM Standard C1611, 2009. "Standard Test Method for Slump Flow of Self-Consolidating Concrete." West Conshohocken, Pennsylvania: ASTM International. 2009.

ASTM Standard C1260, 2007. "Standard Test Method for Potential Alkali Reactivity of Aggregates." West Conshohocken, Pennsylvania: ASTM International. 2007.

Dinwiddie, C.L., D.R. Bannon, M.K. Todt, G.R. Walter and M.M. Roberts. “Draft Fiscal Year 2012 Meso- and Intermediate-Scale Grout Monolith Test Bed Experiments: Results and Recommendations.” San Antonio, Texas: Center for Nuclear Waste Regulatory Analyses. June 2012.

Dinwiddie, C.L., G.R. Walter, G. Light, S. Winterberg, D. Wyrick, D. Sims, and K. Smart. “Bonding and Cracking Behavior and Related Properties of Cementitious Grout in an Intermediate-Scale Grout Monolith.” San Antonio, Texas: Center for Nuclear Waste Regulatory Analyses. September 2011.

ML12191A210. Persinko, A., “U.S. Nuclear Regulatory Commission June 12, 2012, Onsite Observation Report for the Savannah River Site F-Tank Farm Closure.” Memorandum to J. Folk. ADAMS ML12191A210. September 5, 2012.

ML12212A192. “U.S. Nuclear Regulatory Commission Plan for Monitoring Disposal Actions Taken by the U.S. Department of Energy at the Savannah River Site F-Area Tank Farm Facility in Accordance with the National Defense Authorization Act for Fiscal Year 2005.” ADAMS ML12212A192. Washington, DC: U.S. Nuclear Regulatory Commission. January 2013.

ML12299A190. Mohseni, A. “U.S. Nuclear Regulatory Commission September 26-27, 2012, Onsite Observation Report for the Savannah River Site F-Tank Farm Closure.” Memorandum to J. Folk. ADAMS ML12299A190. Washington, DC: U.S. Nuclear Regulatory Commission. December 5, 2012.

ML13127A291. Felsher, H. "Summary of May 1, 2013, Clarifying Teleconference Call Between the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy Regarding Tank 18 Grouting Operation Videos from F-Area Tank Farm at the Savannah River Site." Note to File PROJ0734. ADAMS ML13127A291. Washington, DC: U.S. Nuclear Regulatory Commission. May 24, 2013.

SRNL-STI-2012-00087, Denham, M.E. "Evolution of Chemical Conditions and Estimated Plutonium Solubility in the Residual Waste Layer During Post-Closure Aging of Tank 18." Revision 0. Aiken, South Carolina: Savannah River National Laboratory. February 2012.

SRR-CWDA-2010-00003, "Industrial Wastewater Closure Module for the Liquid Waste Tanks 18 and 19 F-Area Tank Farm, Savannah River Site." Revision 2. Aiken, South Carolina: Savannah River Remediation, LLC. January, 2012.

SRR-CWDA-2013-00049, Rev. 1, "Savannah River Site Liquid Waste Facilities Performance Assessment Maintenance Program—FY2013 Implementation Plan." Revision 1. Aiken, South Carolina: Savannah River Remediation LLC. May 2013.

SRS-REG-2007-00002, Rev 1. "Performance Assessment for the F-Tank Farm at the Savannah River Site." Revision 1. Aiken, South Carolina: Savannah River Remediation, LLC. March 31, 2010.

Walter, G.R., C.L. Dinwiddie, D. Bannon, G. Frels, and G. Bird. "Intermediate Scale Grout Monolith and Additional Mesoscale Grout Monolith Experiments: Results and Recommendations." Status Report. San Antonio, Texas: Center for Nuclear Waste Regulatory Analyses. September 2010.

WSRC-STI-2007-00544, Denham, M.E. "Conceptual Model of Waste Release from the Contaminated Zone of Closed Radioactive Waste Tanks." Revision 2. Aiken, South Carolina: Savannah River National Laboratory. November 2010.