December 16, 2014

MEMORANDUM TO: Gregory Suber, Chief
Low-Level Waste Branch
Division of Decommissioning, Uranium Recovery, and Waste Programs
Office of Nuclear Material Safety and Safeguards

THRU: Christepher McKenney, Chief **/RA/**
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FROM: Leah Parks, Systems Performance Analyst **/RA/**
Performance Assessment Branch
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SUBJECT: TECHNICAL REVIEW: U.S. DEPARTMENT OF ENERGY DOCUMENTATION RELATED TO TANKS 5F AND 6F 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 5F and 6F 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 5F and 6F closure are generally consistent with initial bulk 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 from its reference case preferential flow through the tank grout monolith.

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During its review of tank grouting video, NRC staff observed potential bleedwater segregation of tank grout during placement that could result in inhomogeneity of the monolith which can affect flow patterns. The NRC staff expects DOE to provide additional information related to the extent of shrinkage and its performance impact on 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. NRC staff also expects DOE to provide additional information on the potential for thermal cracking of the grout monolith for Tanks 5F and 6F. 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 grout bleedwater while grout is being placed and consequent impacts of grout segregation on flow through the grout monolith and waste release under Monitoring Factor 3.4, "Grout Performance". This information is needed for NRC to have reasonable assurance that the closure of FTF tanks will meet 10 CFR Part 61, Subpart C, protection of the general population from releases of radioactivity, and protection of individuals from inadvertent intrusion.

The NRC staff will also continue to monitor void volumes in the waste tanks to the extent that 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"). It is NRC staff's viewpoint that 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 5F and 6F Grout Formulations, Operations, and Final Closure at the F-Area Tank Farm at the Savannah River Site

During its review of tank grouting video, NRC staff observed potential bleedwater segregation of tank grout during placement that could result in inhomogeneity of the monolith which can affect flow patterns. The NRC staff expects DOE to provide additional information related to the extent of shrinkage and its performance impact on 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. NRC staff also expects DOE to provide additional information on the potential for thermal cracking of the grout monolith for Tanks 5F and 6F. 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 grout bleedwater while grout is being placed and consequent impacts of grout segregation on flow through the grout monolith and waste release under Monitoring Factor 3.4, "Grout Performance". This information is needed for NRC to have reasonable assurance that the closure of FTF tanks will meet 10 CFR Part 61, Subpart C, protection of the general population from releases of radioactivity, and protection of individuals from inadvertent intrusion.

The NRC staff will also continue to monitor void volumes in the waste tanks to the extent that 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"). It is NRC staff's viewpoint that 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 5F and 6F Grout Formulations, Operations, and Final Closure at the F-Area Tank Farm at the Savannah River Site

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Technical Review of Waste Release Documents Supporting FTF Closure

Date: December 19, 2014

Reviewers:

Leah Parks, The U.S. Nuclear Regulatory Commission (NRC)
Cynthia Dinwiddie, Southwest Research Institute®
Cynthia Barr, NRC
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Documents:

1. C-DCF-F-01576. "Revise Zero Ammonia Requirement in SRR Tank Closure Grout Specification, Section 3.2.3.4, Design Change Form." Aiken, South Carolina: Savannah River Remediation, LLC. August 8, 2013.

2. C-SPP-F-00055. Forty, R.W. "Furnishing and Delivery of Tank Closure Grout." Revision 4. Aiken, South Carolina: Savannah River Remediation, LLC. December 18, 2012.

3. 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 1. Aiken, South Carolina: Savannah River National Laboratory. April, 2013.

4. 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.

5. 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.

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

7. SRR-CES-2012-00031. "Summary Report of the Equipment Grout Mock-up Test." Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. April 13, 2012.

8. SRR-CWDA-2014-00015. "Tank 5 and 6 Grouting Project Lessons Learned." Savannah River Remediation, Aiken, South Carolina. February 2014.

9. SRR-CWDA-2014-00020. "Tanks 5 and 6 Final Configuration Report for F-Tank Farm at the Savannah River Site." Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. July, 2014.

10. SRR-LWE-2012-00087. "Grout Strategy for Tanks 5 and 6 Closure." Revision 2. Aiken, South Carolina: Savannah River Remediation, LLC. May 28, 2013.

11. SRR-LWE-2013-00024. "Tank 5F and Tank 6F Closure Assurance Plan." Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. June 13, 2013.

12. SRR-LWP-2013-00036. "SRR Subcontractor Surveillance Plan Furnishing & Delivery of Tank Closure Grout (TK 5/6)." Aiken, South Carolina: Savannah River Remediation, LLC. August 12, 2013.

13. USQ-FTF-2013-00317. "New Data – Failure to Meet the Requirements of Grout Fill Formulation Specification Water Volume" and 2013-NCR-15-WFC-0006, Batch Tickets for September 19, 2013.

14. USQ-FTF-2013-00320. "New Data – Failure to Meet the Requirements of Grout Fill Formulation Specification on Several Grout Test Cylinders."

15. Work Order No: 01199252-30. "Tank 5 Grout Placement." Revision 1. Aiken, South Carolina: Savannah River National Laboratory. July 29, 2013.

16. Work Order No: 01199252-46. "Tank 5 Grout Placement STP Equip." Revision 1. Aiken, South Carolina: Savannah River National Laboratory. July 29, 2013.

17. Work Order No: 01199254-18. "Tank 6 Grout Placement." Revision 1. Aiken, South Carolina: Savannah River National Laboratory. July 29, 2013.

18. Work Order No: 01199254-58. "Tank 6 Grout Placement STP Equip." Revision 1. Aiken, South Carolina: Savannah River National Laboratory. July 29, 2013.

19. Work Order No: 01199254-65. "Tanks 5-6 Pump Standing Water in Risers." Revision 0. Aiken, South Carolina: Savannah River National Laboratory. December 10, 2013.

20. WSRC-STI-2008-00172. Harbour, J.R., et al. "Closure of HLW Tanks–Formulation for a Cooling Coil Grout." Revision 0. Aiken, South Carolina: Savannah River National Laboratory. April, 2008.

21. WSRC-STI-2008-00298. Hansen, E.K., et al. "Closure of HLW Tanks–Phase 2 Full Scale Cooling Coils Grout Fill Demonstrations." Aiken, South Carolina: Savannah River National Laboratory. June 2008.

<u>C-DCF-F-01576. "Revise Zero Ammonia Requirement in SRR Tank Closure Grout Specification, Section 3.2.3.4, Design Change Form." Aiken, South Carolina: Savannah River Remediation, LLC. August 8, 2013.</u>

This document described the revision of Section 3.2.3.4 of the Tank Closure Grout Specification that had required zero ammonia content in the fly ash for the tank closure grout mix. Because "zero" ammonia is not achievable, the requirement needed to be revised. The revised design required that fly ash be processed to remove ammonia through a high-temperature treatment used in standard industry practice.

C-SPP-F-00055. Forty, R.W. "Furnishing and Delivery of Tank Closure Grout." Revision 4. Aiken, South Carolina: Savannah River Remediation, LLC. December 18, 2012.

C-SPP-F-00055 provided 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. NRC staff reviewed Revision 2 of this document in Technical Review Report: "Tanks 18F and 19F Final Configuration and Grouting" (ML12241A159). Since Revision 2, Department of Energy (DOE) states that it has "Incorporated lessons learned from Tanks 18/19F closure throughout the specification for closure of Tanks 5 & 6F and other future tanks by grouting." In this revision, DOE: (i) deleted the option to use a shrinkage compensating component; (ii) updated applicable American Society for Testing & Materials (ASTM) standards; (iii) deleted flow rate and stability testing requirements; (iv) allowed conditional submittal of Certificates of Conformance when laboratory test results are considered proprietary; (v) allowed alternative approval by Savannah River Remediation for testing laboratory qualification; (vi) updated average capacity of batch plant for an eight-hour period; (vii) deleted specific data for Tanks 18F and 19F; (viii) added electronic file submittals for Engineering Document Requirements (EDR) and Quality Verification Document Requirements (QVDR); (ix) clarified intent of air content testing; (x) optimized compressive strength sampling and testing requirements; (xi) revised the Attachments detailing the Inspection and Testing of Production Tank Closure Grout and Production Tank Closure Grout Mix Components; and (xii) in Attachment 5.5 of C-SPP-F-0005, deleted use of "SIKA ViscoCrete" as high-range water reducer and corrected units of measure for mix components. The estimated duration of grout production was six months and the estimated quantity of grout was 17,064 yd^3 [13,046 m^3], based on filling Tanks 18F and 19F.

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 1. Aiken, South Carolina: Savannah River National Laboratory. April, 2013.

NRC staff reviewed Revision 0 of this document in Technical Review Report: "US DOE Documentation Related to Tanks 18 and 19 Final Configurations with an Emphasis on Grouting from Recommendations and Testing, to Final Specifications and Procedures" (ML12241A159). In Revision 1, DOE corrected a value in Table 3-6 {Moisture retention as a function of applied pressure for [grout formulas] LP#8-016 and LP#8-020} that followed a correction in a contractor test report. Otherwise, Revision 1 is the same as Revision 0 and the reader should refer to NRC staff's prior technical review for a summary of the reference.

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.

NRC staff reviewed the same revision of this document in Technical Review Report: U.S. DOE Documentation Related to Tanks 18 and 19 Final Configurations with an Emphasis on Grouting from Recommendations and Testing, to Final Specifications and Procedures (ML12241A159). The reader is referred to NRC staff's prior technical review for a summary of the reference.

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.

NRC staff reviewed the same revision of this document in Technical Review Report: U.S. DOE Documentation Related to Tanks 18 and 19 Final Configurations with an Emphasis on Grouting from Recommendations and Testing, to Final Specifications and Procedures (ML12241A159). The reader is referred to NRC staff's prior technical review for a summary of the reference.

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

NRC staff reviewed this document in Technical Review Report: "US DOE Documentation Related to Tanks 18 and 19 Final Configurations with an Emphasis on Grouting from Recommendations and Testing, to Final Specifications and Procedures" (ML12241A159). This report documents the results of a 4 yd^3 [3 m^3] bulk fill scale-up test on the grout formulation recommended for filling Tanks 18-F and 19-F, which was intended to demonstrate proportioning, mixing, and transportation of material 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. The reader is referred to NRC staff's prior technical review for a summary of the reference.

SRR-CES-2012-00031. "Summary Report of the Equipment Grout Mock-up Test." Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. April 13, 2012.

This report summarized the results of a scaled-up version of the equipment grout mock-up tests that were performed by SRNL (SRNL-STI-2011-00564). For this test, the equipment grout batch size was increased from 0.25 ft^3 [0.0071 m^3] to 6.3 ft^3 [0.178 m^3] and the T1a-62.5FA grout formula was tested in the field. The mock-up test was performed in an 8-ft [2.4-m]-long test form. The purpose of this test was to verify field-formulated grout properties and to demonstrate the feasibility of continuous fill using gravity, as well as determine an acceptable fill rate. The tests showed that the grout maintains flowability long enough to fill equipment, but that ambient temperature should be controlled because increased temperatures can increase viscosity and affect flowability. The test also showed that the fill rate was a critical factor to achieve complete filling of the equipment.

SRR-CWDA-2014-00015. Tank 5 and 6 Grouting Project Lessons Learned. Savannah River Remediation, Aiken, South Carolina. February 2014.

This report documented the operational lessons learned from grouting Tanks 5F and 6F that had been developed by the grouting team. The following recommendations were included: (i) evaluate increasing the permitted drop height to minimize tremie adjustment and thus, radiation exposure; (ii) work with camera crew to ensure satisfactory camera placement; (iii) use less Slick Willie during the final lifts to minimize potential for unincorporated liquid; (iv) prevent cooling coil grout addition line pluggage through increasing flush frequency, increasing flush water velocity, installing screens to prevent solids from plugging the line, increasing the pig diameter, and pre-charging the line with water. The report also discussed stop work for high radiation readings and additional shielding. To minimize unintended use of out-of-specification grout, the report recommended refresher training to personnel reviewing batch tickets to aid identification of non-conforming grout and to modify procedures to include a specific review of formulation values at delivery.

SRR-CWDA-2014-00020. "Tanks 5 and 6 Final Configuration Report for F-Tank Farm at the Savannah River Site." Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. July, 2014.

This report documented data from the grouting of Tanks 5F and 6F and included deviations from the configuration described in the Closure Module (SRR-CWDA-2012-00071, Rev. 1). The data included important dates during 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 5F and 6F from those that had been planned in the Closure Module (SRR-CWDA-2012-00071, Rev. 1).

DOE reported average compressive strength test results from a total of 374 test cylinders. The average of the results for the compressive strength tests that were performed after a 28-day cure was 2,966 psi [20.4 MPa], with all tested cylinders having strengths greater than the design compressive strength minimum value of of 2,000 psi [14 MPa]. DOE also reported that the volume of bulk fill grout was estimated at 3,927 yd^3 [3,002 m^3] for Tank 5F, and 3,922 yd^3 [2,999 m^3] for Tank 6F, while actual bulk fill volumes were 3,871 yd^3 [2,960 m^3] and 3,849 yd^3 [2,943 m^3] for Tank 5F and 6F respectively. The document compares estimated fill volumes of the internal void space of in-tank equipment to actual grout volumes injected into the equipment. Estimated fill volumes are theoretical values based on assumptions about internal void space and potential grout flow paths.

SRR-LWE-2012-00087. "Grout Strategy for Tanks 5 and 6 Closure." Revision 2. Aiken, South Carolina: Savannah River Remediation, LLC. May 28, 2013.

This document described the overall strategy for grouting Tanks 5F and 6F, including grout functions, requirements and formulation, pour methodology, in-tank equipment to be grouted, and the sequence of grouting activities.

SRR-LWE-2013-00024. "Tank 5F and Tank 6F Closure Assurance Plan." Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. June 13, 2013.

This document identified requirements from the Tier 1 and Tier 2 closure documentation and provided a strategy to ensure that process requirements were met and required documentation was generated during grouting. The plan was a tool for Savannah River Remediation, LLC. (SRR) to ensure that Tanks 5F and 6F were closed successfully, having met all regulatory process and documentation requirements. The plan stated that the grout testing laboratory qualification must be documented and that DOE should verify that the SRR Testing Laboratory performed grout testing per ASTM Standards as listed in Attachment 5.3 of the grout specification. The plan stated that any non-conformances with the testing should be documented.

SRR-LWP-2013-00036. "SRR Subcontractor Surveillance Plan Furnishing & Delivery of Tank Closure Grout (TK 5/6)." Aiken, South Carolina: Savannah River Remediation, LLC. August 12, 2013.

This document described the method SRR Construction Quality Services would use for performing oversight of the subcontractor during furnishing and delivery of tank closure grout for

Tanks 5F and 6F. The plan outlined the quality control surveillance and assessment to be performed.

USQ-FTF-2013-00317. "Use-As-Is Disposition of the Non-Conformance Report (NCR) 2013-NCR-15-WFC-0006 "F Tank Farm Grout - Tank 6." Non-Conformance Tank 6 Grout Water Content Higher than Allowed per C-SPP-F-00055, Rev. 4 "Furnishing and Delivery of TankClosure Grout" October 3, 2014 and 2013-NCR-15-WFC-0006, Non-Conformance Report." October 2, 2014.

This non-conformance report, waste management question evaluation, and accompanying batch tickets document the occurrence of some of the Tank 6 grout water content being greater than allowed per C-SPP-F-00055, Rev. 4, "Furnishing and Delivery of Tank Closure Grout." On September 19, 2013, grout delivered to Tank 6 had a water volume average in excess of that allowed per Section 3.1.1.4 of the bulk fill grout procurement specification (C-SPP-F-00055, Rev. 4 "Furnishing and Delivery of Tank Closure Grout"). Section 3.1.1.4 of the bulk fill grout procurement specification stated that "the total quantity of water in any batch does not exceed the quantity specified in the grout mixes [48.5 gal/yd^3]." The target water-to-cementitious materials ratio of 0.580 was exceeded for 25 grout batches, ranging from a value of 0.593 to 0.601. This 200 yd^3 [153 m^3] volume represents approximately 5% of the estimated total interior bulk fill grout volume (3,922 yd^3 [3000 m^3]). While the overage was greater than the specification allowed per C-SPP-F-00055, Rev. 4, DOE states that the mass of water added was still within ASTM C94/C94M limits of ±3 percent of the target value of 388 gal/8 yd^3 [1469 l/6.12 m^3] batch. The non-conforming condition was not identified prior to grout placement. The report stated that due to the non-conformance there were no adverse influences and therefore it did not impact the Facility. DOE's report stated that the "observations indicated the grout aggregate did not segregate and the required compressive strengths were obtained. Furthermore, it stated that "significantly surpassing maximum water to cementitious material ratio limit did not occur and therefore it did not result in compromising the permeability of the cement." DOE maintains that the water overage did not result in extreme water-to-cementitious materials ratios and will, therefore, not impact permeability values assumed for PA tank flow modeling.

USQ-FTF-2013-00320. "Use-As-Is Disposition of the Non-Conformance Report (NCR) 2013-NCR-15-WFC-0007 "F Tank Farm Grout – Tank 5 and 6". Non-Conformance Tanks 5 and 6 Grout Test Cylinders Deviation from Requirements of C-SPP-F-00055, Rev. 4 "Furnishing and Delivery of Tank Closure Grout," October 23, 2013.

This non-conformance report documented deviations of the Tanks 5 and 6 Grout Test Cylinders from requirements of C-SPP-F-00055, Rev. 4, "Furnishing and Delivery of Tank Closure Grout." The ASTM specifications required that cure specimens be stored in a temperature range of 73.5 ± 3.5 °F [23 ± 2 °C] and that the storage of the cured specimens shall be maintained in an atmosphere of 95 percent or greater relative humidity. Due to equipment failure, the temperature and humidity were not recorded from September 17, 2013 to October 18, 2013; therefore, it could not be demonstrated that the temperatures and humidity were within the required tolerances. Twenty-six (26) cylinder specimens did not comply with the requirement. The standard also invoked a test time tolerance for the 7-day and 28-day test cylinders. Seventeen (17) cylinder specimens did not comply with the required test frequency and tolerance. While the temperature and humidity conditions in the room could not be verified for these specimens, the cylinder break test results verified the compressive strengths exceeded the minimum requirement of 2000 psi [137.9 bars], as required. DOE found that the deviations had no impact on grout chemical properties, waste tank stability, or tank flow modeling assumptions in the PA. Therefore, DOE deemed the deviations acceptable.

Work Order No: 01199252-30. "Tank 5 Grout Placement." Revision 1. Aiken, South Carolina: Savannah River National Laboratory. July 29, 2013.
Work Order No: 01199254-18. "Tank 6 Grout Placement." Revision 1. Aiken, South Carolina: Savannah River National Laboratory. July 29, 2013.

These two work orders provided detailed lists of activities to be performed during grouting of Tanks 5F and 6F. The orders called for grout to be placed through multiple risers with a maximum drop height of 5 ft [1.5 m]. The work orders included safety precautions and limitations that were to be followed (including radiation control procedures) during grouting.

Work Order No: 01199252-46. "Tank 5 Grout Placement STP Equip." Revision 1. Aiken, South Carolina: Savannah River National Laboratory. July 29, 2013.
Work Order No: 01199254-58. "Tank 6 Grout Placement STP Equip." Revision 1. Aiken, South Carolina: Savannah River National Laboratory. July 29, 2013

These two work orders provided detailed lists of activities to be performed during grouting of equipment for Tanks 5F and 6F. This includes the STP equipment and thermo well for Riser 6 in both tanks to support tank closure. The work orders included safety precautions and limitations that were to be followed (including radiation control procedures) during grouting.

Work Order No: 01199254-65. "Tanks 5-6 Pump Standing Water in Risers." Revision 0. Aiken, South Carolina: Savannah River National Laboratory. December 10, 2013.

This scope of work covered activities for Tanks 5F and 6F risers to remove standing water in them, if necessary. The work order instructed workers how to use a pump to remove excess liquid from the tops of the risers at the end of grouting activities.

WSRC-STI-2008-00172. Harbour, J.R., et. al. "Closure of HLW Tanks–Formulation for a Cooling Coil Grout." Revision 0. Aiken, South Carolina: Savannah River National Laboratory. April, 2008.

This document summarized the development of the cooling coil grout formulation. A grout formulation was recommended that would be composed of 90 percent Masterflow® (MF) 816 and 10 percent blast furnace slag by mass, with a water-to-cementitious materials (MF 816 + slag) ratio of 0.33. The report states that this formulation produced grout that met the fresh and cured grout requirements and showed excellent workability under continuous mixing with minimal change in rheology.

The report recommended this grout formulation for full-scale testing (described in WSRC-STI-2008-00298) and that a backup mixing/pumping system be engaged in the event of a failure of the primary system. In addition, the report recommended a laboratory-scale investigation to determine the impact of operational variation on the properties of the grout (such as temperature and mixing time).

WSRC-STI-2008-00298. Hansen, E.K., et. al. "Closure of HLW Tanks–Phase 2 Full Scale Cooling Coils Grout Fill Demonstrations." Aiken, South Carolina: Savannah River National Laboratory. June 2008.

This document described the full-scale testing of the recommended cooling coil grout formulation, which was conducted by SRNL. The objectives of the full-scale testing were: (i) assess cooling coil grout performance in simulated field conditions and (ii) measure relevant properties of samples prepared under simulated field conditions. SRNL designed, fabricated, assembled, and tested both vertical cooling coil and horizontal cooling coil configurations.

To verify the grout was flowable, the test called for flow cone measurement prior to processing. The flow cone measurement was performed based on ASTM C939. In this test grout was placed in a cone, allowed to equalize (within a minute), the discharge was opened and the time was recorded when the first break in the continuous flow was observed. The acceptable flow time for this grout at 73.4°F [23°C] was between 20-30 seconds. Flow cone tests were performed on the first and fifth batches. For the first batch, the sample was pulled after six minutes of mixing and the flow time was 26 seconds, which was within the acceptable range. The fifth batch had a flow time of 42 seconds, which was outside of the acceptable range; however, this sample was pulled too early from the batch (i.e., after only 1.5 minutes of mixing). The flow cone measurements were performed at process temperatures of 95–100 °F [35–38 °C], instead of within the vendor's recommended temperature range, which was 70–77 °F [21–25 °C]. Therefore, the report recommended that DOE perform bench-scale vane tests to determine the maximum working time of the grout and to quantify temperature effects on flow cone results. The test also measured process flow, pressure, and temperature; samples were obtained and analyzed for weight percent water content and density.

The report stated that the selection of piping material used in the full-scale testing was deemed hydraulically representative of the piping material used in the Type I tanks, assuming no wall slip. The piping materials used in both the horizontal and vertical cooling coil assemblies consisted of schedule 40, 2-in [5-cm] PVC hard piping, ASTM A-53 black iron piping and Vardex® clear steel wire-reinforced PVC suction hose.

Evaluation:

Grout Formulation:

Grout Specifications and Testing

For placement into Tanks 5F and 6F, DOE selected the same final grout formulation (LP#8-16) as had been used for placement into Tanks 18F and 19F (SRNL-STI-2011-00551). Many of the NRC staff's concerns and recommendations regarding the grout formulation resulting from the technical review conducted for Tanks 18F and 19F remain. This evaluation summarizes the recommendations from the prior technical review report, taking into account any new information or changes in DOE's approach for Tanks 5F and 6F and any new non-conformances. It is also important to consider how the differences in the Type I and Type IV tanks impact the grout placement approach and its potential performance. Specifically, Tanks 5F and 6F contain many more internal tank obstructions (e.g., cooling coils), and have a flat roof instead of the domed roof of Tanks 18F and 19F. One significant difference in the grout specification for Tanks 5F and 6F was that a greater slump was specified to ensure flowability around cooling coils. The targeted slump range was 26–30 in [66–76 cm] for Type I Tanks 5/6, in contrast with 24–28 in [61–71 cm] for Type IV Tanks 18/19 [ML13267A452]. DOE achieved higher slump rates even though the formulation was the same through the use of admixtures (i.e., hydration stabilizer, viscosity modifier, and high range water reducer).

In the Technical Review Report prepared for the grouting of Tanks 18F and 19F (ML13269A365), the NRC staff compared the final grout formulation to that assumed in Denham's (WSRC-STI-2007-00544) conceptual model of waste release (and to E_h and pH transitions assumed in the F-Area Tank Farm (FTF) PA [SRS-REG-2007-00002, Rev. 1]). To summarize, while the short-term properties of the LP#8-16 are generally consistent with FTF PA assumptions, the testing did not address the physical and chemical evolution of the tank grout over time. The potential for bypass of infiltrating water around tank grout within the tank is not explicitly addressed in the DOE grout specifications. Because DOE assumed in its reference case (i.e., Case A) that infiltrating groundwater moves into the matrix of and reacts with the tank grout, thereby being chemically altered by those interactions, this distinction between matrix flow versus bypass flow is important to performance. NRC staff acknowledges the difference in impact of shrinkage on performance within a Type I tank containing cooling coils versus a Type IV tank (e.g., Tanks 18F and 19F) with no cooling coils. Theoretically, if shrinkage were to occur around cooling coils in addition to the walls and few major pieces of equipment within the tank, infiltrating water could be directed via multiple pathways through the interior of the tank, thereby conditioning the infiltrating water by allowing more surface area contact with the reducing grout. Still, NRC staff expects DOE to provide sufficient information and testing to evaluate conceptual models reflecting preferential flow through the tank grout monolith (whether that flow occurs around the cooling coils, at the interface of individual grout flow lobes, along the length of large-scale equipment or along tank walls) if preferential flow through these pathways cannot be ruled out.

SRNL-STI-2011-00551 states that "Samples were submitted to K. Dixon, SRNL, for moisture retention measurements over the range 15 to 45 bars but results are not available at this time." At the March 2014 onsite observation visit, DOE confirmed that this testing had not been completed at the higher pressure ranges due to inadequate funds.

During the March 26–27, 2014, onsite observation visit, DOE indicated that the requirements of "complete discharge within 90 minutes or before 300 drum revolutions, whichever comes first (within exceptions allowed by the specification)" were easily met [ML14106A573]. DOE also discussed the results of grout testing during the March 26–27, 2014, onsite observation visit. More than 375 grout test cylinders were tested for compressive strength. The average 28-day compressive strength was 2,966 psi [205 bars] and all tested cylinders had a compressive strength greater than the design 28-day compressive strength of 2000 psi [137.9 bars]. During the onsite observation, NRC staff requested that DOE provide records of any non-conformances identified during the grouting of Tanks 5F and 6F, and an assessment of the extent to which any non-conformances may have impacted the integrity of the production grout. DOE identified the following anomalies: (i) the test cylinder curing room temperature and humidity instrumentation were not functioning from September 17 to October 18, 2013, and therefore these properties could not be verified; (ii) the elapsed time interval between pouring test cylinders and compressive strength testing of 17 of the cylinders was not as intended due to the partial stop work order during lapse in budget appropriations; and (iii) all grout placed in Tank 6F on September 19, 2013, had excess water content (approximately 3 percent excess).

DOE explained during the March 2014 onsite observation visit that the excess water was a result of the grout supplier setting the mix with a positive hold on water that resulted in an approximate 1 gal per cubic yard increase relative to that requested by the procurement specification [ML14106A573]. However, even though this grout was outside of the procurement specification, DOE stated that it was still within the ASTM C94 specification during the March, 2014 on-site observation and that the anomaly does not invalidate PA assumptions [ML14106A573].

The NRC staff has reviewed the documentation related to the non-conformance reports and the ASTM C94 specification. The ASTM C94 Section 9.3 states that the total volume of water in a batch should be measured to an accuracy of ±3% of the specified value. In reviewing the batch tickets, batch ticket 039758 indicated a total water value of 401.2 gal [1519 liters], which is 13.2 gal [50 l] greater than the design maximum of 388 gal [1469 l]. This excess amount is slightly greater than 3 percent of the maximum. The NRC staff concludes that these anomalies do not necessarily invalidate PA assumptions because the anomalies are not expected to significantly impact the initial grout properties (e.g., permeability) and the higher water to cement ratio grout meets or exceeds compressive strength requirements. However, inhomogeneity of the monolith caused by placement of grout batches that exceed specifications may affect flow occurring within it: higher permeability zones associated with large water-to-cementitious materials ratios will likely experience increased flow relative to other areas. DOE indicated that corrective actions to prevent future occurrences included increased QC inspections at the batch plant and refresher training for personnel responsible for reviewing batch tickets to improve recognition of non-conforming grout. DOE should consider implementing these corrective actions to prevent future placement of out-of-specification grout.

In addition to the anomaly that occurred on September 19, 2013, one batch ticket (039403) provided to NRC for review documented rejected grout that had, nevertheless, been placed into Tank 6. DOE indicated during the October 29, 2014, teleconference that 1 to 4 yd^3 [0.76 to 3.06 m^3] of the out-of-specification grout was pumped into the tank despite being rejected by an onsite construction discipline engineer. DOE stated that the construction discipline engineer did not approve of the appearance of the grout and its consistency and rejected it based on a qualitative observation. Even though the informational “info” test on the batch ticket showed that the result was within specification at 28 in (71.12 cm), the grout was formally tested after being qualitatively rejected and failed slump testing. DOE confirmed that the construction discipline engineer monitored the grout added to the TK70 pump to provide a qualitative check on the grout quality and had the ability to reject a batch at any time. DOE stated that this was the only time they recall that a batch was rejected based on visual observation for Tanks 5 and 6 [ML14330A037]. Because the batch ticket and “information only” slump test did not indicate the grout should be rejected, DOE should consider investigating the cause for this rejected grout to avoid a similar circumstance in the future.

Grout Shrinkage

During an August 27–28, 2013, onsite observation visit to the FTF to observe grouting of Tanks 5F and 6F (ML13267A452), NRC inquired about plans for testing of new formulations to address tank grout shrinkage. DOE indicated that it did not have plans to conduct shrinkage testing, but that it may pursue such tests in the future. More recently, during an October 29, 2014, teleconference, DOE indicated that shrinkage testing of the current grout formulation would occur only if funds were received to enable the testing [ML14330A037]. DOE has no current plans to begin development of a shrinkage compensating grout formula. In SRNL-STI-2011-00551, Stefanko and Langton describe how H.N. Guerrero designed instrumented shrinkage characterization test forms and the test protocol for measuring dimensional changes of the tank fill grout as a function of temperature, time, and relative humidity. However, these shrinkage tests were postponed by Tank Closure Project personnel, and DOE deleted use of shrinkage-compensating admixtures from Revision 3 of C-SPP-F-00055. NRC staff view this work to develop shrinkage-compensating grout formulas as potentially important to the adequate closure of tanks that contain significant cooling coil surface area (such as Tanks 5F and 6F). NRC staff concurs with Stefanko and Langton's recommendations in SRNL-STI-2011-00551 for testing of shrinkage-compensating admixtures and implementation of measures to help mitigate tank grout shrinkage. DOE should consider giving higher priority to development of a shrinkage compensating grout formula and its testing. Staff will continue to evaluate this technical issue during future monitoring activities.

Alkali–Silica Reactivity

In the Technical Review Report that NRC prepared concerning the grouting of Tanks 18F and 19F (ML13269A365), NRC staff evaluated the tests that DOE conducted for Alkali–Silica Reactivity (ASR). The NRC staff notes that DOE's criterion for acceptance of Vendor-Supplied Granite aggregate relies on short-term alkali reactivity tests (ASTM Standard C1260), which are 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. DOE should consider conducting tests to evaluate potential ASR in tank grouts and its potential effect on long-term performance of the engineered barrier system. Staff will continue to evaluate this technical issue during future monitoring activities.

Grout Flowability

During the June 12, 2012, onsite observation visit, NRC staff inquired about the extent of mounding at the center of Tanks 18F and 19F and the ability to completely grout such tanks at their periphery (ML12191A210). During the August 27–28, 2013, onsite observation visit, NRC staff inquired about the change in grout formulation from Tanks 18F and 19F, which would allow the grout to flow more easily around cooling coils in Type I Tanks, such as Tanks 5F and 6F (ML13267A452). NRC staff inquired about the maximum water-to-cementitious materials ratio, and if a higher ratio was used in Tanks 5F and 6F versus Tanks 18F and 19F to achieve greater flowability. DOE indicated that the target design ratio of 0.58 for Tanks 5F and 6F was calculated based on the values in the table in Attachment 5.5 to C-SPP-F-00055, which is the same as that for Tanks 18F and 19F. As stated previously, one significant difference in the grout specification for Tanks 5F and 6F was that a greater slump was specified to ensure flowability around the cooling coils. DOE enhanced grout flowability for Tanks 5 and 6 by using a higher range of allowable slump spread (SRR-LWE-2012-00087). The targeted slump range was 26–30 in [66–76 cm] for Type I Tanks 5F and 6F, whereas it had been 24–28 in [61–71 cm] for Type IV Tanks 18F and 19F. DOE indicated viscosity modifying admixtures were used to control slump that would decrease the correlation between water-to-cementitious materials ratio and slump. Acceptable slump was obtained at the batch plant and 8.0 gal [30.3 l] of water were withheld to allow further slump adjustments with water additions after grout was delivered to the site, if needed (per the ASTM C94 specification). NRC staff observed the enhanced flowability of this grout during its review of grouting video footage.

Grout Segregation

In multiple videos of tank grouting operations, NRC staff noted or observed dark water separating (i.e., bleeding) away from flowing grout as grout was being placed into Tanks 18, 19, 5, and 6F. These observations occurred after zero-bleed tests had been conducted. NRC staff note there is potential for bleedwater to segregate from the grout mix during grout flow and placement via the tremie into the tank, whereby lower quality grout might be delivered to portions of the tank and enhance shrinkage. Enhanced shrinkage due to delivery of low quality grout is a technical concern because infiltrating water may be routed around the reducing grout through preferential shrinkage pathways, which may lead to less conditioning of the infiltrating water than if it were to flow primarily through the grout matrix as assumed in DOE's performance assessment. Additionally, if flow occurs primarily through cracks and fractures in the tank grout, a much smaller fraction of the tank grout may come in contact with the infiltrating groundwater, leading to more rapid depletion of the reductive and buffering capacity of the tank grout. Because DOE assumes that the solubility of certain key radionuclides is dependent on the chemistry of the infiltrating water, with lower solubility expected for infiltrating groundwater that is adequately conditioned through its interactions with the tank grout, the extent of interaction between the groundwater and tank grout is risk-significant.

Prior to the March 26–27, 2014, onsite observation visit, NRC requested that DOE provide a video record of Tanks 5F and 6F bulk tank and annulus filling that would be beneficial to NRC staff's understanding of grout attributes, such as (i) the presence/absence of large cracks in dried grout; (ii) shrinkage of the dried grout away from the tank walls or cooling coils; (iii) flowability vs. non-self-leveling behavior of grout, and (iv) segregation of water from the grout mix as the grout flows toward the periphery of the tanks. In the video footage, NRC staff observed potential instances of segregation (e.g., mottling of grout that may be due to incomplete mixing or bleedwater segregation, bright watery sheen at the leading edge of the fresh grout flow lobe, strong color differentials).

The NRC staff reviewed portions of the video with DOE staff during the March 26–27, 2014, onsite observation visit. DOE explained their viewpoint that the watery substance was either chromated water from the failed cooling coil flushing or from the Slick Willie (Enviro-Systems, Smyrna, Georgia) pump-priming agent (Slick Willie is a powder that is added to 9 ft^3 (0.25 m^3) water to form the priming agent). In a teleconference on October 29, 2014, DOE quantified the total volumes of pump-priming agent additions to Tanks 5 and 6 by reviewing grout logs and identifying new pump starts that would have required lubricant addition. DOE estimated that 50 gal [189 l] of Slick Willie and water mixture per pump start was added during the first two weeks and approximately 25 gal [95 l] per pump start was added afterwards. The volume was reduced after the second week to minimize water addition to the tanks. According to DOE's calculations, Tank 5 received approximately 1,050 gal [3,975 l] of Slick Willie and water mixture, while Tank 6 received approximately 875 gal [3,312 l] [ML14330A037]. It is not clear if Slick Willie was added to Tanks 18 and 19, and if so, the total amount of priming agent added. NRC staff has requested additional information from DOE regarding use of Slick Willie in Tanks 18 and 19 grouting. DOE also indicated that they intend to reduce or eliminate the amount of Slick Willie disposed of in tanks that will be grouted in the future because the tank grout formula does not seem to be predisposed to water loss into the slick line [ML14330A037], a secondary purpose of use of Slick Willie. The primary purpose of the Slick Willie was to prime the grout pump making it easier to clean; this priming agent can be dispensed with prior to its transport into the slick line.

The NRC staff notes that there is a lack of evidence that the Slick Willie solution becomes incorporated in tank grout in a manner that does not impact the grout behavior. The DOE has stated such, but has not provided technical support for this explanation. Enviro-Systems published on their website a test report to support their claim that Slick Willie does not impact the chemical properties of the grout [TEC, 2008]. During that experiment, a freshly mixed concrete and Slick Willie solution was tested for slump, unit weight, air content, and time setting. The report also provides results for compressive strength tests for 1, 3, 7, and 28 days. In addition to a Slick Willie-free control specimen, two concrete test specimens had Slick Willie solution thoroughly mixed into the batch at a volume ratio of 4 ounces per 9 cubic yards of concrete and 12 ounces per 9 cubic yards of concrete. This equates to a lower relative proportion (0.01 percent compared to 0.11 to 0.13 percent, or roughly an order of magnitude lower) than what DOE added to the Tank 5 and 6. Tank grout has more cementitious material and water and less aggregate than do either of the Slick Willie test specimens; tank grout also has more fine aggregate and less coarse aggregate than do the Slick Willie specimens. In addition to the differences in relative volume ratio of Slick Willie to grout and differences between the concrete and grout composition, the vendor test procedure called for the Slick Willie solution to be thoroughly mixed with the concrete for three minutes, whereas Slick Willie was added separately into the tanks with no active mixing. Regarding the compressive strength tests performed for the Slick Willie vendor and relative strengthening or weakening observed, not enough tests were performed to produce a statistically significant result. Due to the differences that exist between the conditions in the tanks and those pertaining to the vendor tests, the NRC staff cannot rely on the vendor published information to support DOE's conclusion that Slick Willie solution added to the tanks is incorporated into the grout in a manner that will not physically impact flow behavior within the grout monolith.

In the lessons learned documentation, Lesson Learned #11 states the following: "Near the end of bulk tank filling, liquid was observed near the bottom of a few risers." The report recommends that the grouting team use less Slick Willie to minimize the potential for unincorporated liquid. DOE had prepared the Work Order No: 01199254-65 specifically in the case that workers had to remove excess liquid from the tops of the risers at the end of grouting activities. At the March 2014 on-site observation meeting, DOE stated that this work order was not necessary because there was no free water, but the lessons learned document indicates some free liquid remained near the bottom of a few risers near the end of bulk tank filling [ML14106A573]. It is not clear if at the end of bulk tank filling free liquid was still present. DOE should continue to minimize or eliminate excess water introduction to waste tanks in the form of Slick Willie, and provide evidence that introduction of the excess water (e.g., in the form of Slick Willie) into Tanks 5, 6, 18, and 19 did not reduce the integrity of the various grout monoliths to less than what is assumed in the PA. Staff will continue to evaluate this technical issue during future monitoring activities.

Given that internal tank obstructions and interfaces (i.e., cooling coils) in Tanks 5F and 6F could have led to uneven grout distribution, DOE's grout strategy was to place grout through multiple risers [SRR-LWE-2012-00087]. DOE confirmed at the March 26–27, 2014, onsite observation visit that multiple riser locations were used for each lift to facilitate even grout placement. Grout was poured through Risers 1, 3, 5, and 8 in the tank, as well as through the North, South, Inlet and Exhaust Risers in the annulus. Video cameras were used in Risers 1, 3, 5, and 8 in the tank and in the North, South, East and West Risers in the Annulus. Other risers would have been available for use should DOE have needed them, but the need did not arise. NRC staff observed in the video footage that the grout was flowing to all sides of the tank, which supports the fact that DOE did not need to use additional risers to ensure even grout placement.

Work Order Nos. 01199252-30 and 01199254-18 called for grout to be placed through multiple risers with a maximum drop height of 5 ft [1.5 m]. DOE used <5-ft [<1.5 m] drop height to prevent bleedwater segregation of water from the grout mix. During the March 26–27, 2014, onsite observation visit, DOE clarified that their grout team recommended additional testing before using a drop height >5-ft [>1.5 m] because the higher slump material placed into Tanks 5F and 6F had greater potential for bleedwater segregation. DOE indicated that they plan to test higher drop heights to evaluate the potential for bleedwater segregation. The plans for these tests would analyze drop heights up to 40 ft [12.2 m] high, which would reduce operational exposure and risk associated with cutting and replacing tremies. NRC concurs that testing particularly for enhanced bleedwater segregation is necessary prior to changing the allowable maximum drop heights. Staff will continue to evaluate this technical issue during future monitoring activities.

Thermal Data Evaluation

During a teleconference between the DOE and the NRC on October 29, 2014, the NRC requested available information regarding adiabatic temperature rise in tank fill grout [ML14330A037]. DOE stated that in the future it may instrument one or more tanks with thermocouples prior to grouting activities to obtain actual field temperature data. DOE also indicated that the thermal data collected during the Tank 18F and 19F Grout Scale-Up Test indicate that the semi-adiabatic temperature rise was 23 °C, which met the thermal objective for grout that can be mass placed [SRNL-STI-2011-00749]. However, as stated in a NRC staff technical review for Tanks 18 and 19 (ML13269A365), it is not clear to NRC staff that the temperature profile and evolution measured in the test form are representative of temperatures and temperature gradients that would be attained during grouting of much larger tanks of various configurations. NRC staff notes that environmental monitoring of hydrating tank grout, particularly in regard to its thermal evolution, would yield valuable data that is relevant to grout porosity, hydration products, and the potential for thermal cracking to occur within the various tank types. Staff will continue to evaluate this technical issue during future monitoring activities. NRC's recommendations concerning the thermal properties of the tank grout remain the same as those for Tank 18F and 19F. Specifically, DOE should:

- Conduct a more detailed thermal analysis that considers tank-specific grout pouring sequences and geometries to determine the potential for thermal cracking of the tank grout.
- Measure the adiabatic temperature rise and thermal properties of the grout once placed in the tank, because temperatures/temperature gradients attained may influence porosity, hydration products, and the potential for thermal cracking.

<u>Equipment Grout Evaluation</u>

While the equipment grouting tests performed by DOE focused primarily on the ADMP, these tests are also relevant to the equipment in Tanks 5F and 6F. The ADMP is considered to represent a bounding case for grouting internal tank fixtures because of its large size and complex flow path. Tanks 5F and 6F have similar equipment including robotic crawlers, transfer pumps/jet, and Submersible Transfer Pumps. In the Technical Review Report that NRC staff prepared in response to the grouting of Tanks 18F and 19F (ML12241A159), staff expressed concern that the ADMP mock-up test described in SRNL-STI-2011-00564 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 to eliminate a potential vertical flow path through the grouted Tank 18F. However, the scaled-up version of this mock-up test provided sufficient data to support that conclusion because the flowability was shown to be maintained for the required time and the test showed that the T1a-62.5FA grout could fill and vent through the same 1-in [2.5-cm] diameter opening, successfully filling the mock-up equipment (SRR-CES-2012-00031).

The Tanks 5F and 6F Final Configuration Report states that the largest pieces of equipment in each tank (the Submersible Transfer Pumps) were filled with approximately 82 percent of the estimated grout volume. NRC will continue to monitor 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 bypassing flow around or through the tank grout.

Cooling Coil Grouting Evaluation

The mix design for cooling coils is required to have a reducing capacity at least as great as the mix design for bulk fill grout (WSRC-STI-2008-00172). Because the cooling coil grout formulation was prepared in 2008 before the final grout formulation for bulk fill grout was decided, the NRC staff verified that the final FTF tank grout formulation had a weight percent (wt%) for slag (i.e., 6 wt%) that was less than the cooling coil grout mix of 7.5 wt% slag (SRNL-STI-2011-00551).

During the March 26–27, 2014, onsite observation visit and in the Final Configuration report DOE discussed the results of cooling coil grouting. Tank 5F had seven and Tank 6F had nine failed cooling coils. DOE successfully grouted all failed cooling coils for Tanks 5F and 6F from inlet and outlet. Out of 56 total intact coils, DOE successfully grouted 51. Tank 5 Cooling Coil 17 was approximately 3% filled and Tank 5, Cooling Coil 18 was approximately 27% filled because DOE had not adequately cleaned the grout addition piping line prior to filling, which allowed grout residue to plug the grout addition line. DOE subsequently implemented changes to the cooling coil grouting process (e.g., more flushing, addition of screens to capture debris and larger diameter line cleaning device) to prevent this from recurring. The NRC staff notes that if the cooling coil itself was not plugged, then use of an alternative grout addition line may have allowed DOE to complete filling of these cooling coils. DOE should also consider making a backup grout addition line readily available that can be used should this problem recur. Tank 6, Cooling Coil 24 was approximately 13% filled and Tank 6, Cooling Coil 36 was approximately 5% filled. These two intact coils had known holes and were thought to be plugged during subsequent grouting activities. Work had to stop during the filling of one other coil (Tank 6, Cooling Coil 16) due to high radiation rates associated with the exiting flush water from previous flushing activities [SRR-CWDA-2014-00020]. Some of the recommendations in the lessons learned documentation that may help reduce the radiation associated with grouting of cooling coils are for the cooling coils to be triple rinsed (three line volumes) as part of Tank Closure; to minimize time between coil flushing and coil grouting evolutions; and to plan for high radiation/contamination potential for future coil grouting by establishing temporary shielding and additional contamination controls [SRR-CWDA-2014-00015]. The NRC staff has reviewed the reasons for the 5 unsuccessfully grouted intact cooling coils and finds that DOE is taking the appropriate steps to prevent those circumstances from recurring.

The report describing full-scale grout test WSRC-STI-2008-00298 notes that for insulated piping (such as having cured grout around the pipe, although the heat transfer characteristics of the insulation used in the test are most likely not the same as the tank grout fill) there is a significant temperature rise in the curing grout compared to the uninsulated piping and, therefore, DOE should consider the heat transfer requirements such that the grout does not exceed its boiling temperature. During the March 26–27, 2014 onsite observation visit, NRC staff asked DOE how it controlled the temperature of the grout in the cooling coils and if temperature caused any abnormalities in coiling coil grout activities. DOE indicated that temperature was not a contributing factor for any of the five partially filled intact coiling coils [ML14106A573].

During the full-scale cooling coil grout test described in WSRC-STI-2008-00298, the investigators were concerned with air entrainment, particularly at the top of horizontal coils or at the top of horizontal to U-shaped sections of vertical coils, and in methodologies that could be used to minimize air entrainment. Therefore, the report recommended that DOE employ a mixing system that could blend and process the quantity of material required to fill at least one or more assemblies. The mixing system should have been designed to blend in the solids and minimize air entrainment. During the March 26–27, 2014, onsite observation visit, NRC staff asked DOE about their strategy for reducing air entrainment during grout pumping operations for cooling coils within Tanks 5F and 6F. DOE stated that they used a hand pump to control the pressure and flow. DOE also introduced the grout in a vertical orientation to follow the recommendations in WSRC-STI-2008-00298 as closely as possible [ML14106A573]. The NRC staff finds that DOE followed the recommendations in WSRC-STI-2008-00298 to reduce air entrainment.

The report on the full-scale cooling coil grout test (WSRC-STI-2008-00298) called for filling the intact cooling coil assemblies with water prior to grout placement to help ensure that a liquid-to-liquid interface would be maintained during the grout fill. The water would remove air from the cooling coils to prevent air entrainment and would be collected and disposed of separately at the outtake of the cooling coils. DOE confirmed during the March 26–27, 2014, onsite observation visit that the liquid-to-liquid interface was maintained throughout the process [ML14106A573].

The report WSRC-STI-2008-00298 also recommended that DOE use flow and pressure measurements during grouting operations. During the March 26–27, 2014, onsite observation visit, DOE confirmed that flow was measured but that DOE did not have a reason to measure pressure because the pump would automatically shut down when it reached a pressure cutoff point [ML14106A573].

<u>Annulus Grouting Evaluation</u>

Work Order Nos. 01199252-30 and 01199254-18 called for the annulus to be filled using two of the four annulus risers located 180 degrees apart. Video cameras were located in the East and West positions 90 degrees from the grout placement risers (North and South). Video cameras were repositioned during the riser fills when necessary. During the March 26–27, 2014, onsite observation visit, DOE clarified that the visibility of the annulus with the two cameras in the East and West Risers used to observe grout placement covered approximately 50 percent of the annulus. DOE clarified that they did not need to place grout from the Annulus East and West Risers until the very end of the campaign (for the Riser Fills) due to the ability to see the grout flowing around the annulus from either the Annulus North or South Risers, showing that the midpoints between risers had been filled. The NRC staff notes that the Grout Strategy documentation anticipated that 4 cameras would be used simultaneously to support annulus grouting but indicated that the number of annulus cameras maybe reduced based on field experience [SRR-LWE-2012-00087]. NRC staff observed grout flowing in the midpoints between the risers that had been filled in the grout video provided by DOE [ML14106A573]. However, as the grout placement continued towards the top of the tanks, visibility became more limited due to the camera angles. DOE should consider placing video cameras in all four risers of the annulus when available for improved visibility, or cameras should be repositioned occasionally as grouting takes place if video cameras cannot be placed in all four risers simultaneously during grouting.

During the March 26–27, 2014, onsite observation visit, the NRC staff discussed the grouting of the top of the annulus with DOE staff. The specific discussion points are summarized in the onsite observation visit report (ML14106A573). DOE reiterated confidence that all areas of the duct within the annulus had been filled with grout and referred to the video showing grout flowing both inside and outside of the duct. NRC staff and DOE reviewed portions of the annulus video during Lift 5, where the Slick Willie enters through the duct vent registers. NRC staff inquired about the potential impact on the quality of the grout in portions of the interior of the duct. DOE indicated that they intended to fill the smaller diameter portion of the ventilation duct, so that Slick Willie would be pushed back toward the larger diameter portion of the duct, and then the Slick Willie would eventually be pushed out by grout filling the larger diameter portion of the ventilation, which took longer to fill. NRC staff note from the video footage that it is difficult to verify whether the Slick Willie was indeed pushed out of the ventilation duct. DOE should consider minimizing or eliminating excess water introduction to waste tank annuli in the form of Slick Willie. Staff will continue to evaluate this technical issue during future monitoring activities.

<u>QA Evaluation</u>

The DOE quality assurance plan, as described in SRR-LWE-2013-00024, is clear and, if implemented properly, should have ensured that Tanks 5F and 6F were closed according to plan, while meeting all regulatory process and documentation requirements. NRC staff will continue to evaluate whether the DOE quality assurance plan is being implemented effectively during future onsite observation visits.

<u>Final Configuration Evaluation</u>

The final configuration of Tanks 5F and 6F, as described in SRR-CWDA-2014-00020, and the reported deviations from the Closure Module (SRR-CWDA-2012-00071) are complete but uncertainties exist in the values reported. The actual grout bulk fill volumes for each primary tank were each within 2% of the estimates for Tanks 5F and 6F. The volumes placed in the annulus of each tank were 3% and 5% greater than anticipated, while the volumes placed in the risers were 16% and 29% less than anticipated.

During the March 26–27, 2014 onsite observation visit, DOE clarified that the actual values reported in the final configuration are based on the number of trucks from which grout was poured, and because they do not take into account the exact amount of grout used for testing, the estimates are somewhat uncertain. Specifically with respect to the riser volume estimates quoted in the inputs to the final configuration, DOE stated they were based on grouting time by knowing the total time it took to completely discharge the contents of one grout truck and the time it took to fill a riser. Therefore, riser volume estimates should not be considered highly accurate [ML14106A573]. With regard to equipment grouting, the report provides comparison of the theoretical calculated fill volume and the actual volume of buckets used to deliver the grout. 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). The average 28-day compressive strength was 2,966 psi [204 bar], well above the value of 2,000 psi [138 bar] described in the Tanks 5 and 6 Closure Module. DOE should consider methods for improving the estimated grout volumes to help ensure the equipment void space is fully grouted and to better understand remaining void space.

Teleconference or Meeting:

During a teleconference on October 29, 2014, DOE and NRC discussed NRC staff questions related to Tank 5 and 6 grouting operations [ML14330A037]. One purpose of the teleconference was to discuss the batch tickets DOE had provided to NRC for review. For Tank 5F, DOE provided five accepted and three rejected bath tickets (only three batches were rejected from Tank 5F). For Tank 6F, DOE provided five accepted and five rejected batch tickets. The teleconference also covered remaining open action items from the March 2014 onsite observation. For details regarding the teleconference, please refer to the meeting notes [ML14330A037].

Follow-up Actions:

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 Tank Farm Monitoring Plan (ML12212A192) while focusing on the technical concerns listed in this review report and on any new technical concerns that arise.

Open Issues:

No open issues resulted from this technical review. However, insufficient information is provided to address the likelihood for preferential flow pathways to form through grout monoliths, including those developed due to shrinkage at material interfaces, or from cracking and at voids. DOE testing of shrinkage-compensating grout formulas and related efforts to mitigate against grout shrinkage have been postponed or suspended. NRC staff will continue to follow-up on this technical issue under Monitoring Factor 3.3, "Shrinkage and Cracking" (See ML12212A192).

Conclusions:

Due to the similarities in the grout formulation and approach to grouting Type I Tanks 5F and 6F and Type IV Tanks 18F and 19F, many of the conclusions resulting from the NRC staff's review of documentation related to Tanks 18F and 19F remain relevant. Relevant major and minor conclusions from the Tanks 18F and 19F review are repeated below along with new conclusions from the Tanks 5F and 6F review.

Major Conclusions for Tanks 18F and 19F

- NRC staff concludes that DOE has not provided sufficient information and testing to adequately invalidate alternative conceptual models reflecting preferential flow through tank grout monoliths that might result from grout shrinkage and cracking.
- NRC staff concur with Stefanko and Langton's (2011) recommendations for testing of shrinkage-compensating admixtures and implementation of measures to help mitigate against tank grout shrinkage; staff will continue to evaluate this technical issue in future onsite observations as part of Monitoring Factor 3.3, "Shrinkage and Cracking" (ML12212A192).

Minor Conclusions for Tanks 18F and 19F

- A more detailed thermal analysis that considers the specific grout pour sequence and geometry to determine the impact on grout porosity, hydration products, and 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).
- NRC staff will also continue to monitor (i) void volumes in the emplaced grout (to the extent information is available); (ii) the importance of alkali–silica reactivity on cementitious material degradation; and (iii) the impact of limestone additions to the grout mix on pH buffering of water contacting the emplaced grout.
- The NRC staff is concerned that DOE's criterion for acceptance of vendor-supplied granite aggregate relies on short-term alkali–silica reactivity tests (ASTM C1260), which are unlikely to predict the occurrence of alkali–silica reactivity over the very long compliance period. NRC staff will continue to monitor for compliance with the performance objective specified at 10 CFR 61.41. Staff will continue to evaluate DOE efforts related to understanding the potential for alkali–silica reactivity to occur and its potential effect on long-term performance in future onsite observations under Monitoring Factor 3.3, "Shrinkage and Cracking" (ML12212A192).
- NRC staff is concerned with the use of commercially-available Portland cements in Tanks 5F and 6F. Portland cements can have up to 5 wt% substitution with limestone that could lower the pH buffering capacity of the grout and could affect the timing of release of key radionuclides.

Minor Conclusions for Tanks 5F and 6F

- NRC staff observed grout with higher flowability in the videos of grouting Tanks 5F and 6F as compared to Tanks 18F and 19F as a result of the higher slumps applied.
- NRC staff observed via video potential instances of bleedwater segregation (e.g., mottling of grout that may be due to incomplete mixing or segregation, bright watery sheen at the leading edge of the fresh grout flow lobe, strong color differentials). While NRC staff acknowledges the potential for these observations to be due to the Slick Willie pump priming agent, chromated water, or due to shadows caused by lighting angles,

making that determination is subjective and the priming agent or water may have a potential impact on hydraulic properties and grout quality.

- Two of the failed cooling coils were only partially filled because DOE had not adequately cleaned the line prior to the fill, which allowed grout residue to plug the line. NRC staff notes that the lessons learned report provides several suggestions to prevent cooling coil grout addition line pluggage (e.g. increasing flush frequency, increasing flush water velocity, installing screens to prevent solids from plugging the line, increasing the pig diameter, and pre-charging the line with water). NRC staff will continue to monitor DOE's actions to prevent plugging of the cooling coil grout addition line.
- Due to the fact that only approximately 50 percent of the annulus was visible in the videos of annulus grouting, DOE should consider placing video cameras in all four riser locations within tank annuli when available or rotating camera locations between lifts to improve visibility.
- There should be a failsafe to prevent future placement of out-of-spec grout because inhomogeneity in the grout will affect flow in the monolith due to higher permeability zones receiving higher flow rates relative to surrounding zones.
- DOE should consider giving higher priority to development and testing of a shrinkage compensating grout formula.
- DOE should continue to minimize or eliminate excess water introduction to waste tanks, and provide evidence that introduction of excess water (e.g., in the form of Slick Willie) into Tanks 5, 6, 18, and 19 did not reduce the integrity of the tank grout to less than what is assumed in the PA.
- Testing for enhanced bleedwater segregation is necessary prior to changing the allowable maximum drop heights. Staff will continue to evaluate this technical issue during future monitoring activities.
- Field-collected temperature data from actual waste tanks would provide valuable information regarding grout integrity.

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