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Office of Nuclear Material Safety and Safeguards

THROUGH: Christepher McKenney, Chief
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Signed by McKenney, Christepher on 11/18/20

FROM: Cynthia Barr, Senior Risk Analyst
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SUBJECT: TECHNICAL REVIEW: U.S. DEPARTMENT OF ENERGY DOCUMENTATION RELATED TO TANK 12H GROUTING OPERATIONS WITH EMPHASES ON SPECIFICATIONS, TESTING, RECOMMENDATIONS AND PLACEMENT PROCEDURES (PROJECT NO. PRO0734)

The U.S. Nuclear Regulatory Commission (NRC) has performed a technical review of several documents prepared by the U.S. Department of Energy (DOE) that provide information on grouting and closure of Tank 12H in 2016. The focus of NRC's technical review is grout formulations and specifications, testing, recommendations and placement procedures.

This technical review report supplements information from a previous technical review report focused on grouting of both Tanks 12H and 16H (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16231A444). Because grouting of Tank 12H had just begun during the development of the previous technical review report, NRC staff were only able to reach preliminary findings about Tank 12H. NRC also revisits findings from previous technical review reports related to Tanks 18F and 19F grouted in 2012; and Tanks 5F and 6F grouted in 2013 (ADAMS Accession Nos. ML13269A365 and ML14342A784).

Proper tank grouting is important to several factors for effective long-term performance of the closed tank farms, including chemical conditioning of the water infiltrating into the tanks before contact with the waste layers, stability of the vessels (including filling of void space) and reducing the probability of inadvertent intrusion (e.g., the thick concrete and grout could alert an inadvertent intruder to stop drilling before reaching the waste layer).

Enclosure

This technical review can be tied to several monitoring factors listed in NRC's combined F-Area and H-Area Tank Farm monitoring plan entitled "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 and H-Area Tank Farm Facilities in Accordance with the National Defense Authorization Act for Fiscal Year 2005" (available using ADAMS Accession No. ML15238A761) issued in October 2015 (hereafter, Monitoring Plan). The Monitoring Plan discusses NRC's approach to fulfilling its responsibilities under the National Defense Authorization Act for Fiscal Year 2005 to monitor DOE disposal actions to assess compliance with the Performance Objectives in Title 10 *Code of the Federal Regulations* (10 CFR) Part 61, Subpart C, for DOE wastes (and associated disposal facilities) found to be incidental to reprocessing. NRC's Monitoring Plan lists the technical areas, which are the focus of NRC's monitoring activities. This technical review generally supports NRC's Monitoring Area 3, "Cementitious Material Performance", and particularly Monitoring Factors 3.2 "Groundwater Conditioning via Reducing Grout," 3.3, "Shrinkage and Cracking," and 3.4, "Grout Performance" listed in the NRC's Monitoring Plan.

The NRC staff concludes that performance requirements for the tank grout formulation recommended and tested for Tank 12H closure are generally consistent with initial bulk chemical and hydraulic properties assumed in DOE's H-Area Tank Farm Facility Performance Assessment (PA) (SRR-CWDA-2010-00128). However, DOE has not provided sufficient information and testing to support its exclusion of shrinkage gaps, cracks, and other preferential flow pathways through the grout monolith from the reference case in DOE's PA. These conclusions were also true for performance assessment analyses conducted for Tanks 18F, 19F, 5F, 6F, and 16H, including DOE's F-Area and H-Area Tank Farm Facility PAs.

The NRC staff expects DOE to provide additional information related to the extent and performance impact of tank grout shrinkage to support a reasonable assurance decision that the performance objectives specified in 10 CFR Part 61, Subpart C are met. As stated above, DOE assumes in the PAs for F- and H-Area that the grout does not shrink, crack or fracture in the base or reference case. Rather, the grout is assumed to degrade slowly with a subsequent increase in hydraulic conductivity of the grout matrix over time. This assumption is risk-significant because conceptually DOE assumes that the entire grout matrix is available to condition infiltrating groundwater to relatively low $E_h$ and high pH, which is necessary to maintain the low solubility of many key radionuclides. For the tank grout to condition infiltrating water to relatively low $E_h$ and high pH, water must flow through and interact with the grout. In contrast, if flow is concentrated along fast pathways through the tank grout (e.g., gaps between the tank wall/internal tank components and tank grout, or shrinkage gaps, cracks and fractures in the grout), flow rates through the grout may be significantly faster and the extent of interaction between infiltrating groundwater and tank grout may be significantly less than assumed in DOE's PAs, thereby hastening the time to transition to risk-significant solubility and dose for certain key radionuclides. NRC staff will continue to evaluate the potential for shrinkage- and cracking-induced[1] preferential flow through the tank grout under MF 3.3, "Shrinkage and Cracking" (ADAMS Accession No. ML15238A761), as well as DOE's assumptions regarding flow through the tank grout that influences the extent of groundwater conditioning in MF 3.2 "Groundwater Conditioning via Reducing Grout".

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[1] While cracking may enhance flow through the reducing tank grout in the bulk monolith, which could be beneficial to performance, the impacts of crack formation are not well understood. Additional information in this area would be beneficial to assess the impact of crack formation on tank grout performance.

With respect to submerged (i.e., partially or fully in the saturated zone) tanks, such as Tank 12H, DOE assumes mixing between aquifer water primarily flowing horizontally through the tank grout and infiltrating groundwater primarily flowing vertically through the tank grout. Therefore, the initial chemistry of the water in contact with the waste zone is assumed to be less conditioned (i.e., higher $E_h$ and lower pH) via its interactions with reducing tank grout compared to what is assumed for non-submerged tanks where groundwater primarily flows vertically through the overlying, reducing tank grout. After the reduction capacity of the tank grout is depleted, the chemistry of the waste zone transitions to a higher $E_h$, reflective of oxidized conditions. The assumed $E_h$ for submerged tanks under oxidized conditions is expected to be lower than it would be for non-submerged tanks, owing to the lower oxidation-reduction potential of the groundwater aquifer compared to meteoric water flowing through the tank grout. Likewise, the pH of groundwater in contact with the waste zone of submerged tanks is assumed to be lower because it is less conditioned by the alkaline tank grout. The impact of the more moderate chemical conditions for submerged Tank 12H is potentially higher solubility of key radionuclides such as plutonium and technetium. NRC staff will continue to monitor the impact of submerged groundwater conditions on waste release from H-Tank Farm tanks, such as Tank 12H.

The key radionuclide contributing to dose in DOE's PA for Tank 12H is I-129. The PA assumes no solubility control for I-129, while the results of the Tank 12H waste release experiments suggest potential solubility control for I-129. Although DOE does not take credit for solubility control to limit I-129 dose in its PAs, DOE does take credit for sorption of I-129 in cementitious materials. Therefore, NRC staff will continue to monitor the impact of groundwater chemistry on I-129 attenuation and dose, including the impact of aquifer chemistry on I-129 waste release from submerged tanks, such as Tank 12H.

Although DOE did not take credit for solubility control of I-129, based on the results of the Tank 12H waste release experiments and associated geochemical modeling, I-129 solubility in Tank 12H could be sensitive to $E_h$ and pH. If DOE takes advantage of solubility control for I-129 for tank farm tanks in the future, a better understanding of the expected evolution of the geochemical conditions in the waste zone would be needed. Additional information to support the expected solubility of I-129 under the assumed geochemical conditions would also be needed, as discussed in more detail in ADAMS Accession No. ML19298A092 (e.g., the targeted $E_h$ and pH in the Tank 12H waste release experiments were inconsistent with the reference case conditions assumed in DOE's H-Tank Farm PA). Additionally, the results of the waste release experiments show that the H-Tank Farm PA likely under-predicted the solubility of other key radionuclides for the tank farm by orders of magnitude (e.g., Pu and Tc). A comparison of the Tank 18F and Tank 12H waste release experiments also suggest that there is significant variability in key radionuclide mobility from tank to tank; most notably, the observed Pu concentrations in Tank 18F were orders of magnitude higher compared to Tank 12H and those assumed in the F-Tank Farm PA. Therefore, tank grout performance and related impacts on waste release may be more risk significant for other H-Tank Farm tanks with unknown tank waste geochemistry and uncertain final inventories. Without a good understanding of the controls on aqueous phase concentrations in the waste zones of tank farm tanks, it would be difficult to extrapolate the results of the Tank 18F and Tank 12H waste release experiments to other tanks. NRC staff will continue to monitor the extent of groundwater conditioning via reducing tank grout in submerged and unsubmerged tanks, as well as the impact of waste geochemistry on key radionuclide release from F-Area and H-Area tank farm tanks.

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 impacts on the (i) pH buffering capacity of tank grout and (ii) timing of release of key radionuclides that will derive from its Portland cement containing up to 5 wt percent limestone (Monitoring Factor 3.4, “Grout Performance”). It is NRC staff’s position that this information would support reasonable assurance determinations that the performance objectives listed in 10 CFR Part 61, Subpart C are met.

Other conclusions unique to Tank 12H grouting include the following:

- With regard to the change in slag grade (from grade 100 to grade 120 slag) during Tank 12H grouting:

    - DOE should address the performance impact of using two different slag cements in Tank 12H reducing tank grout: Holcim Grade 100 grout [163 cubic meters (43,000 gal)] was placed in the bottom of the first lift in the primary and Lehigh Grade 120 grout [2840 cubic meters (750,000 gal)] was placed above this Grade 100 grout.

    - NRC staff will continue to monitor the impact of slag grade on chemical reactivity and hydraulic conductivity. Additionally, results of 28-day compressive strength measurements were unexpectedly lower for Tank 12H, which used primarily Grade 120 slag, compared to Tank 16H, which used Grade 100 slag. This result may be related to the chemical reactivity of the Grade 120 slag.

- Results documented in the grout drop test report (RPT-5539-EG-0016) suggest the potential for even more segregation and bleed water production if grout is dropped from a tremie into standing water. In-leakage of groundwater into the submerged annulus and tank led to delays in grouting and the need for mitigative measures, such as, pumped removal of groundwater and avoidance of grouting directly into areas of the tank containing standing water. DOE should provide additional information about how contractors avoided placing grout directly into areas of the tank that had collected water, unremoved by pumping, and the spatial maps of where the standing water was relative to the risers through which Lift 1 grout was placed. DOE should provide information about the potential performance impact of standing water in Tank 12H during grouting. The NRC staff will continue to monitor the potential for segregation of grout bleed water and consequent impacts on future water flow through the grout monolith and waste release

In this report, there is no significant change to the NRC staff overall conclusions from the F- and H-Tank Farm TERs regarding compliance of DOE disposal actions with the 10 CFR Part 61 performance objectives. Likewise, there is no significant change to the status of Monitoring Factors 3.2 “Groundwater Conditioning via Reducing Grout,” 3.3, “Shrinkage and Cracking,” and 3.4, “Grout Performance” listed in the NRC staff’s Monitoring Plan for the tank farm facilities (ADAMS Accession No. ML15238A761).

Enclosure:
Technical Review of Documents Related
to Tank 12H Grout Formulations,
Testing, Procedures, and Operations at the
H-Area Tank Farm at the Savannah River Site

SUBJECT: TECHNICAL REVIEW: U.S. DEPARTMENT OF ENERGY DOCUMENTATION RELATED TO TANK 12H GROUTING OPERATIONS WITH EMPHASES ON SPECIFICATIONS, TESTING, RECOMMENDATIONS AND PLACEMENT PROCEDURES (PROJECT NO. PRO0734) DATED: NOVEMBER 18, 2020

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**ADAMS Accession No.: ML20296A550** ***via e-mail**

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# Technical Review of Documents Related to Tank 12H Grout Formulations, Grout Testing, Procedures, and Grouting Operations at the H-Area Tank Farm at Savannah River Site (Supplement to Technical Review Report on Tank 16H and 12H [ML16231A444])

Date: October 2020

Reviewers:

Cynthia Dinwiddie, Southwest Research Institute®

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General Grout Documents:

1. 2015-NCR-15-WHC-0008. Redwood, A.R. "Nonconformance Report No. 2015-NCR-15-WHC-0008." Aiken, South Carolina. June 29, 2015. [ADAMS Accession No. ML20302A273]
2. 2015-NCR-15-WHC-0013. Redwood, A.R. "Nonconformance Report No. 2015-NCR-15-WHC-0013." Aiken, South Carolina. October 20, 2015. [ADAMS Accession No. ML20302A274]
3. C-ESR-G-00003. Waltz, R.S. "SRS High-Level Waste Tank Crack and Leak Information." Revision 13. Aiken, South Carolina: Savannah River Remediation, LLC. 26 October 2015. [ADAMS Accession No. ML14079A609]
4. HTF-SKM-2015-00010. "Tank 12 Flush & Grout Fill Configuration Intact Coils [WO] 1337683-31 (2 Sheets)." Revision B. Closure Engineering, Savannah River Site, Aiken, South Carolina, October 28, 2015. [ADAMS Accession No. ML20279A781]
5. HTF-SKM-2015-00021. "Tank 12 Grout Placement Plan – Sketch 1 (Associated with WO 01337683-33)." Revision 0. Savannah River Site, Aiken, South Carolina, 2015. [ADAMS Accession No. ML20279A782]
6. SDDR No. 13182. "Supplier Deviation Disposition Request No. 13182 (Slag Cement not Meeting ASTM C989, Grade 100)." Aiken, South Carolina: Savannah River Site. June 2015. [ADAMS Accession No. ML16119A339]
7. SDDR No. 13307. Ganguly, A. "Supplier Deviation Disposition Request No. 13307 (Bleeding of Concrete)." Aiken, South Carolina: Savannah River Site. October 28, 2015. [ADAMS Accession No. ML20279A783]
8. SRR-CWDA-2012-00051. Layton, M. "Critical Assumptions in the Tank Farm Operational Closure Documentation Regarding Waste Tank Internal Configurations." Revision 2. Aiken, South Carolina: Savannah River Remediation, LLC. January 2016. [ADAMS Accession No. ML13078A206].
9. SRR-CWDA-2015-00074. "Addendum to the Industrial Wastewater Closure Module for Liquid Waste Tank 12H H-Area Tank Farm, Savannah River Site, SRR-CWDA-2014-00086, Revision 0, May 2015." Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. October 2015. [ADAMS Accession No. ML15294A364]
10. SRR-CWDA-2015-00100. "Evaluation of the Use of an Alternative Tank 16 Fill Grout (Per Specification C-SPP-Z-00012) (Interoffice Memorandum to G.C. Arthur from M.H. Layton)." Revision 2. Aiken, South Carolina: Savannah River Remediation, LLC. September 1, 2015. [ADAMS Accession No. ML16119A341]

11. SRR-CWDA-2016-00068. "Tank 12 Final Configuration Report for H-Tank Farm at the Savannah River Site." Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. December 2016. [ADAMS Accession No. ML18235A409].
12. SRR-CWDA-2017-00015. "Consolidated General Closure Plan for F-Area and H-Area Waste Tank Systems." Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. February 2017. [ADAMS Accession No. ML20279A784]
13. SRR-CWDA-2018-00047. "Savannah River Site F and H Area Tank Farms, NRC Onsite Observation Visit: *Tank 12 Grouting Calendar (Slide 21)*." Revision 1. Aiken, South Carolina: Savannah River Remediation, LLC. 13–14 August 2018. [ADAMS Accession No. ML18247A080]
14. SRR-CWDA-2020-00052. Romanowski, L. "Follow-Up to Tanks 12H and 16H Grouting Operations Document Request in Support of U.S. Nuclear Regulatory Commission F and H Area Tank Farms Monitoring Activities (Memo to A. White of U.S. DOE)." Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. June 10, 2020. [ADAMS Accession No. ML20279A785]
15. SRR-CWDA-2020-00058. Romanowski, L. "Type I Waste Tanks Dehumidification System Heating and Ventilation Ductwork [From Dwg. #W146593]." Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. July 8, 2020. [ADAMS Accession No. ML20279A786]
16. SRR-LWE-2016-00036. Voegtlen, R.O. "Tank 12 Final Configuration Report Inputs." Revision 2. Aiken, South Carolina: Savannah River Site. December 2016. [ADAMS Accession No. ML20279A787]
17. SRR-TCR-2015-00024. Davis, B. "Tank 16 Grouting Lessons Learned (Memo)." Aiken, South Carolina: Savannah River Remediation, LLC. January 27, 2016. [ADAMS Accession No. ML16119A346]
18. SRR-TCR-2016-00007. Davis, B. "Tank 12 Grouting Liquid Spill Lessons Learned." Aiken, South Carolina: Savannah River Remediation, LLC. May 9, 2016. [ADAMS Accession No. ML20279A788]
19. USQ-HTF-2015-00706. Layton, M. "Supplier Deviation Disposition Request (SDDR) Number 13307 – Deviation from Specification C-SPP-F-00055, Revision 4 (Technical Review Package)." Revision 0. Place. October 2015. [ADAMS Accession No. ML20279A789]
20. VSL-14R3330-1. Papathanassiu, A.E. et al. "Saltstone Clean Cap Grout Assessment (Final Report)." Revision 0. Washington, DC: Vitreous State Laboratory, The Catholic University of America. March 2014. [ADAMS Accession No. ML20279A790]
21. VSL-15R3740-1. Gong, W. et al. "Investigation of Alternate Ground Granulated Blast Furnace Slag for the Saltstone Facility (Final Report)." Revision 0. Washington, DC: Vitreous State Laboratory, The Catholic University of America. August 26, 2015. [ADAMS Accession No. ML16117A355]
22. WO 01324150-64. Fail, J.A. "TK CLOS & REG CN TO PERFORM GROUT PREP/GROUT PLACEMENT TK 16." Revision 0. August 22, 2014. [ADAMS Accession No. ML16119A351]
23. WO 01337683-31. Alexander, O. "TK.12 Flush & Grout Intact Chromate Cooling Coils." Revision 1. November 2, 2015. [ADAMS Accession No. ML20279A791]
24. WO 01337683-31-A. "Attachment 'A' – Tank 12 Coil Flushing Spreadsheet." [ADAMS Accession No. ML20279A792]
25. WO 01337683-31-F. "Attachment F – Coil Grout Spreadsheet." [ADAMS Accession No. ML20279A794]

26. WO 01337683-33. Patton, G.W. “Placement of Bulk Fill Grout (Tank 12 Work Order).” Revision 2. [ADAMS Accession No. ML20279A795]
27. WO 01337683-33-A. “Attachment A – Tank 12 Tremie Installation Steps.” [ADAMS Accession No. ML20279A796]
28. WO 01337683-33-B. “Attachment B – Tank 12 Cleaning/Pigging of Slickline.” [ADAMS Accession No. ML20279A797]
29. WO 01337683-50. Alexander, O. “TK12 Grout Failed Coils.” August 12, 2015. [ADAMS Accession No. ML20279A798]
30. WO 01337683-51. Patton, G.W. “TK 12 Closure Constr Perform Equipment Grouting.” [ADAMS Accession No. ML20279A799]

**<u>NRC Technical Reviews</u>**

Summaries of the primary documents listed above, which are related to Savannah River Site (SRS) Tank Farm grouting, are provided in Appendix A. Technical reviews of the grout-related documents listed above, as well as reports that NRC reviewed previously (ADAMS Accession No. ML16231A444), are the basis for NRC’s evaluation of SRS Tank 12H grouting operations and final configuration, and Tanks 12H and 16H grouting lessons learned, discussed next.

The staff coordinated with the State of South Carolina Department of Health and Environmental Control (DHEC) to identify areas of grout operations to focus on as they have nearly constant oversight of tank grouting operations. The staff inquired as to whether there were incidents or abnormal situations during the grouting that resulted in variance from procedure. (ADAMS Accession No. ML16111B174)

**<u>Evaluation</u>**

<u>Tank Grout Formulation, Testing, Placement and Performance</u>

Many of NRC staff’s concerns about the waste tank grout formulation that resulted from the original technical review of Tank 18F and 19F grouting and subsequent review of Tank 5F, 6F, 12H and 16H grouting operations remain at the time of this writing. This technical review, which is focused on Tank 12H grouting operations and Tanks 12H and 16H grouting lessons learned, summarizes remaining NRC staff recommendations from prior technical review reports and accounts for new information or changes to DOE’s approaches for Tank 12H and 16H. To fill the primaries and annuli of Tank 12H, DOE selected the same LP#8-016 reducing tank grout that had been used previously to fill Tanks 5F, 6F, 16H, 18F, and 19F (C-SPP-F-00055, Attachment 5.5). The following discussion addresses tank grout specifications and testing, grout placement, flowability and mounding, bleed water segregation, cracking, and occurrences of groundwater in-leakage.

*Grout Specifications and Testing*

The tank grout specification for Tanks 5F, 6F, 12H, and 16H (C-SPP-F-00055, Revision 4) differed from that of Tanks 18F and 19F (C-SPP-F-00055, Revision 2) in that a greater slump flow range was specified to enhance grout flowability in tanks containing cooling coils. Higher slump flow was achieved by increasing the dose of high-range water-reducer ADVA Cast 575 (W.R. Grace & Co., Cambridge, Massachusetts) to 1.18 to 1.2 liters (L) (40 or 41.25 fluid ounces (oz)) per cubic yard[2] (ADAMS Accession No. ML13267A452; SRR-CWDA-2013-00026, Attachments 3 and 4); however, 1.18 L per cubic yards (40 fluid oz per cubic yard) is the

[2] Note that 1 cubic yard is equivalent to 0.76 cubic meters.

maximum amount allowed by the specification (C-SPP-F-00055, Revision 4, Attachment 5.5). NRC staff requested 5 accepted and 5 rejected batch tickets for Tank 12H, in part to understand the range of admixture dosages used during grouting of this tank, but the tickets received (SRR-CWDA-2020-00052) were illegible (**Table 1**). RECOVER is a hydration stabilizer; 1.5 L per cubic yards (50 fluid oz per cubic yard) is added to the grout mix at the batch plant, and any additional volume used depends on ambient and operational conditions such as temperature, humidity, rapidity of travel, appearance of prior grout batch, etc. (ADAMS Accession No. ML18311A184)). Experimental work conducted to design a clean cap grout for use in the Saltstone Disposal Facility (and in Tank 16H) found that use of ADVA Cast 575 in this particular formula significantly increased bleed water production and rapid segregation of most of the grout solids from the liquid mass (VSL-14R3330-1). This observation may explain similar behavior of reducing tank grout from which bleed water separates to rapidly flow downgradient into pools at the tank perimeter during grouting operations.

**Table 1. Evolution of Admixture Dosages Used to Batch Tank Grout**

| Admixture | Dose in Fluid Ounces per 8-cubic-yard Batch | | | | | | |
|---|---|---|---|---|---|---|---|
| | Procurement Specification | Tank 5F | Tank 6F | Tank 12H | Tank 16H | Tank 18F | Tank 19F |
| ADVA 575 | 80–320 | 320 | | ND | 330 | 160 | |
| RECOVER | As Required | 50–60 | | ND | 30–60 | 30 | |
| EXP 958 | Up to 330 | 330 | | | | | |

ND=No data
1 fluid onces=30 ml
1 cubic yards=0.76 cubic meters

By April 2015, it had become known to DOE that Holcim Grade 100 slag would cease to be available in the near future (SRR-LWE-2015-00032; SRR-CWDA-2016-00068). DOE began preparing to switch to a different source for ground granulated blast furnace slag cement in the tank grout formulation in part by contracting-out a study of slag alternatives to Vitreous State Laboratory at The Catholic University of America. Based upon these test results, Lehigh Grade 120 slag was recommended for use (VSL-15R3740-1) by August 2015. Grade 120 slag was evaluated by DOE and its use in tank grout was determined to be consistent with the inputs to and assumptions of the PA (SRR-CWDA-2015-00088, SRR-CWDA-2015-00057). The grout specification (C-SPP-F-00055) was subsequently revised (Rev. 4) to allow use of either Lehigh Grade 100 or Lehigh Grade 120 slag cement. Work order (WO) 01337683-33 addressed grout preparations for bulk fill tank grout. It is notable that *Lehigh* Grade 100 slag cement, which may be used in tank grout per the revised grout specification, has not been put through the same set of tests as other slag alternatives (VSL-15R3740-1). Holcim's discontinued Grade 100 slag cement has been shown to have a smaller mean grain size (13 µm ≤ $d_{50}$ ≤ 16.05 µm; VSL-14R3330-1, VSL-15R3740-1) than Lehigh's Grade 120 slag ($d_{50}$ ~18.47 µm; VSL-15R3740-1), and Holcim's discontinued Grade 100 slag had higher sulfide content than Lehigh's Grade 120 slag (VSL-15R3740-1). Substituting a generic Grade 120 slag for Holcim's Grade 100 slag was hypothesized to result in a reducing tank grout having a higher compressive strength due to enhanced surface area (i.e., smaller particle size) and reactivity (VSL-15R3740-1). The authors of these test reports did not dwell on their unanticipated finding that Holcim's Grade 100 slag may have typically had a finer mean diameter than the Grade 120 slags they tested for DOE. The impact of slag particle size variability on compressive strength, hydraulic conductivity, and chemical reactivity of the reducing tank grout is uncertain, as is the extent to which slag particle size from a given slag manufacturer varies with time.

The switch to use of Grade 120 slag occurred on the second day of Tank 12H grouting (i.e., on 20 January 2016), after the first ~163 cubic meters (~213 cubic yards or ~43,000 gallons (gal)) of Lift 1 had been placed (SRR-LWE-2016-00036; SRR-CWDA-2016-00068) by 20 trucks on the first day and 7 additional trucks on the second day [ADAMS Accession Nos. ML16167A237 and ML18247A080 (Slide 21)]. For purposes of checking grout volume estimates, based upon these numbers, a concrete mixing truck delivered ~6 cubic meters (~7.9 cubic yards or ~1,600 gal) of grout per truck, rather than 6.1 cubic meters (8 cubic yards), which could be due to an inability to discharge the full contents of a 6.1 cubic meters (8 cubic yard) cement truck into the tank. Further discussion of pre- and post-grouting grout volume estimates is provided later in NRC's evaluation of *Grout Transferability, Flowability and Mounding*.

The glass content of ground granulated blast furnace slag cement is important to performance, and should not be less than 67 percent; slag having greater than 90 percent glass content offers the most satisfactory properties (Siddique and Kaur, 2012). CNWRA staff recently examined DOE's vendor-provided Holcim Grade 100 and Lehigh Grade 120 slags using X-ray Diffraction (Walter and Dinwiddie, 2020). Holcim's Grade 100 slag produced no XRD peaks because it consists of amorphous glassy particles, whereas Lehigh's Grade 120 slag indicated a degree of crystallinity; therefore, reducing grouts comprised of each slag may differ in important properties. Minerals fit to the Grade 120 slag spectra included pyrophylite, periclase, and nacrite. Some underfit peaks of Grade 120 slag may be clays; they did not fit minerals in the database. Reduced-sulfur-bearing minerals were not identified in the Grade 120 slag samples, although the detection limit is higher than would be observed for reduced sulfur-bearing minerals based on their expected abundance. Crystalline slag forms are not typically used as cementitious materials because they are not as chemically reactive as glassy slag. Although NRC previously concluded that switching from Holcim Grade 100 to Lehigh Grade 120 slag was likely beneficial with respect to the chemical performance of grout placed in Tank 12H due to anticipated higher reducing capacity (ADAMS Accession No. ML16231A444), the effect of slag Grade on chemical performance and hydraulic conductivity is uncertain. NRC staff will continue to monitor the impact of slag Grade on chemical performance of the tank grout.

CNWRA has continued to perform grout water-conditioning experiments in recent years. In a recent experiment, 31 ~1-$cm^3$ samples of reducing tank grout comprised of Holcim's Grade 100 slag having a mass of 99 g and mixed with 538 mL synthetic SRS groundwater achieved a minimum $E_h$ of +171 mV under slowly diminishing oxic conditions. That is, the tank grout has been very slowly depleting the synthetic SRS groundwater (sSRS) of dissolved oxygen. If the experiment is allowed to continue until most of the oxygen is consumed, $E_h$ may begin to more rapidly decrease from current values of +219 mV at ~64% dissolved oxygen saturation. In another recent water-conditioning experiment, 31 ~1-$cm^3$ samples of reducing tank grout comprised of Lehigh's Grade 120 slag having a mass of 98 g and mixed with 560 mL synthetic SRS groundwater achieved a minimum $E_h$ of +224 mV under slowly diminishing oxic conditions. As before, this tank grout has been very slowly depleting the aqueous solution of oxygen, and if the experiment is allowed to continue until most of the oxygen is consumed, $E_h$ may begin to more rapidly decrease from current values of +248 mV at ~63% dissolved oxygen saturation. The cubed samples of reducing grout used in these experiments were freshly cut from the interior of two cylindrical specimens cast in August 2015 (Holcim Grade 100) and April 2016 (Lehigh Grade 120). Nevertheless, the grout may have become oxidized or less reactive over time. In previous experiments using fresh, pulverized grout (representing best case conditions) the lowest $E_h$ observed was −303 mV. In another recent CNWRA grout water-conditioning experiment conducted with 24 grout cube samples, freshly cut from the interior of a different April 2016 reducing grout specimen, weighing 106 g and mixed with 517 mL synthetic SRS groundwater, the minimum $E_h$ achieved was −30 mV with dissolved oxygen saturation of 0.34%. A notable difference between the two April 2016 reducing grout specimens is that the latter one had been broken free from its glass mold on January 2, 2018, and was, therefore, exposed to air for a longer period when it was sectioned and interior cubes were removed for use in these recent experiments, whereas the former specimen was not removed from its glass mold until January 2, 2020, and may therefore be fresher, less oxidized, and more reactive. Nevertheless, the samples removed from the latter specimen reacted more quickly with the groundwater and achieved a lower minimum Eh, which is a counterintuitive result, although the higher solid to water ratio may have also affected the results. Based on previous experiments with individual components of the reducing tank grout, the ground granulated blast furnace slag (GGBFS) is the only component of tank grout that produces strongly reducing conditions (such as $E_h$ on the order of −200 to −300 mV). Based on these fiscal year (FY) 2020 experiments and previous experiments with laboratory-prepared reducing grout specimens, it is uncertain that SRS reducing tank grout will produce strong reducing conditions in infiltrating contact water.

Although DOE performed waste release experiments to study the solubility of Tank 12H key radionuclides under various chemical conditions, the results of the waste release experiments may not be representative of conditions expected in the waste zone for submerged tanks, such as Tank 12H. As discussed in NRC staff's Tank 12H waste-release TRR (ADAMS Accession No. ML19298A092), the targeted chemical conditions in the experiments (see column "Target Experimental Conditions" in Table 2) were inconsistent with the assumed chemical conditions for what is referred to as "Condition C" and "Condition D" in DOE's H-Area Tank Farm PA [see column "HTF PA (for Submerged Tanks such as Tank 12H)" in **Table 2**].

**Table 2. Assumed and Targeted Chemical Conditions in Submerged Tank 12H from Table 5 in NRC's Tank 12H Waste Release TRR (ADAMS Accession No. ML19298A092)**

| | Measured Quantity | HTF PA (for Submerged Tanks such as Tank 12H) | Target Experimental Conditions | Actual Experimental Conditions |
|---|---|---|---|---|
| **Condition C (HTF PA) or RRII (Target)** | pH | 8.8 | 11.1 | 10.8 - 11.5 |
| | E*h* (mV) | -310 | -470 | -71 to +205 |
| **Condition D (HTF PA) or ORII (Target)** | pH | 8.8 | 11.1 | 10.6 |
| | E*h* (mV) | +360 | +560 | +340 |
| **ORIII** | pH | 9.2 | 9.2 | 9.2 |
| | E*h* (mV) | +290 | +680 | +410 |

Experimental work conducted to design a clean cap grout for use in the Saltstone Disposal Facility—a grout that was also used to complete filling Tank 16H—found that switching from use of Holcim Grade 100 to Lehigh Grade 120 slag in that formula led to increased bleed-water production (VSL-14R3330-1).

Although DOE's position has been that the hydraulic conductivity of tank grout would not be impacted by the change in slag Grade (SRR-CWDA-2015-00057), Grade 120 slag may produce a grout with a lower hydraulic conductivity than assumed in the HTF PA, which in turn may enhance rapid bypass of infiltrating water around the grout mass rather than through it. CNWRA experimental work with synthetic saltstone samples comprised of Lehigh Grade 120 slag had lower hydraulic conductivity than synthetic saltstone comprised of Holcim Grade 100 slag, resulting in longer residence times for sSRS water in the matrix and enhanced diffusive release of Tc-99 from the simulated waste form (ADAMS Accession No. ML20289A873), although the limited experimental results do not support a causative relationship between slag grade and hydraulic conductivity.

Similar to the concern NRC raised in the Tank 16H grouting TRR (ADAMS Accession No. ML16231A444), DOE used two different grouts to fill Tank 12H (163 cubic meters or 213 cubic yards or ~43,000 gal) of grout constructed with Grade 100 slag on the bottom of the tank and grout constructed with Grade 120 slag for the remainder of the tank). Had DOE used only Lehigh Grade 120 slag-based grout throughout Tank 12H, a more homogeneous monolith may have developed. NRC will follow-up with DOE concerning the likely increased uncertainty on performance that may be associated with use of two different grout formulations with potentially different hydraulic conductivities.

The HTF PA assumes that tank grout has adequate compressive strength [i.e., minimum of 13,800 kilopascals (2000 psi or 138 bars) at 28 days post-placement, per HTF PA Table 3.2-9 (SRR-CWDA-2010-00128)], to withstand the overburden load on each tank[3], thereby providing stability upon closure and a physical barrier that will discourage intruders. Forty-one sets of seven test cylinders were prepared with Tank 12H grout, yielding 287 test cylinders. To confirm that the minimum assumed strength was achieved for grout placed into Tank 12H, DOE conducted compressive strength testing of 205 grout test cylinder specimens collected at the point of delivery and aged either 7 or 28 days (SRR-CWDA-2016-00068). Compressive strength of grouts made with slag is dependent on slag chemical composition (e.g., CaO content), the proportion of slag used in the grout mixture, slag particle size, and environmental conditions during hydration. The compressive strength of the Lehigh Grade 120 slag reducing tank grout was expected to be greater than the Holcim Grade 100 slag grout at 28 days (VSL-15R3740-1; ADAMS Accession No. ML16231A444), but this result did not occur. Grout made with Lehigh Grade 120 slag, which CNWRA found to have a degree of crystallinity, may pozzolanically react, set up, and strengthen more slowly than the former tank grout made with glassy, amorphous slag, but additional testing beyond 28 days would be necessary to support this hypothesis. Up to 82 of the 287 test cylinders prepared with Tank 12H grout may remain available for compressive strength testing at this time. Although all tested Tank 12H grout cylinder specimens had compressive strengths greater than the design 28-day compressive strength of 13,800 kilopascals (2000 psi or 138 bars), the average 28-day compressive strength of Tank 12H tank grout was 16,400 kilopascal (2,383 psi or 164 bars) (SRR-LWE-2016-00036), which was less than the Tank 16H average of 19,200 kilopascals (2,788 psi or 192 bars) (SRR-CWDA-2015-00159).

Notwithstanding the potential issues listed above, assuming grout performance and testing requirements are met, tank grout comprised in part of Grade 120 slag likely will meet PA assumptions for closure of Tank 12H (ADAMS Accession No. ML16231A444).
Additional information about the impact of Grade 120 slag on hydraulic conductivity and chemical reactivity of the tank grout would help reduce uncertainty in the PA results.

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[3] Although DOE indicates that the compressive strength of the tank grout is adequate to withstand the overburden load on each tank, it is not clear to NRC that the tank grout, which is not expected to be fully bonded to the tank and vault, would initially be relied on to accept the load of overlying surface materials, including an engineered cover system to be placed over the tank farms. The reinforced concrete vault will initially be relied on to withstand the overburden load on each tank until such time that the vault fails. When discussing site stability during the July 2015 onsite observation (ADAMS Accession No. ML15239A612), NRC similarly noted that a bounding structural analysis might consider the mass of the tank grout without the associated stiffness of a solid, grout-filled monolith, because the tank grout is not expected to create a solid monolith with the tank/vault given the potential for shrinkage and cracking.

*Grout Placement*

Grouting operations at Tank 12H began on January 19, 2016, and were completed on May 2, 2016 (SRR-LWE-2016-00036; SRR-CWDA-2016-00068; SRR-CWDA-2018-00047). Tank primary grouting began on January 19, 2016, and ended on March 7, 2016 (SRR-LWE-2016-00036; SRR-CWDA-2018-00047; ADAMS Accession No. ML20280A286). Annulus grouting began on February 8 and ended on March 1, 2016 (SRR-LWE-2016-00036; SRR-CWDA-2018-00047; ADAMS Accession No. ML20280A286). Failed cooling coil grouting began on January 26 and ended on January 29, 2016 (ADAMS Accession No. ML20280A286). Intact cooling coil grouting began[4] on March 16, 2016 (SRR-LWE-2016-00036), or March 17, 2016 (SRR-CWDA-2018-00047; HTF-SKM-2015-00010), and ended on March 21, 2016 (SRR-LWE-2016-00036; SRR-CWDA-2018-00047; HTF-SKM-2015-00010). Riser grouting began[5] on March 31, 2016 (SRR-LWE-2016-00036), or April 5, 2016 (SRR-CWDA-2018-00047; ADAMS Accession No. ML20280A286), and ended[6] on April 23, 2016 (ADAMS Accession No. ML20280A286), or April 27, 2016 (SRR-LWE-2016-00036; SRR-CWDA-2018-00047). Additionally, a spray chamber located above Riser 5 of Tank 12H was grouted on May 2, 2016 (SRR-CWDA-2016-00068).

NRC recently reviewed DOE's Tank 16H grouting operations lessons learned document, which included the recommendation to devise grout placement sequence/lift height plans on real grout data for set-up time, specific gravity, etc., instead of on bounding values to potentially provide more placement flexibility. For Tank 12H, a structural analysis was performed to estimate the stresses that would be applied to the wall of the primary during grout placement (T-CLC-F-00496), but given that Tank 12H grouting began within months of Tank 16H grouting, the Tank 12H structural analysis likely assumed bounding values. Real grout data should be used during future Tank 15 structural analyses for grout placement. Based on the results, the following lift height limits were implemented to prevent tank wall failure:

1. Height of annulus grout above primary grout was limited to ≤1.8 m (6 ft).
2. Height of primary grout above annulus grout was limited to ≤2.4 m (8 ft) (SRR-CWDA-2016-00068).

A 9-lift grout-placement sequence was devised to cycle between grouting the tank primary and the annulus to remain within the calculated lift-height limits (SRR-LWE-2016-00036). Tank interior bulk fill was comprised of Lifts 1, 4, 6, and 8 (SRR-LWE-2016-00036). Annulus grout was comprised of Lifts 2, 3, 5, 7, and 9 (SRR-CWDA-2016-00068). A 0.6-m-(2-ft)-thick Lift 1 was placed in the primary first to eliminate tank-floating concerns and support the in-tank carbon steel cooling coils (SRR-CWDA-2016-00068). Due to groundwater ingress into the annulus, placement of Lift 2 was delayed until after Lift 4 in the tank had been poured. Under continuous placement conditions, the grout discharge rate into the tank primary and annulus ranged from 0.76 to 1.07 cubic meters per minute (1.0 to 1.4 cubic yards per minute or

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[4] Grouting operations video folders provided by DOE for March 16 (ADAMS Accession No. ML20280A286) are labeled "Annulus Inlet Duct" and "Tank Riser Inspections 1, 3, 5, 8, Center, E, W," and no video was provided for March 17–21. As a matter of practicality, intact cooling coil grouting was likely not filmed; therefore, the March 16, 2016 start date may be incorrect.

[5] Grouting operations video provided by DOE "Riser 3, 4, N, W, fills" indicates that riser grouting began on April 5, 2016 (ADAMS Accession No. ML20280A286), which contradicts the SRR-LWE-2016-00036–provided date of March 31, 2016—a date for which no video was provided.

[6] Final grouting operations video provided by DOE, i.e., "Riser Center, 5, 8, 6," has a date of April 23, 2016 (ADAMS Accession No. ML20280A286); no video was provided of riser grouting that may have occurred on April 27, 2016.

202 to 283 gal per minute) (RPT-5539-EG-0016), which is consistent with NRC staff notes that 6 to 7 minutes of time elapsed during grout placement from a single truck.

*Grout Transferability, Flowability and Mounding*

Type I tanks, such as Tanks 5F, 6F, and 12H, contain both vertical and horizontal cooling coils to cool waste, and 12 steel and concrete support columns. Cooling coils and support columns are obstructions that make it challenging to clean waste from the bottom of the tank and to grout the tank. More than 6.9 km (4.3 mi) of cooling coils are present in Tank 12H. To completely fill tanks that contain cooling coils and support columns with tank grout, DOE enhances tank grout flowability by specifying a higher range of desirable slump flow values (C-SPP-F-00055, Revision 4, Attachment 5.5), achieved solely through the use of admixtures (i.e., high-range water reducer). Acceptable slump flow is obtained at the batch plant and 30.3 L (8.0 gal) of water is withheld to allow further slump adjustments through water addition after grout is delivered to the site (per ASTM C94). During the October 2014 teleconference about Tanks 5F and 6F grouting operations (ADAMS Accession No. ML14330A037), NRC inquired about the process DOE uses to reach the desired slump through use of water additions and admixtures. DOE explained that their contractors provide slump flow test results to the Argos batch plant in the morning, after the first cement mixer trucks reach the site, so that the plant can modify slump through addition of admixtures at the batch plant without requiring water additions at the tank site. For Tank 12H and its annulus, DOE used 6 risers as grout entry points (Risers 1, 3, 5, and 8 in the tank primary, and the East and West Risers in the annulus (SRR-CWDA-2020-00052, Attachment 3). Reducing grout flowed over the waste material on the floor of the tank, stabilizing and immobilizing it (SRR-CWDA-2016-00068). Grout flowed around internal obstructions (cooling coils and support columns) without significant mounding (SRR-CWDA-2016-00068; SRR-LWE-2016-00036). Camera inspections of the waste tank identified no significant issues with filling void space at the top of the tank due to mounding (SRR-LWE-2016-00036), and there was only a small deviation between pre-estimated and final calculated tank grout volumes (SRR-CWDA-2016-00068). Void volume estimates for grouting Tank 12H were documented in the final configuration report inputs (SRR-LWE-2016-00036).
DOE estimated that 3,000 cubic meters (3,928 cubic yards or 793,411 gal) of grout would be required to fill a generic, empty Type I tank (U-CLC-G-00001), excluding riser volumes. For Tank 12H specifically, DOE conservatively estimated that the actual volume of the tank was 3,010 cubic meters (3,937 cubic yards or 795,082 gal), and that the volume of residual material remaining on the floor of the primary (**Figure 1**) and on cooling coils (**Figure 2**) totaled 9 cubic yards (1,900 gal) (SRR-LWE-2016-00036; U-ESR-H-00125; M-CLC-H-03256). Accounting for the residual material volume, the final estimated Tank 12H grout volume (excluding risers) was 3,000 cubic meters (3,927 cubic yards or 793,182 gal). Based on design drawings, the estimated volume of grout that would be taken up by the primary risers and 4 spray chambers was 21 cubic meters (28 cubic yards or 5,655 gal) (SRR-LWE-2016-00036). DOE estimated that a volume of 422 cubic meters (552 cubic yards or 111,549 gal) of grout would be required to fill a generic Type I tank annulus (U-CLC-G-00001). For the Tank 12H annulus, however, DOE conservatively estimated that the actual volume of the tank annulus was 446 cubic meters (583 cubic yards or 117,653 gal), excluding risers. Based on design drawings, the estimated volume of grout that would be taken up by Tank 12H annulus risers was 17 cubic meters (22 cubic yards or 4,443 gal) (SRR-LWE-2016-00036).

According to operations logs [i.e., Work Order (WO) 01337683-33], 2980 cubic meters (3,902 cubic yards or 788,103 gal) of grout were placed as bulk fill in the primary (2,970 cubic meters or 3,887 cubic yards) and primary risers (11 cubic meters or 15 cubic yards), and 477 cubic meters

(624 cubic yards or 126,032 gal) of grout were placed as bulk fill in the annulus (469 cubic meters or 613 cubic yards) and annulus risers (8.4 cubic meters or 11 cubic yards), for a total of 3,460 cubic meters (4,526 cubic yards or 914,134 gal) (SRR-LWE-2016-00036).

The actual grout volume placed into the primary was calculated based upon the assumption that 486 trucks used to deliver grout to the primary each nominally contained 6.1 cubic meters (8 cubic yards or 1,616 gal) of grout (SRR-CWDA-2016-00068); Lift 1 data provided by DOE, however, suggests that mixer trucks may discharge only ~6.0 cubic meters (7.9 cubic yards or 1,596 gal) of grout in practice, which would consequently imply that at the low end 2,935 cubic meters (3,839 cubic yards or 775,378 gal) was placed into the Tank 12H primary, a ~2.2 percent difference between the pre-estimate and the actual amount of grout placed. Risers penetrating Tank 12H (SRR-CWDA-2020-00052, Attachment 1) were filled with grout to the bottom of the top riser cover/plate, above grade level (SRR-LWE-2016-00036), but during riser grouting, the amount of grout actually placed was about half the amount estimated. DOE explained that some of the riser void volume was grouted during primary or annulus grouting, prior to formally beginning riser grouting, and that not all riser plugs were removed from the risers, such that riser grout volumes were originally overestimated (SRR-LWE-2016-00036).

**Figure 1. Residual WIR on the Floor of the Tank 12H Primary Appears Similar to Mud Cracks. Light Reflects off a Pool of Water beyond the Column in the Bottom Image. Date of Video: January 19, 2016.**


**Figure 2. Residual WIR on cooling coils within the Tank 12H Primary. Date of Video: January 19, 2016.**

The Tank 16H grout strategy indicated that having 8 to 10 cement mixer trucks in rotation was ideal (SRR-LWE-2014-00013), whereas the Tank 12H grout strategy later clarified that a grout delivery rate of 8 to 10 trucks per hour (SRR-LWE-2014-00147) was ideal. Eight to 10 trucks per hour converts to 49 to 61 cubic meters per hour (64 to 80 cubic yards per hour [assuming discharge of 6.1 cubic meters, 8 cubic yards or 1,616 gal of grout per truck], consistent with Section 3.6.1.2 of the procurement specification, which requires a sustained average delivery of 57 cubic meters per hour (74 cubic yards per hour) during an 8-hr work day (C-SPP-F-00055, Revision 4). When NRC staff asked about the feasibility of establishing contractual obligations for the number of cement mixer trucks in rotation, DOE indicated that such contractual obligations would lead to significantly higher costs because it has to compete with other customers for trucks (ADAMS Accession No. ML16167A237). Instead, DOE contractors work with the batch plant to schedule tank grouting during weeks when the plant can supply sufficient trucks to the tank closure effort (ADAMS Accession No. ML16167A237). DOE noted that while less than the optimal number of trucks were in rotation during Tank 12H grouting operations, no significant mounding issues occurred (ADAMS Accession No. ML16167A237).

Grout mounding may have been a less significant issue for Tank 12H than for Tank 16H in part because tank primary and annulus grouting operations took place during winter and early spring (19 January–28 April 2016), instead of during high-temperatures summer months. NRC has reviewed the Tank 16H grouting operations lessons learned document (SRR-TCR-2015-00024) recently provided by DOE, which recommended that highly flowable clean cap grout be tested and evaluated to ensure that it meets tank farm PA requirements, so that if needed in the future, it can be used with confidence to again fill a tank primary or annulus between any mounds of reducing grout that may form and the tank ceiling. Additionally, the lessons learned document advised that grouting operations be planned around seasonal weather expectations, because high summer temperatures were thought to have resulted in the unusual mounding observed only in Tank 16H, to date. This report also noted that highly flowable clean cap grout could not be placed inside Tank 12H without obtaining pre-approval from SC DHEC.

The Tank 16H lessons learned document also addressed needs to (i) remove diversion valves from the grout slickline, because such use resulted in grout plugging and ineffective cleaning of the slickline, and (ii) develop a better method to ensure that the grout slickline is fully wetted/lubricated prior to grout introduction to minimize grout plugging (SRR-TCR-2015-00024).

*Bleed Water Segregation*

Staff reviewed some of the video footage that DOE provided of Tank 12H bulk tank and annulus grouting (ADAMS Accession No. ML20280A286). Rapidly migrating dark water was observed to bleed from slowly flowing, light-colored grout lobes as they moved away from the discharge zones of Tanks 18F, 19F, 5F, 6F, and 16H. NRC staff note the potential for bleed water to segregate from the grout mix during grout flow and distribution throughout the tank (see also VSL-14R3330-1, and its discussion of the bleed water effects of use of ADVA Cast 575), whereby potentially higher water-to-cement-ratio grout is delivered to outlying portions of the tank, far from the discharge riser (ADAMS Accession No. ML16231A444). Dark water emerges from the free surfaces of freshly flowing, light-colored grout lobes: from their front edges, side edges, and top surfaces (**Figure 3**). Video cameras recorded aqueous ponds forming at lower elevations near the tank perimeter, away from mounded grout located beneath the discharge riser (SRR-CWDA-2015-00170; ADAMS Accession No. ML16231A444). NRC staff found that bleed water was exuding from the bulk mass of flowing tank grout when it was being distributed throughout Tank 16H, and that this exudate increased the overall volume of water that collected


**Figure 3. Photo of Bleed Water Segregation Occurring in Grout Poured into the Tank 12H Primary. The Dark Outline Surrounding a Freshly Deposited Lobe of Grout is Segregated Water Separating from the Grout Mass. Date of Video: January 19, 2016.**

in pools at the tank wall beyond the amount introduced as slickline and tremie lubricant[7] (ADAMS Accession No. ML16231A444). Exposed grout lying above pools of water will hydrate in a relatively dry microclimate, whereas grout submerged under standing water at the tank perimeter will hydrate in a saturated microclimate; because of this, grout properties are unlikely to be uniform (ADAMS Accession No. ML13127A291). Tank grout that hydrates and hardens in a subaqueous environment may have different properties relative to that forming subaerially; although it is not entirely clear what environment will produce higher-quality, better-performing grout (ADAMS Accession No. ML16231A444). NRC staff recently reviewed the Tank 16H lessons learned document, which had a recommendation to analyze data from Tank 16H grout testing to develop an acceptable, non-zero range for bleed-water production.

DOE discussed in the Tank 12H final configuration report how water tended to accumulate in low areas at the tank perimeter, rather than under discharge risers, such that grout was not directly placed into standing water (SRR-CWDA-2016-00068); this description is generally consistent with NRC staff's prior observations of grout placement and bleed water segregation in other grouted tanks. DOE stated that water resting on the surface of underlying grout at the perimeter of the tanks is not expected to degrade cured grout properties (SRR-CWDA-2016-00068). DOE made the point that grout was not placed into standing water in Tank 12H because grout drop test results (RPT-5539-EG-0016) found a greater potential for bleed water

[7] During the July 28–29, 2015, onsite observation visit, DOE approximated that 18.9 to 26.5 L (5 to 7 gal) of water per day (quantity dependent on the length of the line) was used to lubricate the Tank 16H slicklines and tremies at the beginning of the day and then discharged into the primary or annulus.

segregation to occur when grout is directly placed into aqueous pools (SRR-CWDA-2016-00068; SRR-LWE-2014-00147; ADAMS Accession No. ML16111B174). Residual pools of flush water present on the floor of the tank before grouting began were mapped so that those areas could be purposefully avoided during initial grouting of Tank 12H (ADAMS Accession No. ML16111B174).

Although DOE indicated in the Tank 12H grout strategy document that grout could generally be placed from a significant drop height through diffuse freefall (SRR-LWE-2014-00147; RPT-5539-EG-0016), it subsequently indicated that a tremie was always used during Tank 12H grouting operations to control grout placement (ADAMS Accession No. ML16167A237) and that tremies would continue to be used during future grouting operations (ADAMS Accession No. ML16167A237). DOE drops one 1.5 m (5 ft) section of tremie at a time into the tank as the grout level rises; DOE does not drop grout into the tank from full height. Because some freefalling grout could drop directly into pools of water, which would locally enhance bleed water segregation, NRC evaluates that use of tremies is a good practice to more carefully control grout placement.

Groundwater in-leakage into submerged Tank 12H led to delays in grouting and/or need for mitigative measures to avoid grouting into areas of the tank with standing water. DOE has worked with the State to ensure that ventilation systems of sufficient capacity remain operable at the time of grouting to avoid future problems with groundwater in-leakage for submerged tanks. DOE should continue to ensure that grouting does not occur in standing water which could lead to detrimental impacts to grout quality or provide additional support that the tank specific conditions do not locally degrade cured grout properties or negatively impact performance.

NRC staff will continue to monitor the extent of bleed water segregation that is visible during tank grouting operations.

*Grout Cracking*

Within Lift 6 in the Tank 12H primary, several small, isolated cracks were observed to have formed in the grout below Riser 1 during the morning inspection on February 22, 2016 (SRR-CWDA-2016-00068; SRR-LWE-2016-00020). The longest crack was estimated to be <1 m (<3 ft) (SRR-CWDA-2016-00068. Grout was last placed through Riser 1 during the previous grout placement day, which was five days earlier. DOE contractor staff speculated that the cracks would not extend deeper than the grout thickness poured during the prior work day [i.e., ≤0.6 m (≤2 ft)] (SRR-CWDA-2016-00068); however, whether this is accurate would depend on the mechanism that caused the cracks to form (Dinwiddie et al., 2011). DOE indicated that the cracks in the grout appeared surficial and localized, and therefore they were expected to have minimal impact on system performance because they were thought to be unlikely to significantly increase the quantity of groundwater that would flow through the monolith to residual waste at the bottom of Tank 12H (SRR-LWE-2016-00020; SRR-LWE-2016-00036). In the final configuration report, no indication was given about the size range of the observed crack apertures. DOE stated that these cracks would not appreciably impact grout performance with respect to waste tank stability, flow through the tank, or the reducing capacity of the grout (SRR-CWDA-2010-00128; SRR-CWDA-2015-00074; SRR-LWE-2016-00036). Large-aperture cracks were previously observed to have formed in the annulus grout of Tank 16H, shortly after the grout had been placed. DOE could provide additional information to assess the impact of crack formation on tank grout performance. Additionally, information about the mechanisms of crack formation, including thermal cracking, for all waste-stabilizing grout monoliths, including

Tanks 12H and 16H would be beneficial in better understanding the nature and extent of cracking to assess the impact on performance.

*Groundwater In-Leakage in Tank 12H*

During a May 17, 2016, teleconference, NRC inquired whether DOE had placed constraints on grouting operations related to accumulation of water in tanks. DOE contractors responded that they use expert judgement to determine when (and under what conditions) grouting should proceed (ADAMS Accession No. ML16167A237).

Placement of Lifts 2 and 3 in the Tank 12H annulus was delayed (ADAMS Accession No. ML16111B174) until 8 February 2016 (SRR-CWDA-2016-00068), due to groundwater accumulation in the annulus (**Figure 4**) when the temporary ventilation system, which forced unheated air through the annulus, was shut off (ADAMS Accession No. ML16167A237). As expected, groundwater accumulated in the annulus faster when air was "pulled" under negative pressure than it did when it was "pushed" with positive pressure (ADAMS Accession No. ML16167A237 and SRR-LWE-2015-00048). DOE estimated that ~3,785 L (~1000 gal) of groundwater was pumped out of the Tank 12H annulus (ADAMS Accession No. ML16167A237), reducing the water level to no more than 5 cm (2 in). Any standing water remaining in the annulus when grouting began likely would have enhanced bleed water segregation in Lift 2 (cf. RPT-5539-EG-0016, Test 2), leaving an as-yet-unquantified impact on the hydraulic conductivity of the bottom layer of grout (i.e., Lift 2) in the annulus (cf. SRNL-STI-2012-00576).


**Figure 4. Groundwater In-Leakage in the Annulus, as viewed from the West Riser. Date of Video: January 19, 2016.**

As tank grout placed into Tank 12H primary approached the tank roof and risers, liquid perched on the grout surface was observed from several of the risers (SRR-CWDA-2016-00068; SRR-LWE-2016-00036). DOE contractors speculated that the liquid may have initially been (i) the "hundreds of gallons of liquid (that) remained on the tank floor" when grouting of the primary began, (ii) rainwater that intruded from riser openings, (iii) liquid used to lubricate the

slicklines and tremies, and/or (iv) groundwater in-leakage at a rate of 18.9 L/hr (5 gal/hr) through a crack in the wall near the base of Riser 8 (SRR-LWE-2016-00036). Tank 12H is located entirely below the water table, allowing in-leakage to occur. Grout was placed into Riser 8 in less than 1.5 hrs after the liquid in the riser was pumped out (SRR-LWE-2016-00036). DOE did not consider whether the liquid perched on the grout surface could have been bleed water that segregated away from grout flow lobes, flowing to low spots near the tank wall.
DOE contractors indicated they pumped 4.5 cubic meters (5.94 cubic yards or 1,200 gal) of liquid from 7 of 9 risers in the tank primary (i.e., Risers 1, 2, 5, 6, 7, 8, and Center). Per DOE contractors, the pump was typically capable of pumping the liquid level down to approximately 5 cm (2 in) or less if ventilation were running. NRC staff will follow-up with DOE about whether some of the liquid that was pumped out of the risers could have been bleedwater.

Dehumidification with heating was also employed in the tank primary to evaporate water (ADAMS Accession No. ML16167A237). During the May 17, 2016, teleconference, DOE indicated that it is working with SCDHEC to enable original, operational ventilation systems to remain in place during future grouting operations (ADAMS Accession No. ML16167A237) to better manage water ingress. NRC staff will follow-up with DOE on this topic.

Water was also observed flowing into the vertical ventilation inlet duct of the Tank 12H annulus (SRR-CWDA-2020-00058) through a crack in the clay ventilation duct wall before its grouting was completed (SRR-CWDA-2016-00068; August 2018 OOV). Doe contractors speculated that groundwater was leaking into the duct because its elevation is below the water table (SRR-CWDA-2016-00068). Approximately 1,893 L (500 gal) of water was pumped out of the annulus, leaving an estimated 5-cm (2-in) water-level in the annulus prior to adding the final grout needed to fill the dehumidification ductwork inlet (SRR-LWE-2016-00036; SRR-CWDA-2016-00068). The water level in Tank 12H was measured with a steel tape; i.e., workers dropped a measuring tape with attached weight into the water and read the water level from the tape with a camera (SRR-CWDA-2016-00068). DOE contractors estimated the rate of groundwater in-leakage was approximately 22.7 L/hr (6 gal/hr) (SRR-CWDA-2016-00068). Cooling coil grout was poured into the ductwork approximately 1.5 hrs after groundwater was pumped out (WO 01337683-33; SRR-LWE-2016-00036; SRR-CWDA-2016-00068).

DOE maintains that the final physical and chemical properties of the hydrated cooling coil grout placed into the Tank 12H vertical dehumidification ductwork are consistent with HTF PA assumptions for waste tank stability and hydrologic transport, or what they referred to as “tank flow modeling” (SRR-CWDA-2016-00068). DOE stated that the “small amount of water in the dehumidification duct would not create grout property conditions different from those assumed” in the HTF PA (SRR-CWDA-2016-00068).

Annulus and Ventilation Duct Grouting

During the February 2–3, 2016, onsite observation visit, DOE stated that Tank 12H annulus cameras were located in the East and West Risers and that one might also be placed in the South Riser, but that none could be placed in the North Riser (ADAMS Accession No. ML16111B174). Recently, DOE clarified that video cameras in the Tank 12H annulus were located only in the East and West Risers (SRR-CWDA-2020-00052, Attachment 2).
For improved visibility of annulus grouting operations, the NRC staff previously recommended that DOE consider placing video cameras in *all* tank annuli risers, if available, or else consider repositioning cameras during grouting operations if they cannot be placed in all risers simultaneously (ADAMS Accession No. ML14342A784).

Also, during the February 2–3, 2016, onsite observation visit, DOE noted that placement of Lifts 2 and 3 in the Tank 12H annulus and horizontal ventilation duct had been delayed due to accumulated groundwater that had leaked into the annulus (**Figure 4**). While DOE pumped out most of the standing water and waited for the rest to evaporate, Tank 12H grouting proceeded directly from placement of Lift 1 to 4 in the primary (ADAMS Accession No. ML16111B174).

Annulus grouting (Lifts 2, 3, 5, 7, and 9) commenced on 8 February 2016, and was completed on 1 March 2016 (SRR-CWDA-2016-00068; ADAMS Accession No. ML20280A286). Although the Tank 12H closure module (SRR-CWDA-2014-00086) had suggested that a more flowable grout might be used to grout future ventilation ducts, and although DOE reiterated the potential use of a more flowable grout for ductwork during the February 2–3, 2016, onsite observation visit, the Tank 12H grout strategy document (SRR-LWE-2014-00147) did not address the issue (ADAMS Accession No. ML16111B174). Recently, however, a work order for grouting the tank interior was made available for NRC review, and it indicates that Lifts 5, 7, and 9 partially consisted of placement of cooling coil grout inside the annulus ventilation duct (WO 01337683-33), addressing the issue of grout flowability within the ductwork. The rest of the tank annulus was filled with the same reducing grout formulation used to fill the Tank 12H primary (using Grade 120 slag) (SRR-LWE-2016-00036). It is NRC staff's understanding that this is the first tank for which flowable cooling coil grout was placed into the annulus ventilation duct.

Structural-support–related grouting procedures used when grouting the annuli of Tanks 5F, 6F, and 12H have involved pre-grouting (Lift 2) from the steel pan up to the base of the smallest horizontal duct, 15 to 30 cm (6 to 12 in) above the pan (e.g., SRR-LWE-2014-00147). During the May 17, 2016, teleconference with NRC, DOE indicated that if a horizontal ductwork is substantially intact, they will always fill waste tank ventilation ducts from inside, via the vertical inlet and exhaust ducts as grout entry points (ADAMS Accession No. ML16167A237). Except for Tank 16H, the other grouted tanks have had their vertical inlet and exhaust sections of their ventilation ducts filled nearly simultaneously with external placement of grout in the annuli to ensure the structural integrity of the ducts was maintained. DOE indicated that it returned to this cautious approach when grouting the annulus and ventilation duct of Tank 12H (ADAMS Accession No. ML16167A237). Grout poured into the ductwork inlet was observed by a camera in the East Riser to flow out of two ventilation registers or air supply slots [i.e., 15 cm × 36 cm (6 in × 14 in) openings in the top of the horizontal duct into the annulus (SRR-CWDA-2016-00068). DOE interpreted that the grout observed flowing out of the registers indicated that this section of the ductwork was filled with grout (SRR-CWDA-2016-00068). DOE concluded that the entire ventilation duct was sufficiently filled with grout because, during a complete camera-based inspection conducted in 2012 (C-ESR-G-00003, Revision 13), the duct had no collapsed areas that could obstruct grout flow. A total of 16 rectangular ventilation registers (**Figure 5**) in the top of the horizontal ductwork provided openings, spaced 5 m (17 ft) apart, into or from which grout could flow during duct and annulus grouting (SRR-CWDA-2016-00068, SRR-CWDA-2020-00058).

The continuity of grout placement when filling contaminated ducts is particularly important. Uninterrupted flow of grout is essential to ensure that permanent porosity does not develop inside ductwork. DOE should try to place and position cameras in such a manner as to maximize visualization of grout entry and exit from ventilation duct registers.


**Figure 5. Photograph of Rectangular Ventilation Register in the Annulus, as viewed from the West Riser. Date of Video: January 19, 2016.**

Improved visualization will increase the evidentiary support for ventilation duct voids having been filled, and will enhance DOE's ability to develop lessons learned related to grout placement strategies that will increase the likelihood that ducts are fully grouted and do not contain risk-significant void space (ADAMS Accession No. ML16231A444).

DOE contractors pre-estimated that 446 cubic meters (583 cubic yards or 117,751 gal) of grout would be required to fill the Tank 12H annulus (SRR-LWE-2016-00036), but approximately 469 cubic meters (613 cubic yards or 123,810 gal) were placed into the annulus (SRR-CWDA-2016-00068) based on the number of cement mixer trucks that discharged grout and assuming a nominal volume of 6.1 cubic meters (8 cubic yards or 1,616 gal) of grout per truck.  This final calculated volume of grout placed into the annulus was as much as 4.9 percent greater than the pre-estimated volume needed, suggesting that no significant voids remained in the annulus upon completion.  NRC staff will continue to evaluate technical issues associated with grouting the annuli and ventilation ductwork of waste tanks during future monitoring activities.

<u>Equipment Grouting</u>

SRR-LWE-2015-00032 provides the grout formulation (T1A-62.5FA) used to grout voids within in-tank equipment in Tank 12H.  Voids were grouted with a pre-blended mix of cable grout, slag, fly ash and water (WO 01337683-51) that had been designed and tested to flow into and fill small spaces (SRNL-STI-2011-00592).  The formulation called for Grade 100 slag cement, but DOE used Grade 120 slag to grout Tank 12H equipment.  DOE has indicated there are no regulatory requirements for the properties of equipment grout, so there are no quality control test requirements associated with its production (SRR-LWE-2015-00032).  Equipment grout was mixed by SRR Construction and work was controlled via work order (SRR-LWE-2015-00032; WO 01337683-51).

During the February 2–3, 2016, onsite observation visit, DOE staff described equipment grouting operations (ADAMS Accession No. ML16111B174; see also SRR-CWDA-2015-00095) that would occur later, on April 7, 2016, long after the primary had been filled with grout. In-tank equipment resting on the floor of the primary or annulus were not filled with equipment grout (SRR-LWE-2016-00036). Equipment grout is prepared onsite in small batches. SRR personnel measure the dry ingredients by weight, pre-mix them, and then combine the premix with water per the formulation. The mixture hydrates using a low-shear mixer, and then a high-shear mixer is engaged to finish mixing and thin the equipment grout, after which there is a short timespan before it sets up. Equipment grout is metered using hand-poured buckets with known volume as it is slowly and deliberately placed into small openings in each piece of equipment using gravity-driven flow through a hose and funnel (SRR-LWE-2016-00036). Prior to filling with grout, equipment is vented by either drilling a vent at a high point or by removing components to open a vent in the equipment (SRR-CWDA-2016-00068; see also SRR-LWE-2014-00147). High point vents collect overflow and indicate that equipment filling is complete (SRR-LWE-2014-00013). The volume of grout accepted by each piece of equipment is recorded (SRR-CWDA-2016-00068), based on the total volume of buckets poured (SRR-LWE-2016-00036).

Estimated fill volumes for in-tank equipment were based on assumptions about internal void space and potential grout flow paths (SRR-CWDA-2016-00068). These estimates were later compared to actual grout volumes placed into the equipment. Equipment grout was delivered from buckets of a known volume (SRR-CWDA-2016-00068). The actual grout volumes used to fill in-tank equipment were based on bucket volume and the number of buckets poured. DOE contractors made a concerted effort to slowly, carefully pour the highly flowable grout into the in-tank equipment (see SRR-CWDA-2014-00086 for equipment list) to ensure filling of void space. As needed, DOE contractors attempted to fill challenging pieces of equipment multiple times, first allowing an initial (and then subsequent) pours of grout to flow in and settle before continuing the filling process (SRR-LWE-2016-00036). Grout poured to fill the Submersible Transfer Pump in Riser 7, thermowells in Risers 4 and 7, and other equipment in Tank 12H (see SRR-CWDA-2020-00052, Attachment 1) minimized the potential for formation of vertical fast flow paths in association with this equipment, which might otherwise have expedited delivery of water to residual material on the waste tank floor (SRR-LWE-2014-00147). Equipment grouting continued until the Tank 12H equipment was unable to receive additional grout. Grout delivery flow rate, settling time, and equipment venting are examples of parameters and techniques identified during mock-up testing that were controlled during grouting to minimize residual void space (SRR-CWDA-2016-00068). Exceptions (SRR-LWE-2016-00036) to the Tank 12H in-tank equipment grout plans (SRR-CWDA-2014-00086) that occurred are described next.

- In November 2015, a wall crawler with an ultrasonic wall thickness testing device was installed in the annulus East Riser; SRR-CWDA-2014-00086 did not list the crawler equipment because the report was published before the equipment was installed. After being used to conduct wall inspections, the crawler was abandoned in the annulus and entombed in grout (SRR-CWDA-2016-00068).
- The grout plan (SRR-CWDA-2014-00086) stated that the transfer jet in Riser 6 (SRR-CWDA-2020-00052, Attachment 1) would be grout-filled. DOE contractors found the abandoned transfer jet suspended in the riser below the top riser plate. Based on transfer jet location and misalignment with the riser plate opening, the jet could not be directly grouted. Instead, contractors gravity fed an indeterminate amount of grout into the transfer jet when placing grout into the riser, and the transfer jet was entombed.

DOE expects that this transfer jet is partially grouted but does not expect it to have a configuration and sufficient void space to appreciably impact grout performance (SRR-CWDA-2016-00068).

- SRR-CWDA-2014-00086 listed a high level liquid conductivity probe (HLLCP) in the North Annulus Riser and another in the South Annulus Riser (SRR-CWDA-2020-00052, Attachment 1). During grouting operations, however, DOE contractors discovered that both risers contained two HLLCPs, which were grouted (SRR-CWDA-2016-00068).
- DOE contractors found a spray lance in Riser 4 during grouting that was not listed in SRR-CWDA-2014-00086; it was grouted (SRR-CWDA-2016-00068).
- DOE contractors found a caisson lance installed in Riser 7 that was not listed in SRR-CWDA-2014-00086; it was grouted (SRR-CWDA-2016-00068).
- Two small dewatering pumps and hose sections that were not listed in SRR-CWDA-2014-00086 were entombed with grout (SRR-CWDA-2016-00068).

DOE indicated that its effort to fill the internal void space of in-tank equipment in Tank 12H was successful (SRR-LWE-2016-00036, SRR-CWDA-2012-00051), and provided a comparison between pre-estimated equipment grout fill volumes against actual fill volumes in Table 3.2-1 of the final configuration report. Two exceptions of note are worth mentioning:

- An additional 64 L (17 gal) was recorded as having been used to fill a submersible transfer pump (STP) in Riser 7 (SRR-CWDA-2020-00052, Attachment 1) because grout initially flowed out of the open end of the bottom of the pump; upon noticing the outflow, its grouting was halted until after grout was placed in the bottom of the STP caisson to seal the open end of the pump.
- A narrow annulus opening less than 0.5 in wide within a steam jet jacket inside the North Annulus Riser (SRR-CWDA-2020-00052, Attachment 1) was difficult to fill and received only 3.8 L (1.0 gal) of equipment grout, instead of a planned 32 L (8.5 gal).

The NRC staff will continue to monitor equipment grouting, equipment grout shrinkage, and testing of the recommended equipment grout fill formulation for future tanks.

<u>Cooling Coil Flushing and Grouting</u>

The Tank 16H grouting operations lessons learned document (SRR-TCR-2015-00024) was recently made available to NRC staff for review. A recurring issue, for which several recommendations were developed, was the cooling-coil grouting process. DOE indicates that grouting of cooling coils is the highest hazard grouting operation. One recommendation was to evaluate the impact on the PA of eliminating the cooling-coil grouting process, altogether. Until such time as it may be determined that the cooling-coil grouting process can be abandoned, however, a recommendation was made to develop a management control plan to conduct cooling-coil grouting dry runs. The lessons learned document also noted that use of decant totes during the intact cooling-coil grouting process resulted in high hazard potential, and recommended their replacement with waste totes. Finally, it was recommended that a method be developed to flush cooling coils immediately prior to grouting to reduce associated hazards, use of resources, and setup time.

Tank 12H contains 36 chromate-water, 5-cm (2-in)-diameter, schedule 40 carbon steel, cooling coils (i.e., seamless pipes) in its primary (SRR-LWE-2014-00147; SRR-CWDA-2016-00068). Of these, 28 coils had failed, meaning they could not maintain pressure (SRR-LWE-2016-00036), and 8 coils were intact. The 0.6-m- (2-ft)-thick Lift 1 was first placed into the primary to provide structural support to the cooling coils (ADAMS Accession No. ML16167A237;

SRR-CWDA-2016-00068) before they were filled. Lift 1, placed on January 19–20, 2016, was the minimum amount of grout needed to provide support to vertical coils, while maximizing the potential for guillotined or severed coils to vent during grouting (SRR-LWE-2014-00147; ML18247A080, Slide 21).

WSRC-STI-2008-00172 provides the cooling coil grout formulation (90 wt% Masterflow 816 and 10 wt% Grade 100 ground granulated blast furnace slag cement, plus water). Masterflow 816 is marketed by BASF Corporation as a cement-based, aggregate-free, fluid, non-shrink, non-bleeding, high-strength cable grout with extended working time. For Tank 12H, DOE used Grade 120 slag in place of Grade 100 slag to produce the cooling coil grout[8]. There are no requirements for the physical properties of cooling coil grout, so no quality control or test requirements were associated with its production (SRR-LWE-2015-00032). The work orders that addressed cooling coil grouting are WO 01337683-50 (failed coils) and WO 01337683-31 (intact coils). WSRC-STI-2008-00172 indicates, however, that cooling coil grout is required to have a reductive capacity at least as great as tank grout, if not greater. Because the cooling coil grout formulation was selected before the formulation for tank grout, NRC staff verified that tank grout had a weight percent (wt%) of blast furnace slag cement (i.e., 6 wt%) that is less than that of cooling coil grout (7.5 wt%) (SRNL-STI-2011-00551; ADAMS Accession No. ML16231A444).

During the February 2–3, 2016, onsite observation visit, DOE staff described Tank 12H failed cooling coil grouting operations (SRR-CWDA-2015-00095 and ADAMS Accession No. ML16111B174). WSRC-STI-2008-00298 recommended that DOE employ a mixing system that could blend the quantity of material required to fill one or more cooling coils. The total volume of cooling coils ranges from 284 to 439 L (75 to 116 gal) (ADAMS Accession No. ML16111B174; SRR-CWDA-2015-00159). Therefore, 568-L (150-gal) batches of cooling coil grout (C-SPP-F-00057) were prepared and pumped into each failed cooling coil (WO 01337683-50). Dry ingredients were premixed at a vendor facility and delivered to the site in a Super Sack® (BAG Corp, Richardson, Texas) (ADAMS Accession No. ML15239A612). SRR Construction personnel then batched 284 L (75 gal) of water with the coil grout dry mix in one Super Sack and blended the materials for 6 min in a skid-mounted grout mixer (WO 01337683-31 and Attachment F; WO 01337683-50). Cooling coil grout was mixed in a hopper near the tank top, and SRR Construction used a small pump to deliver grout into cooling coils (SRR-CWDA-2016-00068). A hand pump was used to control pressure and flow to meter the grout into the cooling coils (ADAMS Accession No. ML15239A612). A totalizer at the flow meter provided the quantity of grout added to the coils in real time. Failed cooling coils were grouted on January 26, 27, and 29, 2016, from each end (inlet and outlet) per the grout strategy (SRR-LWE-2014-00147 and WO 01337683-50), and grouting was considered successful when grout was observed exiting the coil into the waste tank from the failure point (SRR-CWDA-2016-00068; ML18247A080, Slide 21).

During the May 17, 2016 teleconference, DOE indicated that, for worker protection, it would be best to flush intact coils once, immediately prior to grouting (ADAMS Accession No. ML16167A237). DOE abandoned triple rinsing of intact cooling coils during grouting of Tank 16H and double rinsing continued during grouting of Tank 12H (ADAMS Accession No. ML16167A237). WSRC-STI-2008-00298 called for filling intact cooling coils with water prior to grout placement to remove air, prevent air entrainment, and help ensure that a liquid-to-liquid interface is maintained during cooling coil grouting. Intact cooling coils were flushed once prior to grouting to remove chromate water, which was sent through a hose to Tank 10H, Riser 3

[8] NRC has not yet reviewed documentation confirming that Grade 120 slag was used to grout the Tank 12H cooling coils.

(SRR-CWDA-2020-00052; WO 01337683-31-A; HTF-SKM-2015-00010). Intact cooling coils remained full of water at the conclusion of flushing (SRR-CWDA-2020-00052). After Lift 8 was complete and the primary had been filled with bulk grout (ML18247A080, Slide 21), flushwater remaining in the coils was flushed again on March 17 and 21, 2016, through hoses into stand-alone, 1135-L (300-gal) gray-water collection totes by grout pumped into the coils (HTF-SKM-2015-00010); this process minimized air entrainment and helped maintain the water-to-grout interface inside the coils (ADAMS Accession No. ML16167A237). The 8 intact cooling coils were grouted only from the coil inlet (SRR-LWE-2016-00036). When a solid stream of grout was visually detected at the coil outlet, a minimum surplus of 38 L (10 gal) of grout was introduced to the coil to ensure complete filling (ADAMS Accession No. ML15239A612; SRR-CWDA-2015-00159; SRR-LWE-2016-00036; WO 01337683-31-F). The flushwater/grout volume accumulated in the 300-gal collection tote was solidified and disposed of separately (ADAMS Accession No. ML15239A612; SRR-CWDA-2015-00159; SRR-LWE-2016-00036).

WSRC-STI-2008-00298 demonstrated that internally grouted piping surrounded by an insulating material underwent significant temperature rise during hydration. During the March 26–27, 2014, onsite observation visit, NRC staff asked DOE how it controlled the temperature of cooling coil grout (ADAMS Accession No. ML14106A573). NRC staff also raised the issue of the potential for cooling coil grout to boil during hydration due to any significant insulation provided by external tank grout (ADAMS Accession No. ML14342A784). During the July 28–29, 2015, onsite observation visit, DOE contractors indicated that grouting of the Tank 16H primary was 94 percent complete when in-tank equipment and cooling coil grouting began (ADAMS Accession No. ML15239A612), which implied that the coiling coils were insulated by exterior grout when they were filled during the period from August 13–28, 2015 (SRR-CWDA-2015-00170, Attachment 1). Likewise, the Tank 12H primary had been completely filled with bulk grout when its 8 intact cooling coils were grouted (ML18247A080, Slide 21). DOE should continue to consider heat transfer requirements such that cooling coil grout does not exceed its boiling temperature after placement into a highly insulated system that is also producing its own heat of hydration (WSRC-STI-2008-00298). NRC staff will continue to monitor how DOE controls the temperature of freshly placed cooling coil grout under locally insulated conditions.

No exceptions occurred to DOE's planned cooling coil grouting process, described in the Tank 12H closure module and grout strategy (SRR-CWDA-2014-00086, SRR-LWE-2014-00147, SRR-LWE-2016-00036). No information, however, was provided in the final configuration report regarding the estimated volumes of grout to be placed in the cooling coils versus the actual amounts that were placed in the cooling coils of Tank 12H. NRC staff will continue to monitor cooling coil grouting, cooling coil grout shrinkage, how DOE minimizes air entrainment and the potential for boiling, any future testing undertaken of the cooling coil grout formulation, and future coil grouting operations. NRC staff will also continue to monitor the steps that DOE takes to prevent in-process grouting delays that enable premature hardening of grout in coils before they are fully filled. DOE should consider making a backup grout slickline readily available that can be used if needed. NRC staff will continue to monitor future actions taken by DOE to prevent plugging of the cooling coil grout addition line.

Riser Grouting

Grouting of 9 risers in the primary tank (Risers 1–8 plus Center Riser) and 4 risers in the annulus (E, W, N and S Risers) of Tank 12H was facilitated by removing equipment components from risers and disconnecting and lowering hoses and cables onto the Tank 12H grout of the filled primary (SRR-LWE-2014-00147; SRR-CWDA-2016-00068). The work order that addressed grout preparations for riser fill is WO 01337683-33.

It was pre-estimated that 34 cubic meter (45 cubic yards) of tank grout (9,089 gal) would be required to fill the risers, including four spray chambers (SRR-LWE-2016-00036). However, only approximately 20 cubic meters (26 cubic yards or 5,241 gal) of tank grout were used to fill the risers and spray chambers and this is consistent with the grouting operation work order's description of the estimated riser fill volumes, which total 20 cubic meters (26.2 cubic yards) (WO 01337683-33). Visual inspections conducted by DOE contractors indicated the risers and spray chambers were filled with grout (SRR-CWDA-2016-00068). DOE previously stated that riser volume estimates should not be considered highly accurate because these estimates are based on the total time it takes to completely discharge one truckload of tank grout and the time it takes to fill a riser (ADAMS Accession No. ML14106A573).

Groundwater in-leakage from a source near the bottom of Riser 8 was informally estimated by DOE contractors to be approximately 19 L/hr (5 gal/hr). After the liquid had been pumped down to an approximately 5 cm (2 in) level, grout was placed into Riser 8 in less than 1.5 hrs (SRR-CWDA-2016-00068). DOE considered the amount of liquid observed in Riser 8 to be inconsequential to grout integrity (SRR-CWDA-2016-00068). DOE maintains that the final physical and chemical properties of the hydrated tank grout are consistent with HTF PA assumptions for waste tank stability and hydrologic transport, or what they referred to as "tank flow modeling" (SRR-CWDA-2016-00068). DOE stated that the "small amount of water in the riser would not create grout property conditions different from those assumed" in the HTF PA (SRR-CWDA-2016-00068). DOE noted that no free liquid was observed in Riser 8 while it was being filled with grout (SRR-CWDA-2016-00068). DOE contractors removed 4500 L (1200 gal) standing water or liquid from risers (August 2018 OOV).

Final riser grout fill activities were completed on 2 May 2016 (SRR-CWDA-2016-00068). The document "Tank 12 Grouting Liquid Spill Lessons Learned" (SRR-TCR-2016-00007) recently became available for NRC staff review. This memo was prepared within one week of final riser fill activities, and while this document does not explicitly describe the spill event that took place, it indirectly provides considerable information of interest. First, 95-to-190 L water per day (25-to-50-gal water per day) were introduced into the tank primary and annulus through the grouting slickline as it was being wetted in preparation for placing grout. Next, during the grouting of failed cooling coils, several thousand gallons of free liquid water were added to the tank primary. In addition to these planned water additions, segregation of bleedwater from the grout mass is yet a third way that liquid accumulates inside waste tanks during grouting (ML16231A444). During the final stages of riser grouting in the Tank 12H primary, a liquid spill onto the tank top occurred when liquid that had accumulated in the primary overtopped a riser (August 2018 OOV). DOE thinks the liquid spill was from a riser that was not being monitored by a camera, but the specific riser that was overtopped was not identified (SRR-TCR-2016-00007). The lessons learned document identified a number of factors that contributed to the liquid spill, including (i) spray chambers that were a visual obstruction inside risers with cameras, which made it difficult to monitor liquid levels inside risers used to both grout the primary and monitor grouting activities; (ii) lack of an explicit grouting termination plan or plan to control riser liquid levels in the work order for filling the tank primary; (iii) lack of a grout spill plan in the work order that would explicitly call for intentionally locating spill kits near the active riser to minimize the impact and spread of any liquid spill; (iv) lack of an approved plan for mitigating free liquid in risers through addition of a dry grout mix to assimilate or absorb liquid; (v) schedule-driven grouting, especially after the failed cooling coils were grouted, did not allow sufficient time for free liquid to be absorbed during the grout's slow hydration process; (vi) lack of work orders for removing accumulated liquid from the risers via pumping; (vii) potential failure to evaluate the specific configuration and condition of individual risers that might increase their likelihood of causing spillage, so that work order plans could be adapted accordingly; (viii) that video cameras were the only instruments used to monitor rising grout/liquid levels in risers, and (ix) that cameras were only placed into four of the nine risers in the tank primary, so riser grouting was not always directly monitored via video camera. Recommendations included (i) reevaluating the costs/benefits of removing spray chambers from risers so that they are not an obstruction to video camera viewing; (ii) improving grouting work orders to better control and mitigate rising liquid/grout levels in risers and plan for quick, effective responses to liquid spills; (iii) evaluating alternatives for wetting grouting slicklines other than adding water to the tank; (iv) plan grouting schedules around the need to remove excess liquid from tanks, so that water is either absorbed, evaporated, or pumped out over a necessary period of time; (v) adapt work order development to account for actual field conditions of tank risers; (vi) reevaluate the costs/benefits of preparing all tank risers with a grout plate to allow insertion of video cameras that can monitor rising liquid levels inside all risers; (vii) evaluate the potential future use of other liquid level instruments in each riser that can sound an alarm when a threshold liquid level is exceeded.

Final Configuration

The final configuration of Tank 12H and deviations from the closure module (SRR CWDA-2014-00086), are described in SRR-CWDA-2016-00068, but uncertainties exist in the fill volumes reported. In the final configuration report, DOE indicated that the final calculated reducing grout volumes reported were based on the total number of grout batches (i.e., truckloads) discharged into the tank and annulus, assuming 6.1 cubic meters (8 cubic yards) per load of tank grout (SRR-CWDA-2016-00068). The final calculated reducing grout volume placed into the Tank 12H primary was within 2.2 percent of the pre-estimate, and the volume placed into the annulus was as much as 4.9 percent greater than anticipated.

The volume of tank grout placed into the primary and annulus risers of Tank 12H was 42 percent less than anticipated, possibly because lower portions of risers had been filled earlier, during tank and annulus grouting operations. Because DOE does not account for the amount of each grout batch that is used for testing and discarded, the relatively small riser grout volume estimates are particularly uncertain. DOE previously stated that riser volume estimates should not be considered highly accurate because these estimates are based on the total time it takes to completely discharge one truckload of tank grout and the time it takes to fill a riser (ADAMS Accession No. ML14106A573).

The final configuration report compares the pre-estimated equipment void volume and the final calculated volume of buckets and the number of buckets used to deliver equipment grout (SRR-CWDA-2016-00068, Table 3.2-1). Neither the Tank 12H final configuration report (SRR-CWDA-2016-00068) nor the Tank 12 final configuration report inputs (SRR-LWE-2016-00036) discussed the pre-estimated void volume of cooling coils in Tank 12H or the final calculated volume of grout placed into its cooling coils.

ASTM C39 compressive strength testing indicated that the strength of emplaced tank grout exceeds the compressive strength assumed in the HTF PA (SRR-CWDA-2010-00128). The average 28-day compressive strength of tank grout placed into Tank 12H was 16,430 kilopascals (2,383 psi or 164 bars), well above the minimum acceptable value of 13,800 kilopascals (2,000 psi or 138 bars) described in the closure module (SRR-CWDA-2014-00086).

DOE should consider ways to improve grout volume pre-estimates and final calculated grout volumes placed for the tanks, annuli, equipment, cooling coils, and risers to help ensure void space is fully grouted and better understand the nature of any remaining void space. One option would be to create an overall tally of the void volume estimated for the primary, annulus, and risers, and compare this sum to the overall volume that was placed into the three areas of each tank. DOE could also provide information on volume and void volume uncertainty (or uncertainty in each of the data and measurement components that go into the void volume/percent calculation).

Quality Assurance

Quality control of Tank 12H grout production and delivery were implemented in accordance with the grout procurement specification (C-SPP-F-00055, Revision 4, Attachment 5.5). DOE's quality control program included documentation of grout component compliance with specified standards, compressive strength testing of hydrated grout test cylinders, and surveillance and audits of grout production and delivery activities. DOE's closure assurance plan for Tank 12H, as described in SRR-LWE-2015-00032, is clear and should ensure that Tank 12H was closed according to plan, while meeting all regulatory process and documentation requirements. This document, reviewed previously, indicated that the tank grout formulation to be placed into Tank 12H could exercise the option to use Grade 120 slag cement, whereas Grade 100 had been used during prior tank grouting operations. The NRC staff will continue to evaluate whether the DOE closure assurance plan is being implemented effectively during future onsite observation visits and technical reviews.

## Teleconference or Meeting

None.

## Follow-Up Actions

NRC staff will continue to monitor DOE's bulk fill, equipment, and cooling coil grout formulations under Monitoring Factors 3.2 "Groundwater Conditioning via Reducing Grout," 3.3, "Shrinkage and Cracking," and 3.4, "Grout Performance" listed in NRC staff's Tank Farm Monitoring Plan (ADAMS Accession No. ML15238A761) while focusing on the technical issues listed in this technical review report and on any new technical issues that arise. A comprehensive list of follow-up action items, which includes items prepared following the May 17, 2016, teleconference, as well as new items identified when completing this technical review report, is found below in Appendix B.

## Open Issues

No open issues resulted from this technical review. However, insufficient information is provided to address the likelihood for preferential flow pathways that enable bypass flow to form through grout monoliths due to shrinkage, cracking, and void space. NRC staff will continue to follow-up on this technical issue under 3.2 "Groundwater Conditioning via Reducing Grout," and Monitoring Factor 3.3, "Shrinkage and Cracking" (See ADAMS Accession No. ML15238A761).

## **Conclusions**

Due to the similarities in the grout formulation and approach to grouting Type I Tanks 5F, 6F, and 12H, Type II Tank 16H, and Type IV Tanks 18F and 19F, many of the conclusions resulting from the NRC staff's previous reviews of documentation related to Tanks 5F, 6F, 18F, 19F, and 16H remain relevant to the review of Tank 12H grouting operations. Relevant major and minor conclusions from the Tanks 5F, 6F, 18F, 19F and 16H reviews are repeated below along with new conclusions from the Tank 12H review.

Major Conclusions for Tanks 18F and 19F:

- 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). The NRC staff also concludes, however, that DOE has not provided sufficient information and testing to support its exclusion of shrinkage gaps, cracks, and other preferential flow fast pathways through the tank grout monolith from its reference case. DOE's reference case assumes that grout degrades slowly with gradual increase in matrix $K_{sat}$. Primarily, the NRC staff expects 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 observed potential segregation of tank grout from excess water that could enhance the extent of shrinkage along the periphery of the Type IV tanks (i.e., along the tank walls). 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 ADAMS Accession No. ML15238A761). 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."

Minor Conclusions for Tanks 18F and 19F:

The NRC staff will also continue to monitor void volumes in the emplaced grout 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"). NRC staff also expects DOE to provide additional information about the potential for thermal cracking of the grout monolith for Tanks 18F and 19F.

Major Conclusions for Tanks 5F and 6F:

Major and minor conclusions from the Technical Review Report for Tanks 18F and 19F grouting were repeated in the Tanks 5F and 6F Technical Review Report. Additional conclusions (or additional detail regarding a previous conclusion) were also listed as below:

Additional Conclusions for Tanks 5F and 6F:

- NRC staff observed grout with higher flowability in the Tanks 5F and 6F grouting operation videos compared to that placed into Tanks 18F and 19F due to the higher slump specified for use in tanks with cooling coils.
- NRC staff observed, via video, potential instances of bleed water 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.
- DOE should 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 5F and 6F (and 18F and 19F) did not reduce the integrity of the tank grout to less than what is assumed in the FTF PA (SRS-REG-2007-00002, Revision 1).
- DOE should take reasonable measures to prevent future placement of out-of-specification grout because inhomogeneity in the grout will affect flow in the monolith due to higher permeability zones fostering higher flow rates than surrounding zones.
- DOE should consider giving higher priority to development and testing of a shrinkage compensating tank grout formulation.
- Given that only approximately 50 percent of the tank annuli were visible in videos documenting annulus grouting, DOE should consider placing video cameras in all riser locations within tank annuli during grouting operations or else occasionally reposition video cameras into different available risers to improve visibility.
- Two of the failed cooling coils were only partially filled because DOE had not adequately cleaned the grout slickline prior to the fill, which allowed grout residue to plug the slickline. NRC staff notes that the lessons learned report (SRR-CWDA-2014-00015) provides several suggestions to prevent plugging of the cooling coil grout slickline (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 slickline.
- Field-collected temperature data from actual waste tanks would provide valuable information regarding grout integrity given the potential for thermal cracking of large, hydrating grout monoliths.

Conclusions for Tank 16H:

- DOE should take reasonable measures to ensure a sufficient number of cement trucks are in rotation to optimize grout distribution throughout the tank and minimize mounding.
- DOE should take measures to continuously fill cooling coils with grout to ensure complete filling and to avoid creating grout blockages within intact coils that could have otherwise been fully filled (SRR-CWDA-2015-00159). Complete filling of cooling coils is needed to eliminate in-tank void space and preferential flow paths. DOE should continue to document related lessons learned and implement a path forward that will mitigate future occurrences.
- DOE should consider heat transfer requirements such that highly insulated cooling coil grout (i.e., in coils surrounded externally by tank grout) does not exceed its boiling temperature shortly after placement (WSRC-STI-2008-00298).

- NRC staff observed via Tank 16H grouting video instances of bleed water segregation. Non-uniformly distributed excess water in the tank and annulus may have a potential impact on hydraulic properties and grout quality, and enhance shrinkage along the tank wall, resulting in unintended inhomogeneous material properties that would affect water percolation patterns through the monolith. DOE should remove excess ponded water from the tank before, during, and near the end of grouting operations, whenever aqueous ponds are present, to ensure adequate quality grout is placed into tanks and annuli. Alternatively, DOE could provide additional information to support a determination that the quantities of water present in the tanks during grouting do not adversely impact grout performance.
- More flowable clean cap grout used to fill remaining void space at the top of the Tank 16H primary and annulus may have significantly different hydraulic properties compared to the rest of the bulk fill grout placed in the primary and annulus of Tank 16H. DOE should address the potential for either a capillary or permeability barrier to form at the interface between the two different grout types near the top of the tank due to the varying hydraulic conductivity of the clean cap and bulk fill grout used in Tank 16H.

<u>Conclusions for Tank 12H</u>:

- With regard to the change in slag grade (from 100 to 120 grade slag) during Tank 12H grouting operations:

  - Tank 12H was grouted with two different types of grout. DOE should address the performance impact of using two different slag grades in Tank 12H reducing tank grout: Grade 100 grout [163 cubic meters (213 cubic yards or 43,000 gal)] was placed in the bottom of the first lift in the primary and Grade 120 grout [2840 cubic meters (3714 cubic yards or 750,182 gal)] was placed above this Grade 100 grout. DOE should evaluate the potential for either a capillary or a permeability barrier to form at the interface between the two different grout types near the contaminated zone of the tank due to a potentially lower hydraulic conductivity of Lehigh Grade 120 slag tank grout relative to that of the underlying Holcim Grade 100 slag tank grout.

  - DOE should evaluate differences in chemical reactivity and hydraulic conductivity between the Grade 100 and Grade 120 slag tank grout that was used to fill Tank 12H and any resulting performance impact. NRC staff will continue to monitor the impact of slag grade on chemical reactivity and hydraulic conductivity. Additionally, results of 28-day compressive strength measurements were unexpectedly lower for Tank 12H, which used primarily Grade 120 slag, compared to Tank 16H, which used Grade 100 slag. This result may be related to the chemical reactivity of the Grade 120 slag.

- During its review of Tank 12H grouting video (ADAMS Accession No. ML20280A286), NRC staff observed bleed water segregation of tank grout during placement that could enhance shrinkage along the periphery (i.e., at the wall) of the tank and result in inhomogeneous material properties affecting water percolation patterns through the monolith. Results documented in the grout drop test report (RPT-5539-EG-0016) suggest the potential for even more segregation and bleed water production if grout is dropped from a tremie into standing water. In-leakage of groundwater into the submerged annulus and tank led to delays in grouting and the need for mitigative measures such as pumped removal of groundwater and avoidance of grouting directly into areas of the tank containing standing water. DOE should provide additional information about how contractors avoided placing grout directly into areas of the tank that had collected water, unremoved by pumping, and the spatial maps of where the standing water was relative to the risers through which Lift 1 grout was placed. DOE should provide information about the potential performance impact of standing water in Tank 12H during grouting. The NRC staff will continue to monitor the potential for segregation of grout bleed water and consequent impacts on future water flow through the grout monolith and waste release.

In this report, there is no significant change to the NRC staff overall conclusions from the F- and H-Tank Farm TERs regarding compliance of DOE disposal actions with the 10 CFR Part 61 performance objectives. Likewise, there is no significant change to the status of Monitoring Factors 3.2 “Groundwater Conditioning via Reducing Grout,” 3.3, “Shrinkage and Cracking,” and 3.4, “Grout Performance” listed in the NRC staff’s Monitoring Plan for the tank farm facilities (ADAMS Accession No. ML15238A761).

## REFERENCES

2015-NCR-15-WHC-0008. Redwood, A.R. "Nonconformance Report No. 2015-NCR-15-WHC-0008." Aiken, South Carolina. June 29, 2015. [ADAMS Accession No. ML20302A273]

2015-NCR-15-WHC-0013. Redwood, A.R. "Nonconformance Report No. 2015-NCR-15-WHC-0013." Aiken, South Carolina. October 20, 2015. [ADAMS Accession No. ML20302A274]

ASTM C1611/C1611M. "Standard Test Method for Slump Flow of Self-Consolidating Concrete." West Conshohocken, Pennsylvania: ASTM International. 2018.

ASTM C232/C232M - 14(2019). "Standard Test Method for Bleeding of Concrete." West Conshohocken, Pennsylvania: ASTM International. 2019.

C-CLC-G-00364. Phillips, J.J. "Type I and Type II Waste Tank Cooling Coil to Tank Volume Ratios and Area Ratios." Revision 0. Aiken, South Carolina: Savannah River Site. March 2007.

C-ESR-G-00003. Waltz, R.S. "SRS High Level Waste Tank Crack and Leak Information." Revision 13. Aiken, South Carolina: Savannah River Site. 26 October 2015. [ADAMS Accession No. ML14079A609]

C-SPP-F-00055. Ganguly, A. "Furnishing and Delivery of Tank Closure Grout." Revision 4. Aiken, South Carolina: Savannah River Remediation, LLC. 20 December 2012.

C-SPP-F-00057. McCord, J.B. Furnishing and Delivery of Cooling Coil Grout Dry Feeds. Revision 2. Aiken, South Carolina: Savannah River Site. July 16, 2014.

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.

HTF-SKM-2015-00010. "Tank 12 Flush & Grout Fill Configuration Intact Coils [WO] 1337683-31 (2 Sheets)." Revision B. Closure Engineering, Savannah River Site, Aiken, South Carolina, October 28, 2015. [ADAMS Accession No. ML20279A781.

HTF-SKM-2015-00021. "Tank 12 Grout Placement Plan – Sketch 1 (Associated with WO 01337683-33)." Revision 0. Savannah River Site, Aiken, South Carolina, 2015. [ADAMS Accession No. ML20279A782]

M-CLC-H-02820. Wong, H. "Volume and Surface Area Percentages of the Cooling Coils in Type III and Type IIIA Tanks." Rev. 0. Aiken, South Carolina: Savannah River Site. April 2007.

M-CLC-H-03256. Grim, G.M. "Tank 12 Internal Component Solid Coating Volume Estimation." 2014.

M-ESR-H-00444. Massey, D.C. "Federal Facility Agreement Assessment Report for Capping Waste Tank 12H Waste Transfer Piping." Revision 0. Aiken, South Carolina: Savannah River Site. 18 August 2014.

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 (Docket No.

PROJ0734, Note to File).” Washington, DC: U.S. Nuclear Regulatory Commission. May 24, 2013. [ADAMS Accession No. ML13127A291]

ML13267A452. Mohseni, A. “The U.S. Nuclear Regulatory Commission August 27–28, 2013, Onsite Observation Visit Report for the Savannah River Site F-Tank Farm Facility.” Memorandum to J. Ridley. Washington, DC: U.S. Nuclear Regulatory Commission. November 12, 2013. [ADAMS Accession No. ML13267A452]

ML14330A037. Shaffner, J. “Summary of 10/29/2014 Telephone Conference Call Between the NRC Staff and DOE Representatives Concerning NRC Staff Questions Regarding Tank 5 and 6 Grouting Operations.” Washington, DC: U.S. Nuclear Regulatory Commission. November 26, 2014. [ADAMS Accession No. ML14330A037]

ML15238A761. “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 and H-Area Tank Farm Facilities in Accordance with the National Defense Authorization Act for Fiscal Year 2005.” Washington, DC: U.S. Nuclear Regulatory Commission. October 2015. [ADAMS Accession No. ML15238A761]

ML15239A612. Persinko, A. “The U.S. Nuclear Regulatory Commission July 28–29, 2015, Onsite Observation Visit Report for the Savannah River Site Combined F and H-Tank Farm Closure (Docket No. PROJ0734).” Memorandum to J. Ridley. Washington, DC: U.S. Nuclear Regulatory Commission. October 5, 2015. [ADAMS Accession No. ML15239A612].

ML16111B174. “NRC February 2–3, 2016, Onsite Observation Visit Report for the Savannah River Site Combined F and H Tank Farm Closure.” Memorandum to J. Ridley. Washington, DC: U.S. Nuclear Regulatory Commission. May 17, 2016. [ADAMS Accession No. ML16111B174]

ML16167A237. “Summary of Telephone Conference Call Held on May 17, 2016, Between NRC Staff and DOE Representatives Concerning NRC Staff Questions Regarding Tanks 12H and 16H Grouting Operations.” Note to File (PROJ0734). Washington, DC: U.S. Nuclear Regulatory Commission. July 18, 2016. [ADAMS Accession No.ML16167A237]

ML16231A444. “Technical Review of Documents Related to Tanks 16H and 12H Grout Formulations, Testing, Procedures, and Operations at the H-Area Tank Farm at Savannah River Site.” Washington, DC: U.S. Nuclear Regulatory Commission. August 19, 2016. [ADAMS Accession No. ML16231A444].

ML19298A092. “Technical Review of Tank 12H Waste Release Reports and Associated Impact Analysis.” Washington, DC: U.S. Nuclear Regulatory Commission. December 20, 2019. [ADAMS Accession No. ML19298A092].

ML20289A873. “Center for Nuclear Waste Regulatory Analyses FY2017 and FY2018 Final Saltstone Experimental Report.” Prepared for U.S. Nuclear Regulatory Commission. San Antonio, Texas: Center for Nuclear Waste Regulatory Analyses. May 2019. [ADAMS Accession No. ML20289A873].

RPT-5539-EG-0016 (SRRA051386-2-A). Diener, G. “Savannah River Remediation Tank Closure Grout Assessment Final Report (Grout Drop Test Report).” Revision 0. Barnwell, South Carolina: EnergySolutions. December 16, 2014.

Siddique, R. and D. Kaur. Properties of Concrete Containing Ground Granulated Blast Furnace Slag (GGBFS) at Elevated Temperatures. *J. of Advanced Res.* Vol. 3, 45–51, 2012.

SDDR No. 13182. “Supplier Deviation Disposition Request No. 13182 (Slag Cement not Meeting ASTM C989, Grade 100).” Aiken, South Carolina: Savannah River Site. June 2015. [ADAMS Accession No. ML16119A339]

SDDR No. 13307. Ganguly, A. “Supplier Deviation Disposition Request No. 13307 (Bleeding of Concrete).” Aiken, South Carolina: Savannah River Site. October 28, 2015. [ADAMS Accession No. ML20279A783]

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.

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

SRR-CWDA-2010-00128. “Performance Assessment for the H-Area Tank Farm at the Savannah River Site.” Revision 1. Aiken, South Carolina: Savannah River Remediation, LLC. November 2012.

SRR-CWDA-2011-00054. “Comment Response Matrix for United States Nuclear Regulatory Commission Staff Comments on the Draft Basis for Section 3116 Determination and Associated Performance Assessment for the F-Tank Farm at the Savannah River Site.” Revision 1. Aiken, South Carolina: Savannah River Remediation, LLC. June 2011.

SRR-CWDA-2012-00051. Layton, M. “Critical Assumptions in the Tank Farm Operational Closure Documentation Regarding Waste Tank Internal Configurations.” Revision 2. Aiken, South Carolina: Savannah River Site. January 11, 2016. [ADAMS Accession No. ML13078A206]

SRR-CWDA-2014-00011. “Evaluation of Vendor Supplied Clean Cap Material for Saltstone Disposal Units.” Revision 0. Aiken, South Carolina: Savannah River Site. March 2014.

SRR-CWDA-2014-00015. Cantrell, J.R. “Tank 5 and 6 Grouting Project Lessons Learned.” Revision 0. Aiken, South Carolina: Savannah River Remediation. February 6, 2014.

SRR-CWDA-2014-00086. “Industrial Wastewater Closure Module for the Liquid Waste Tank 12H H-Area Tank Farm, Savannah River Site.” Revision 0. Aiken, South Carolina: Savannah River Site. May 2015.

SRR-CWDA-2014-00102. Layton, M.H. “Disposal of Cooling Coil Grouting Liquid Within Tank 16.” Revision 0. Aiken, South Carolina: Savannah River Site. November 2014.

SRR-CWDA-2015-00057. “Evaluation of the Use of Grade 120 Slag Cement in Tank Closure Grout versus Performance Assessment Assumptions (Interoffice Memorandum to G.C. Arthur from M.H. Layton).” Revision 1. Aiken, South Carolina: Savannah River Remediation, LLC. August 27, 2015.

SRR-CWDA-2015-00074. “Addendum to the Industrial Wastewater Closure Module for Liquid Waste Tank 12H H-Area Tank Farm, Savannah River Site, SRR-CWDA-2014-00086, Revision 0, May 2015.” Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. October 2015. [ADAMS Accession No. ML15294A364]

SRR-CWDA-2015-00088. Layton, M.H. “Unreviewed Waste Management Question Evaluation—Use of Grade 120 Slag in Tank Closure Grout.” Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. September 2015. [ADAMS Accession No. ML16057A471]

SRR-CWDA-2015-00095. “Savannah River Site F and H Area Tank Farms NRC Onsite Observation Visit, July 28–29, 2015.” Revision 1. Aiken, South Carolina: Savannah River Remediation, LLC. August 2015.

SRR-CWDA-2015-00100. “Evaluation of the Use of an Alternative Tank 16 Fill Grout (Per Specification C-SPP-Z-00012) (Interoffice Memorandum to G.C. Arthur from M.H. Layton).” Revision 2. Aiken, South Carolina: Savannah River Remediation, LLC. September 1, 2015. [ADAMS Accession No. ML16119A341]

SRR-CWDA-2015-00159. “Tank 16 Final Configuration Report for H-Tank Farm at the Savannah River Site.” Revision 1. Aiken, South Carolina: Savannah River Remediation, LLC. May 2016. [ADAMS Accession No. ML16193A052]

SRR-CWDA-2016-00068. “Tank 12 Final Configuration Report for H-Tank Farm at the Savannah River Site.” Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. December 2016. [ADAMS Accession No. ML18235A409]

SRR-CWDA-2017-00015. “Consolidated General Closure Plan for F-Area and H-Area Waste Tank Systems.” Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. February 2017. [ADAMS Accession No. ML20279A784]

SRR-CWDA-2018-00047. “Savannah River Site F and H Area Tank Farms, NRC Onsite Observation Visit: ‘Tank 12 Grouting Calendar (Slide 21).’” Revision 1. Aiken, South Carolina: Savannah River Remediation, LLC. 13–14 August 2018. [ADAMS Accession No. ML18247A080]

SRR-CWDA-2020-00052. Romanowski, L. “Follow-Up to Tanks 12H and 16H Grouting Operations Document Request in Support of U.S. Nuclear Regulatory Commission F and H Area Tank Farms Monitoring Activities (Memo to A. White of U.S. DOE).” Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. June 10, 2020. [ADAMS Accession No. ML20279A785]

SRR‐CWDA‐2020‐00058. Romanowski, L. “Type I Waste Tanks Dehumidification System Heating and Ventilation Ductwork [From Dwg. # W146593].” Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. July 8, 2020. [ADAMS Accession No. ML20279A786]

SRR-LWE-2010-00175. “Tanks 18 and 19 Internal Equipment Evaluation.” Revision 1. Aiken, South Carolina: Savannah River Remediation, LLC. September 2010.

SRR-LWE-2014-00147. Chandler, T. “Tank 12H Grout Strategy.” Revision 1. Aiken, South Carolina: Savannah River Remediation, LLC. August 31, 2015.

SRR-LWE-2014-00162. Voegtlen, R. O. “Video Inspection Plan for Tank 12 During Tank Grouting Activities.” February 2015.

SRR-LWE-2015-00032. Ostler, M. “Tank 12-H Closure Assurance Plan.” Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. April 2015.

SRR-LWE-2015-00048. Griffin, A.L. “Path Forward for Tank 12 Annulus Liquid Removal (Interoffice Memorandum to E. Patten et al. from A.L. Griffin and G.C. Arthur).” Aiken, South Carolina: Savannah River Remediation, LLC. Revision 0. July 7, 2015.

SRR-LWE-2016-00020. Voegtlen, R.O. “Tank 12 Grout Cracks under Riser 1.” 2016.

SRR-LWE-2016-00036. Voegtlen, R.O. “Tank 12 Final Configuration Report Inputs.” Revision 2. Aiken, South Carolina: Savannah River Site. December 2016. [ADAMS Accession No. ML20279A787]

SRR-TCR-2015-00024. Davis, B. “Tank 16 Grouting Lessons Learned (Memo).” Aiken, South Carolina: Savannah River Remediation, LLC. January 27, 2016. [ADAMS Accession No. ML16119A346]

SRR-TCR-2016-00007. Davis, B. “Tank 12 Grouting Liquid Spill Lessons Learned.” Aiken, South Carolina: Savannah River Remediation, LLC. May 9, 2016. [ADAMS Accession No. ML20279A788]

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

U-CLC-G-00001. Phillips, J.J. “Total Fill Volumes of High Level Waste Tanks.” February 2009.

U-ESR-H-00125. Clark, J.L. “Tank 12 Final Volume Determination and Uncertainty Estimate.” 2014.

USQ-HTF-2015-00706. Layton, M. “Supplier Deviation Disposition Request (SDDR) Number 13307 – Deviation from Specification C-SPP-F-00055, Revision 4 (Technical Review Package).” Revision 0. October 2015. [ADAMS Accession No. ML20279A789]

VSL-14R3330-1. Papathanassiu, A.E. et al. “Saltstone Clean Cap Grout Assessment (Final Report).” Revision 0. Washington, DC: Vitreous State Laboratory, The Catholic University of America. March 2014. [ADAMS Accession No. ML20279A790]

VSL-15R3740-1. Gong, W. et al. “Investigation of Alternate Ground Granulated Blast Furnace Slag for the Saltstone Facility (Final Report).” Revision 0. Washington, DC: Vitreous State Laboratory, The Catholic University of America. August 26, 2015. [ADAMS Accession No. ML16117A355]

Walter, G.R. and C.L. Dinwiddie. “Tank Grout Water Conditioning Tests—Fiscal Year 2019 Status Report.” San Antonio, Texas: Center for Nuclear Waste Regulatory Analyses. April 2020.

WO 01324150-64. Fail, J.A. “TK CLOS & REG CN TO PERFORM GROUT PREP/GROUT PLACEMENT TK 16.” Revision 0. August 22, 2014. [ADAMS Accession No. ML16119A351]

WO 01337683-31. Alexander, O. “TK.12 Flush & Grout Intact Chromate Cooling Coils.” Revision 1. November 2, 2015. [ADAMS Accession No. ML20279A791]

WO 01337683-31-A. “Attachment ‘A’ – Tank 12 Coil Flushing Spreadsheet.” [ADAMS Accession No. ML20279A792]

WO 01337683-31-F. “Attachment F – Coil Grout Spreadsheet.” [ADAMS Accession No. ML20279A794]

WO 01337683-33. Patton, G.W. “Placement of Bulk Fill Grout (Tank 12 Work Order).” Revision 2. [ADAMS Accession No. ML20279A795]

WO 01337683-33-A. “Attachment A – Tank 12 Tremie Installation Steps.” [ADAMS Accession No. ML20279A796]

WO 01337683-33-B. “Attachment B – Tank 12 Cleaning/Pigging of Slickline.” [ADAMS Accession No. ML20279A797]

WO 01337683-50. Alexander, O. “TK12 Grout Failed Coils.” August 12, 2015. [ADAMS Accession No. ML20279A798]

WO 01337683-51. Patton, G.W. “TK 12 Closure Constr Perform Equipment.” [ADAMS Accession No. ML20279A799]

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.

WSRC-STI-2008-00298. Hansen, E.K. et al. “Closure of HLW Tanks—Phase 2, Full Scale Cooling Coils Grout Fill Demonstrations.” Revision 0. Aiken, South Carolina: Savannah River National Laboratory. June 2008.

## Appendix A

**Review Status of General Grout Documents:**

2015-NCR-15-WHC-0008. Redwood, A.R. "Nonconformance Report No. 2015-NCR-15-WHC-0008." Aiken, South Carolina. August 20, 2015. [ADAMS Accession No. ML20302A273]

This nonconformance report addresses disposition of curing-temperature nonconformances for 12 lab numbers associated with Tank 16H grout compressive strength cylinders that would later be tested for 7- and 28-day compressive strength. According to specification C-SPP-F-00055 and ASTM C31 paragraph 10.1.3.1, the cylinders should be held at a laboratory temperature of 73.5 ± 3.5 °F, but due to equipment failure, the room temperature rose to 78.5 °F for a period of 2 hrs on June 17, 2015, for cylinders associated with lab numbers 150102, 150103, 150104, 150105, 150106, 150107, 150113, 150114, 150115, 150116, 150119, and 150120. The NCR indicated that the laboratory temperature exceeded the upper end of the intended temperature range by 1.5 °F for 2 hrs. The Concrete Test Report for lab number 150103 indicates that three of five 28-day compressive strength tests conducted on June 30, 2015, plus the overall average value, did not meet the 13,800 kilopascals (2000 psi or 138 bar) compressive strength threshold, and the Concrete Test Report for lab number 150120 indicates that one of three 28-day compressive strength tests, conducted on July 14, 2015, did not meet the 13,800 kilopascals (2000 psi or 138 bar) compressive strength threshold, although the average compressive strength did meet the threshold. Initially, the field engineering disposition recommendation errantly indicated that all of the 28-day breaks exceeded the design requirement compressive strength, and that the disposition recommendation was to "use-as-is." Later, the document acknowledged that some cylinder breaks conducted on June 30 and July 14, 2015, exhibited compressive strengths below the design requirement, but stated that the "results are within the tolerances of the applicable testing standards ASTM C94 and ACI 301…and as such comply with the strength requirement of specification C-SPP-F-00055." The curing temperature and tolerance prescribed are meant to ensure that accurate compressive strength data are obtained from cylinder break tests. Most of the break tests appended to this NCR indicated that compressive strengths of this reducing tank grout, which was placed into Tank 16H, exceeded the minimum compressive strength design requirement.

2015-NCR-15-WHC-0013. Redwood, A.R. "Nonconformance Report No. 2015-NCR-15-WHC-0013." Aiken, South Carolina. October 20, 2015. [ADAMS Accession No. ML20302A274]

This nonconformance report addresses disposition of curing-temperature nonconformances for 31 lab numbers and associated Tank 16H grout compressive strength cylinders that would later be tested for 7- and 28-day compressive strength. According to specification C-SPP-F-00055 and ASTM C31 paragraph 10.1.3.1, the cylinders should be held at a laboratory temperature of 73.5 ± 3.5 °F, but due to equipment failure, the room temperature rose to 79 °F for a period of 5 hrs on July 19, 2015, affecting cylinders associated with lab numbers 150127, 150128, 150130, 150131, 150132, 150133, 150134, 150135, 150140, 150141, 150143, 150144, 150145, 150146, 150148, 150149, 150152, 150153, 150156, 150157, 150158, 150159, 150162, 150163, 150166, 150167, 150169, and 150170, and again the room temperature rose to 79 °F for a period of 9 hrs on July 27, 2015, followed by another 6 hrs at 78.5 °F on July 28, 2015, affecting lab numbers 150140, 150141, 150143, 150144, 150145, 150146, 150148, 150149, 150152, 150153, 150156, 150157, 150158, 150159, 150162, 150163, 150166, 150167, 150169, 150170, 150171, 150172, and 150173. In addition, the room temperature was again out of tolerance at 80.5 °F on July 30, 2015, for 9 hrs, affecting cylinders associated with lab numbers 150148, 150149, 150152, 150153, 150156, 150157, 150158, 150159, 150162, 150163, 150167, 150169, 150170, 150171, 150172, and 150173. The NCR indicated that the laboratory room temperature exceeded the upper end of the intended temperature range by 2.0 °F for 5 hrs on July 19, 2015, by 2.0 °F for 9 hrs on July 27, 2015, by 1.5 °F for 6 hrs on July 28, 2015, and by 3.5 °F for 9 hrs on July 30, 2015. For this NCR, all of the 28-day breaks did exceed the design requirement of 13,800 kilopascals (2000 psi or 138 bars) compressive strength, so the construction engineering recommended disposition of the nonconformance was to use the grout that had been placed inside the tank as is (use-as-is).

<u>C-ESR-G-00003. Waltz, Jr., R.S. "SRS High Level Waste Tank Crack and Leak Information." Revision 13. Aiken, South Carolina: Savannah River Site. 26 October 2015. [ADAMS Accession No. ML14079A609]</u>

This report documents the location of known cracks and provides estimates of the quantity of leaked waste that remains on the floor of the annulus of the underground high-level waste storage tanks. The document is revised regularly as new cracks or other evidence are found. Revision 13 contains all known conditions as of 26 October 2015, including leak sites identified in Tank 15. This technical review report is the first to have reviewed the tabulation of data contained within C-ESR-G-00003. A portion of the Revision 13 summary table is captured below for SRS tank closure activities that NRC has monitoring responsibilities for under the 2005 NDAA. Based on this table, review of Revision 11 would provide a more complete understanding of the available information about cracks, leak sites, and waste in the annuli in SRS's underground HLW storage tanks.

| Tank | Tank Type | Known Leak Sites | Date of Discovery | Waste on Annulus Floor? | Amount of Waste (est) | Location * | Elevation from Tank Base | Tank Wall Inspected | Acceptable Fitness for Service |
|---|---|---|---|---|---|---|---|---|---|
| 5 | I | 44 | See Rev 11 | | | | | | |
| 6 | I | 11 | See Rev 11 | | | | | | |
| 12 | I | 15 | 1984<br>May 1974<br>Apr 2004<br>Oct 2005<br>Oct 2005<br>2008–2012 | Yes | Waste total for leak sites 1–4 on wall & floor: 2gal<br>1 cup<br>3.4 gal | 1 North<br>2 North<br>3 North<br>4 North<br>5 South<br>6 NE | 93 in<br>105 in<br>95 in<br>70 in<br>129 in<br>85 in | 25% (typical) | Yes<br>-<br>Tank flaws evaluated against calcs: T-CLC-G-00159 & T-CLC-H-00639 and are acceptable |
| | | | Jul 2012<br>Jul 2012<br>Jul 2012<br>Jul 2012<br>Jul 2012<br>Jul 2012<br>Jul 2012<br>Jul 2012<br>Jul 2012 | | nodule<br>¼ gal<br>1 cup<br>1 cup<br>1 cup<br>nodule<br>nodule<br>½ cup<br>½ cup | 7 SW<br>8 SW<br>9 NW<br>10 NW<br>11 NW<br>12 NW<br>13 NW<br>14 SE<br>15 SE | 129 in<br>129 in<br>129 in<br>230 in<br>230 in<br>129 in<br>129 in<br>129 in<br>129 in | 100%<br>-<br>inspected by magnetic crawler device in 2001 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 15 | II | 24 | Apr 1972<br>Apr 1972<br>1973<br>1973<br>1973<br>1973<br>1973<br>1973<br>1973<br>1973<br>1973<br>1973<br>1973<br>1997<br>1998<br>1997<br>2000<br>2000<br>2002<br>2005<br>2015<br>2015<br>2015<br>2015 | Yes | nodules on tank wall with trails to annulus floor and small amount of waste on annulus floor<br>waste on annulus floor observed during re-wetting activities in July 2015 was ~1-2 in deep<br>UT | 1<br>2<br>3<br>4<br>5<br>6<br>7<br>8<br>9<br>10<br>11<br>12<br>13<br>14<br>15<br>16<br>17<br>18<br>19<br>20<br>21<br>22<br>23<br>24 | 34 in<br>34 in<br>150 in<br>88 in<br>30 in<br>96 in<br>30 in<br>74 in<br>30 in<br>30 in<br>150 in<br>34 in<br>150 in<br>150 in<br>150 in<br>200 in<br>30 in<br>30 in<br>129 in<br>31 in<br>73 in<br>100 in<br>92 in<br>126 in | 96% | Yes<br>-<br>Tank flaws evaluated against calcs: T-CLC-G-00159 & T-CLC-H-00639 and are acceptable |
| 16 | II | ~300–350 | No Data | | | | | | |
| 18 | No Data | | | | | | | | |
| 19 | IV | 4 | See Rev 11 | | | | | | Not Applicable |
| *circumferential feet from South riser, clockwise<br>Note: leak sites detailed in this table were documented by the presence of salt nodules or stains and marks. Additional leak sites may exist in uninspected areas. One crack detected in 2002 in Tank 15 was located using UT techniques.<br>Note: 1 inch = 2.54 cm | | | | | | | | | |

<u>HTF-SKM-2015-00010. “Tank 12 Flush & Grout Fill Configuration Intact Coils [WO] 1337683-31 (2 Sheets).” Revision B. Closure Engineering, Savannah River Site, Aiken, South Carolina, October 28, 2015. [ADAMS Accession No. ML20279A781]</u>

This two-sheet document of engineering drawings (or “sketches”) is an attachment to Work Order (WO) No. 1337683-31. Sketch notes indicate that initial intact-coil flushwater is sent to Tank 10 Riser 3, and then a gray-water collection tote receives coil-water after flushing is completed, and the water-to-grout transition interface. Sketches illustrate (i) the flushwater supply, (ii) flushwater manifold, (iii) grout-pumping system, (iv) flushwater supply apparatus, (v) return gray-water apparatus, (vi) return flushwater apparatus, (vii) Tank 10 Riser 3 flushwater apparatus, and a (viii) 300 gal gray-water tote.

<u>HTF-SKM-2015-00021. “Tank 12 Grout Placement Plan – Sketch 1 (Associated with WO 01337683-33).” Revision 0. Savannah River Site, Aiken, South Carolina, 2015. [ADAMS Accession No. ML20279A782]</u>

This sketch is an attachment to Work Order (WO) No. 01337683-33; it illustrates the nine lifts/placements of grout that were originally anticipated to be placed into the tank primary and annulus in numerical order. It also illustrates a tank riser and an annulus riser and their positions with respect to Grade level and the tank ceiling, the tremie attachment point (with its cam-lok coupling), the grout slickline connection point, and riser cover ports. A note on the sketch indicates the tremies used are all released into either the primary or the annulus.

SDDR No. 13182. "Supplier Deviation Disposition Request No. 13182 (Slag Cement not Meeting ASTM C989, Grade 100)." Aiken, South Carolina: Savannah River Site. June 2015. [ADAMS Accession No. ML16119A339]

SDDR No. 13182, initiated in March 2015, proposed a deviation to Specification C-SPP-F-00055 to allow use of Grade 120 slag cement in lieu of Grade 100 (i.e., the "proposed action"). Because the deviation or proposed action would alter the tank grout formulation, the UWMQ Determination was initiated and an UWMQ Evaluation (UWMQE) was performed. UWMQE SRR-CWDA-2015-00088, "Use of Grade 120 Slag in Tank Closure Grout (USQ-HTF-2015-00300)" was approved and the deviation was determined acceptable because its implementation would have no adverse impact on the facility or its systems, nor would it compromise PA conclusions. USQ-HTF-2015-00300 was previously reviewed in the Tank 16H TRR (ADAMS Accession No. ML16231A444). UWMQE SRR-CWDA-2015-00088 was also previously reviewed in the Tank 16H TRR.

SDDR No. 13307. Ganguly, A. "Supplier Deviation Disposition Request No. 13307 (Bleeding of Concrete)." Aiken, South Carolina: Savannah River Site. October 28, 2015. [ADAMS Accession No. ML20279A783]

This supplier deviation disposition request was a result of tank closure grout batches that were prepared by Argos for placement into Tank 16H that exceeded the 0.0 percent maximum bleed requirement after 24 hrs, per ASTM C232/C232M-14 and DOE's specification C-SPP-F-00055. The document has two attachments documenting the two highest bleed results, which were 8.9 percent (June 18, 2015) and 3.3 percent (June 19, 2015), but the deviation description states that none of the bleed tests resulted in zero bleed. Argos proposed disposition for the grout was to use-as-is, and their technical justification for this disposition was given as "bleed water shown will be used for the hydration of slag that will peak hydration around 55 days after placement. After full hydration of the cementitious materials, no free water will be present." SRR's final disposition approach for tank closure grout that did not meet the zero-bleed specification was to use-as-is; the justification was that (i) these batches were a "one-time deviation" from the specification requirement; (ii) other performance requirements (compressive strength and slump flow) were met; and (iii) 8.9 percent bleed or less is still considered "low bleed," and that excess bleed water of 8.9 percent or less will be used by the tank closure grout during its long, slow hydration process.

SRR-CWDA-2012-00051. Layton, M. "Critical Assumptions in the Tank Farm Operational Closure Documentation Regarding Waste Tank Internal Configurations." Revision 2. Aiken, South Carolina: Savannah River Site. 11 January 2016. [ADAMS Accession No. ML13078A206]

This report documented DOE's evaluation of the expected impacts of remnant artifacts (e.g., transfer jets, thermowells, level instrumentation, submersible mixers and pumps, cables, and temporary transfer hoses) left within waste tanks at the time of operational closure and clarifies the difference between negligible impacts from these artifacts and what should be considered significant changes to waste tank closure configurations. DOE considers remnant artifacts within waste tanks that are smaller than (i) cooling coils or (ii) large pieces of equipment to have generally negligible impact with respect to post-closure performance of the waste tank fill grout. Table 3.2-1 presents DOE's preliminary recommendations and general plan for final disposition (i.e., internally grouting, externally encapsulating, or neglecting to further consider) remnant artifacts and materials within waste tanks at the time of their closure. Artifacts and materials listed in the table were identified based on information provided in SRR-CWDA-2010-

00003, SRR-LWE-2010-00175, SRR-CWDA-2011-00054, and SRR-LWE-2014-00147. Nevertheless, the final configuration report for each tank is the ultimate record of how such artifacts and materials were handled during grouting operations.

This report also summarizes the total volume of grout displaced by cooling coils in all SRS waste tank types (Table 4.2-3, repeated here):

Displaced Grout Volume Estimates for Cooling Coils in Select Waste Tank Types

| Tank Type | Displaced Volume Estimate (gal) | Reference |
|---|---|---|
| Type I | 5,243 | C-CLC-G-00364 |
| Type II | 6,762 | C-CLC-G-00364 |
| Type III | 2,060 | M-CLC-H-02820 |
| Type IIIA | 3,708 | M-CLC-H-02820 |
| Type IV | NA/no coils | |

Note: 1 gallon = 3.8 L

DOE estimated that for Type IV waste tanks, in-tank equipment and remnant artifacts would have to displace more than 151,400 L (40,000 gal) of bulk grout to hasten the transition from reducing to oxidizing conditions to occur within the 10,000-yr performance period; all other waste tank types have later grout transition times. Based on these calculations, DOE conservatively selected 75,700 L (20,000 gal) per waste tank as the maximum amount of tank/vault volume that should be occupied by equipment and remnant artifacts when grouting commences; however, the total volume of grout displaced by equipment and remnant artifacts in each waste tank is anticipated to be less than 75,700 L (20,000 gal) in each case. DOE anticipated that due diligence would be exercised by staff to limit the volume of remnant artifacts and materials left inside each tank so that a minimum volume of grout is displaced and the waste tank is filled with grout to the extent practical. The report concludes that any changes to reducing capacity anticipated from materials left behind within waste tanks, which take up negligible fractions of the overall tank and annulus volumes, are not expected to negatively impact results relative to performance objectives defined in the FTF and HTF PAs. The displaced volume of grout taken up by equipment and remnant artifacts in both Tanks 12H and 16H was less than 37,900 L (10,000 gal).

The report summarized the conclusions of the Grout Drop Test Report (RPT-5539-EG-0016), recommending that grout should not be placed directly into standing water due to the potential for significant segregation to occur and for its compressive strength to not meet specifications. However, the report also indicated that the presence of standing water in a tank or annulus during grouting would not necessarily cause segregation to occur or unsatisfactory compressive strength to develop if grout placement is highly controlled (i.e., not placed into standing water). Equipment flushes, which add incidental amounts of water to tanks or annuli, are assumed by DOE to result in water volume overages of approximately 3 percent (SRR-CWDA-2014-00102). DOE expects that in-tank water (e.g., rain, flush and/or bleed water) is expected to mix with grout during pouring, and to have a negligible impact on the grout (Table 3.2-1).

The report indicates that an easier-to-mix-and-pump alternative to tank grout may be emplaced in waste tank risers because the PAs did not assume that riser fill would have the same chemical and physical properties as tank grout. Instead, the PAs assumed that the tank risers are filled with a cementitious material that is equivalent to tank roof concrete (i.e., hydraulic conductivity of $3.4 \times 10^{-8}$ cm/sec) to impede groundwater infiltration.

SRR-CWDA-2015-00074. "Addendum to the *Industrial Wastewater Closure Module for Liquid Waste Tank 12H H-Area Tank Farm, Savannah River Site, SRR-CWDA-2014-00086, Revision 0, May 2015.*" Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. October 2015. [ADAMS Accession No. ML15294A364]

This report documented the final Tank 12H inventory characterization information for residual waste material remaining in the tank. SCDHEC's conditional approval of the original closure module and its approval of this closure module addendum, represented SCDHEC's ultimate agreement that waste-removal activities for Tank 12H could cease, and it authorized stabilization of Tank 12H and its residual contaminants via grouting under Construction Permit #17,424-IW. The conclusions that DOE reached in the Tank 12H closure module were not changed in the addendum.

SRR-CWDA-2015-00100. "Evaluation of the Use of an Alternative Tank 16 Fill Grout (Per Specification C-SPP-Z-00012) (Interoffice Memorandum to G.C. Arthur from M.H. Layton)." Revision 2. Aiken, South Carolina: Savannah River Remediation, LLC. September 1, 2015. [ADAMS Accession No. ML16119A341]

This interoffice memorandum documents an evaluation of the impact of use of a more flowable clean cap grout to complete the Tank 16H primary and annulus [approximately 0.6 m (2 ft) of head space, a maximum of 318,000 L (84,000 gal) in the primary and 38,900 L (10,280 gal) in the annulus] instead of LP#8-016 reducing tank grout, which had mounded-up to such a significant degree that it necessitated a more flowable grout to fill what would otherwise be an irregular void space at the top of the tank and concrete vault. The memo acknowledges that clean cap grout may not meet all of the assumed mechanical and chemical properties for tank grout as specified in the PA, but nevertheless indicates that the Tank 16H closure performance objectives will be met. The clean cap grout proposed for use (Specification C-SPP-Z-00012, Revision 1) was used in the SRS Saltstone Disposal Facility. The memo concludes there would be no impact on the effective reducing capacity of the grout, because clean cap grout has a greater weight percent GGBFS than LP#8-016 reducing tank grout (i.e., 45 wt percent per C-SPP-Z-00012, Revision 1 vs. 30 wt percent per C-SPP-Z-00012, Revision 4. The memo also notes that the clean cap grout volume within the tank would be less than 10 percent of the total tank volume, and would be located at the top of the system instead of near the contaminated zone. Notably, the memo acknowledged that clean cap grout may not have a compressive strength meeting the minimum threshold of 13,800 kilopascals (2000 psi or 138 bars), but argues that the total volume of this grout within the tank is limited and its use will minimize voids, and thereby the memo concludes that the grout material's overall functionality will not be impacted and that the overall stability of Tank 16H will be maintained during the period of concern. The memo also concludes that filling the upper portions of the tank primary and concrete vault with clean cap grout will not impact the ability of the waste tank design elements (e.g., earthen cover and intruder barrier) to serve as inadvertent intruder barriers. Finally, the memo acknowledges that clean cap grout likely will not have the same hydraulic properties assumed in the PA, which in turn may increase the water infiltration rate to the contaminated zone, because its hydraulic conductivity ($K_h$) is anticipated to be $6.4 \times 10^{-9}$ cm/s (SRR-CWDA-2014-00011) rather than the $2.1 \times 10^{-9}$ cm/s assumed in the PA for LP#8-016 reducing tank grout; nevertheless, the memo argues that this higher $K_h$ for less than 10 percent of the straight-line, through-tank flow path would have only a minor impact on the overall flow of water past the contaminated zone, and thereby the system should remain hydraulically similar to the base case PA model. The memo reports that grossly conservative HTF Goldsim deterministic model runs demonstrated that the impact on 1- and 100-m peak contaminant doses would be minor, although the peaks would occur earlier.

SRR-CWDA-2016-00068. "Tank 12 Final Configuration Report for H-Tank Farm at the Savannah River Site." Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. December 2016. [ADAMS Accession No. ML18235A409]

This report documented Tank 12H isolation, data obtained from the grouting of Tank 12H, and it clarified exceptions that occurred relative to the planned configuration described in the closure module (SRR-CWDA-2014-00086). Data presented included grouting operation dates, average 28-day compressive strength test results obtained from tank grout test cylinders, and bulk grout fill, cooling coil grout fill, and equipment grout fill volume calculated actuals versus pre-estimates. Due to discrepancies between the closure module description and the actual closure process, the report also clarified the nature of equipment remaining in Tank 12H that was filled with grout.

DOE reported average compressive strength test results from a total of 205 ASTM C39 test cylinders. The 28-day post-casting compressive strength average was 16,430 kilopascals (2,383 psi or 164 bars). DOE also reported that the volume of reducing grout to be placed inside the primary was pre-estimated at 3,000 cubic meters (3,927 cubic yards or 793,152 gal), while the calculated volume of reducing grout actually placed in the primary (based on the number of concrete mixing trucks discharged and a nominal volume of grout dispensed per truck) was 2,971 cubic meters (3,887 cubic yards or 785,073 gal), which is 99 percent of the estimate. Likewise, the estimated volume of reducing grout required to fill the annulus was 446 cubic meters (583 cubic yards) compared to an actual volume placed of 468.7 cubic meters (613 cubic yards). Finally, 34.4 cubic meters (45 cubic yards) of reducing grout were estimated as needed to fill Tank 12H risers, whereas 19.9 cubic meters (26 cubic yards) were placed.

SRR-CWDA-2017-00015. "Consolidated General Closure Plan for F-Area and H-Area Waste Tank Systems." Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. 127 pp. February 2017. [ADAMS Accession No. ML20279A784]

This report pertains to and supports the future removal from service of FTF and HTF underground waste tanks and ancillary structures regulated under the F- and H-Area High-Level Radioactive Waste Tank Farms Construction Permit No. 17424-IW and the SRS Federal Facility Agreement (FFA) that controls subsequent remediation of FTF and HTF. This consolidated general closure plan is not applicable to previously grouted Tanks 5F, 6F, 12H, 16H, 17F and 20F. This consolidated general closure plan supersedes LWO-RIP-2009-00009 Revision 3 (F-Area) and SRR-CWDA-2011-00022 Revision 0 (H-Area) general closure plans. The purpose of the plan is to describe the general protocol by which DOE intends to remove from service tanks at FTF and HTF that remain to be closed. The plan describes DOE's method of stabilizing waste tank systems and residual contamination. The plan additionally describes the integration of the waste tank system closure activities with existing commitments to remove waste from the waste tank systems.

SRR-CWDA-2018-00047. "Savannah River Site F and H Area Tank Farms, NRC Onsite Observation Visit: 'Tank 12 Grouting Calendar (Slide 21).'" Revision 1. Aiken, South Carolina: Savannah River Remediation, LLC. 13–14 August 2018. [Black and white photocopy is at ADAMS Accession No. ML18247A080; see also SRR-CWDA-2020-00052, Attachment 6]. [ADAMS Accession No. ML18247A080]

Grouting operations at Tank 12H began on January 19, 2016, and were completed on April 27, 2016, with the exception of a spray chamber above Riser 5 that was grouted on May 2, 2016 (SRR-LWE-2016-00036). Tank primary grouting began on January 19, 2016, and ended on March 7, 2016. Annulus grouting began on February 8 and ended on March 1, 2016. Failed cooling coil grouting began on January 26 and ended on January 29, 2016. Intact cooling coil grouting began on March 17 and ended on March 21, 2016. Riser grouting began on April 5 and ended on April 27, 2016 (SRR-CWDA-2020-00052, Attachment 6).

SRR-CWDA-2020-00052. Romanowski, L. "Follow-Up to Tanks 12H and 16H Grouting Operations Document Request in Support of U.S. Nuclear Regulatory Commission F and H Area Tank Farms Monitoring Activities (Memo to A. White of U.S. DOE from L. B. Romanowski)." Revision 0. Aiken, South Carolina: Savannah River Remediation, LLC. June 10, 2020. [ADAMS Accession No. ML20279A785]

This transmittal memo provided follow-up information in response to U.S. NRC's documentation request concerning Tank 12H and 16H grouting operations. It listed the documentation and information that had been requested, and provided some of the requested information in either the memo itself, or in attachments to the memo. Attachment 1 was a diagram of riser penetrations, noting any equipment installed in each riser, in Tank 12H. Attachment 2 was a similar diagram noting risers in which video-camera equipment was installed. Attachment 3 was a diagram of the grouting slickline layout. Five accepted and five rejected Tank 12H grout batch tickets transmitted as Attachments 4 and 5 to the memo were illegible; legibility could not be improved with image-sharpening techniques. Attachment 6 was a color-coded Tank 12H grouting calendar for days when the primary, annulus, risers, failed and intact cooling coils, and equipment were grouted. Additionally, the transmittal memo was accompanied with a set of requested reports and work orders in electronic copy/PDF format. Items NRC requested but were not transmitted with the memo included Tank 12H grouting operations video (DVDs) and a drawing of the Tank 12H annulus, ventilation ductwork and air supply registers, which was later provided in document SRR-CWDA-2020-00058. In anticipation of grouting-operations video being transmitted to NRC shortly thereafter, DOE included Table 1 in the memo to provide date/time stamp information for specific requested grouting operation activities that NRC staff was interested in monitoring.

SRR-CWDA-2020-00058. Romanowski, L. "Type I Waste Tanks Dehumidification System Heating and Ventilation Ductwork [From Dwg. #W146593]." Revision 0. Aiken, South Carolina. Savannah River Remediation, LLC. July 8, 2020. [ADAMS Accession No. ML20279A786]

This is a two-page set of four engineering drawings of Type I tank annuli and their dehumidification system heating and ventilation ductwork, which was based on classified drawing #W146593, but modified recently to only communicate unclassified information and annotated for clarity. This new document was prepared and transmitted in response to a request from NRC staff for DOE to provide a drawing of the Tank 12H internals.

SRR-LWE-2016-00036. Voegtlen, R.O. "Tank 12 Final Configuration Report Inputs (Interoffice Memo)." Revision 2. Aiken, South Carolina: Savannah River Site. December 6, 2016. [ADAMS Accession No. ML20279A787]

This report compiles and documents data from the grouting of Tank 12H. A deviation from the grouting configuration described in SRR-CWDA-2014-00086 is included. Dates when the various grouting operations began and ended are included. Report is referenced extensively in the main body of this technical review report.

SRR-TCR-2015-00024. Davis, B. "Tank 16 Grouting Lessons Learned (Memo)." Aiken, South Carolina: Savannah River Remediation, LLC. January 27, 2016. [ADAMS Accession No. ML16119A346]

This memo documented lessons learned from Tank 16H grouting operations. Fourteen items were identified in a table in the appendix to the memo, including recommendations to (i) remove diversion valves from the grout slickline, because their use resulted in grout plugging and ineffective cleaning of the slickline; (ii) replace use of decant totes with waste totes during intact cooling-coil grouting processes, because decant tote usage resulted in high hazard potential; (iii) evaluate and test highly flowable clean cap grout to ensure it meets PA requirements so it can be used with confidence, if needed in the future, to complete primary/annulus grouting; (iv) base grout placement sequence/lift height plans on real grout data about set time, specific gravity, etc., instead of on bounding values to potentially provide more placement flexibility; (v) evaluate impact of eliminating the cooling coil grouting process, because it is the highest hazard grouting operation; (vi) develop a management control plan to conduct failed and intact cooling-coil grouting dry runs; (vii) develop a better method to ensure that the grout slickline is lubricated/wetted before grout introduction; (viii) analyze data from Tank 16H grout testing to develop an acceptable, non-zero range for bleedwater production; (ix) plan grouting operations around seasonal weather expectations; (x) develop a method to flush a cooling coil immediately prior to grouting the coil to reduce hazards, use of resources, and setup time. The report also noted that highly flowable clean cap grout could not be placed into Tank 12H without pre-approval from SC DHEC provided to DOE staff.

SRR-TCR-2016-00007. Davis, B. "Tank 12 Grouting Liquid Spill Lessons Learned." Aiken, South Carolina: Savannah River Remediation, LLC. May 9, 2016. [ADAMS Accession No. ML20279A788]

This memo documented lessons learned from a Tank 12H liquid spill that occurred during the final stages of grouting of the tank primary. Ten items were identified in a table in the appendix to the memo, including recommendations to (i) reevaluate the costs–benefits of removing spray chambers from risers used to grout future tanks because the presence of the spray chambers makes video-camera monitoring of grout levels in the risers difficult; (ii) provide a grouting termination plan in future work orders to control grout and/or liquid levels in risers so that liquid does not overflow risers and spill onto the tank top; (iii) provide grout spill plan in work orders to prepare and locate spill kits near risers being grouted to minimize the impact and spread of any spill; (iv) provide an approved plan for placing dry grout mix into risers containing free liquid (e.g., bleed water) to assimilate/absorb the liquid; (v) evaluate alternatives for wetting the grouting slickline other than adding 95 to 189 L (25 to 50 gal) water to the line, which is then disposed of inside the tank; (vi) schedule grout placements with more time elapsed between lifts to allow free liquid assimilation into previous grout pours; in particular allow a significant amount of time to elapse after grouting failed cooling coils, which may add several thousand gallons of free liquid to the tank; (vii) prepare work orders to remove accumulated liquid from the risers via pumping with the assumption that liquid removal will be considered a non-waste transfer; (viii) evaluate the specific configuration and condition of individual risers for characteristics that might make them more likely to create a spill situation and adapt work order development accordingly; (ix) evaluate the costs–benefits of preparing all tank risers with a grout plate to allow insertion of video cameras to monitor rising liquid levels during grouting (DOE thinks the liquid spill onto Tank 12H came from a riser that was not being monitored by camera); and (x) evaluate the use of non-video instruments, such as liquid-level indicators, that will sound an alarm when a threshold liquid level is exceeded.

USQ-HTF-2015-00706. Layton, M. "Supplier Deviation Disposition Request (SDDR) Number 13307 – Deviation from Specification C-SPP-F-00055, Revision 4 (Technical Review Package)." Revision 0. Savannah River Site, South Carolina. October 2015. [ADAMS Accession No. ML20279A789]

This technical review package includes the documents Design Authority Technical Review (DATR), Unreviewed Safety Question (USQS) review, and Consolidated Hazard Analysis Process Screening (CHAPS), along with the USQ-HTF-2015-00706 Attachment, the Unreviewed Waste Management Question (UWMQ) Determination, and a related E-Mail from M. Layton to R. Voegtlen, dated October 22, 2015. The proposed activity, which was reviewed, was the "use-as-is" disposition of SDDR No. 13307 – Deviation from Specification C-SPP-F-00055, Revision 4, which required that tank closure grout have 0.0 percent bleed after 24 hrs. set time. The documentation indicates that "several" batches of grout used to fill Tank 16H had greater than zero bleed water, but was not specific about how many batches were affected. The justification for the use-as-is disposition of the non-zero-bleed grout was that the batches which exceeded the zero bleed requirements met all other performance requirements in the specification, and the non-zero-bleed deviation did not invalidate the requirements or compromise the assumptions of or input to the HTF PA.

VSL-14R3330-1. Papathanassiu, A.E. et al. "Saltstone Clean Cap Grout Assessment (Final Report)." Revision 0. Washington, DC: Vitreous State Laboratory, The Catholic University of America. March 2014. [ADAMS Accession No. ML20279A790]

This report documented the fresh grout properties of candidate formulations for clean cap grout. The original clean cap grout formulation had the same water-to-premix (*w:p*) ratio as the saltstone mix, i.e., *w:p* = 0.6, but *w* was only water and not saltstone solution. Ultimately, two new clean cap grout mixes employing a 45 percent Holcim GranCem® Grade 100 slag cement ($d_{50}$ = 13 µm) to 45 percent fly ash to 10 percent Portland cement blend were recommended for use to reduce bleed water production and enhance bleed water reabsorption. One alternative mix reduced the *w:p* ratio to 0.5 and exhibited 40 percent less bleed water production; the other mix also reduced *w:p* to 0.5, and added sodium hydroxide at 1.6 M to the water, which is comparable to that in the salt solution, to reduce bleed water production by 60 to 80 percent. These new clean cap grout formulations exhibited acceptable slump flows (ASTM C1611/C1611M, 2018) from 90.2 to 67.6 cm (35.5 to 26.6 in), respectively, and had sufficiently long set times (>10 hrs) that would enable off-site production. Testing of clean cap grout comprised of finer Grade 120 slag cement by Lafarge ($d_{50}$ = 8.5 µm) or MC-500 Microfine Cement ultrafine slag cement by de Neef Chemicals/Grace Construction Products ($d_{50}$ = 3.5 µm) was undertaken to understand the impact of slag particle size on bleed water production because finer particles were expected to increase reactivity as a result of their enhanced surface area, and thereby promote hydration. The authors found that decreased particle size led to increased bleed water production unless caustic sodium hydroxide aqueous solution was used. Two types of high-range water reducers or superplasticizers were also tested, including

ADVA Cast 575, which is also used to batch SRS's reducing tank grout. The authors observed that use of ADVA Cast 575 as a water-reducing admixture significantly increased bleed water production and rapid segregation of most of the grout solids from the liquid mass. Appendix A of the report reproduces material certification reports and specifications for the various cementitious materials and admixtures tested. The authors anticipated potential vendor reluctance to introduce sodium hydroxide into clean cap grout at either an offsite mixing facility or mixer trucks, so although clean cap grout behavior and performance would improve, future implementation is thought to be unlikely. This report does not address the potential performance of clean cap grout that might be comprised of Lehigh Grade 120 slag cement, which is now in use at SRS.

VSL-15R3740-1. Gong, W. et al. "Investigation of Alternate Ground Granulated Blast Furnace Slag for the Saltstone Facility (Final Report)." Revision 0. Washington, DC: Vitreous State Laboratory, The Catholic University of America. August 26, 2015. [ADAMS Accession No. ML16117A355]

This report describes testing conducted for SRR to assess characteristics of grout specimens prepared using alternative slag cements for use in saltstone, tank grout, and Saltstone Disposal Structure concrete at SRS, given that Holcim's Grade 100 slag would no longer be produced. The report states that Grade 120 slags are now more widely available than Grade 100 slags, and that "the strength differential between the Grade 100 and 120 is provided by the smaller particle size and enhanced reactivity of the higher Grade slag." In general, substituting a Grade 120 slag for Grade 100 should result in higher compressive strength and lower hydraulic conductivity grout if the Grade 120 slag has a finer particle size and enhanced reactivity. Differences in slag chemistry may also impact fresh and hardened properties of cementitious grouts, which could affect long-term performance. Four alternative slag mixes of saltstone simulant were tested, along with the original Holcim Grade 100 slag cement mix, for granulometry, reductive capacity, viscosity, yield stress, temporal gelation behavior (i.e., "gel time" at which point a grout slurry is no longer pourable), and heat of hydration (through the first 12 days post-placement). The saltstone simulants produced with the five slags had broadly similar properties, especially those produced with Holcim, Lafarge, and Lehigh Hanson slags; therefore, the Lafarge and Lehigh Hanson slags were the two best options for replacing Holcim's Grade 100 slag with minimal impact to performance. The Lehigh Hanson Grade 120 slag had the highest reduction capacity (12 percent greater than Holcim Grade 100) and the lowest heat release of all five slags, making it the clear choice to replace the Holcim Grade 100. The authors maintained that substituting Grade 120 slag for Grade 100 slag would result in a higher compressive strength grout due to enhanced surface area (i.e., smaller particle size) and reactivity, but saltstone simulant specimens that resulted from this work were not tested for compressive strength, so this statement could not be verified. It is also notable that the mean particle size for Holcim Grade 100 slag is smaller in this report ($d_{50}$ = 16.05 μm) and even smaller in the aforementioned VSL-14R3330-1 report ($d_{50}$ = 13 μm) than the Lehigh Grade 120 slag ($d_{50}$ = 18.47 μm), but the authors do not dwell on this unanticipated finding that Grade 100 slag may have a finer mean diameter than Grade 120 slag (the most relevant portion of their Table 5.5 and their Figure 5.10a illustrating the particle size distributions of the alternative slags are reproduced next). The impact of slag particle size variability on compressive strength, hydraulic conductivity, and chemical reactivity of the reducing tank grout is uncertain, as is the extent to which slag particle size from a given slag manufacturer varies with time.

Table 5.5. Characteristics of GGBFS Materials for Preparing Saltstone Grout Samples.

| GGBFS Type | Mill Report Data | | | VSL Determined Slag Characteristics | | |
|---|---|---|---|---|---|---|
| | Activity Index | Sulfide | Blaine fineness ($m^2/kg$) | Vol. % Particles Passing 22 µm | Mean Particle Size, µm | Reduction Capacity, µeq/g |
| Holcim Slag Grade 100 | 116 | 1.0% | 643 | 78.72 | 16.05 | 722 |
| Lehigh Slag Grade 120 | 124 | 0.9% | 539 | 73.39 | 18.47 | 812 |

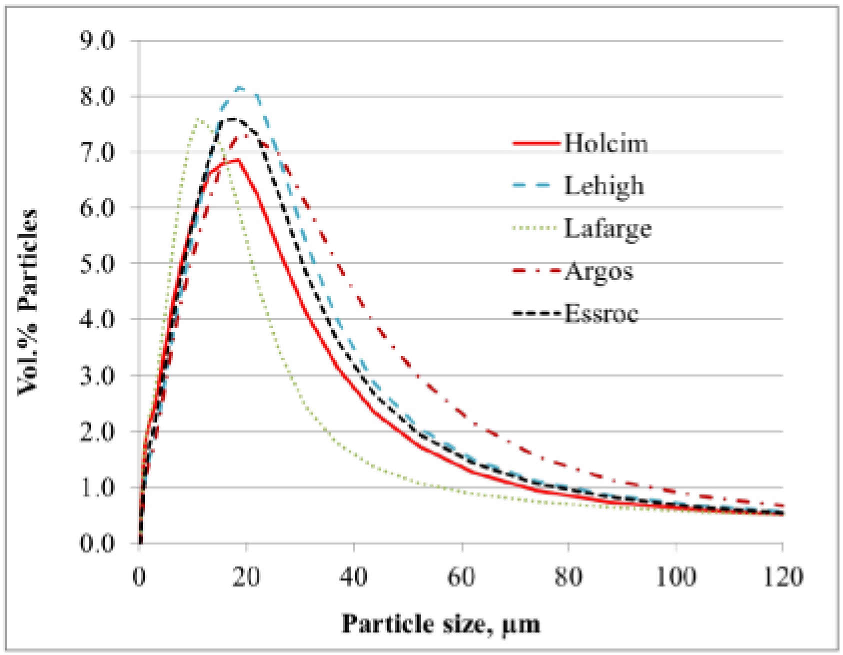


Figure 5.10a. Particle size distributions of various GGBFS materials in terms of volumetric statistics.

WO 01324150-64. Fail, J.A. "TK CLOS & REG CN TO PERFORM GROUT PREP/GROUT PLACEMENT TK 16." Revision 0. August 22, 2014. [ADAMS Accession No. ML16119A351]

This work order is for placing grout in Tank 16H in support of tank closure, including operations such as removal of riser cover port plugs, tremie installation into risers and pumping of grout through slickline piping. Six grout placements (i.e., lifts) are described to fill the primary tank (3 lifts) and the annulus (3 lifts), including their not-to-exceed volumes, necessary to fill the primary tank and annulus, and additional placements for each riser and riser cap. The work order describes personal protective equipment (PPE) used, and for which steps each PPE is used, lists chemicals employed, checklists for steps to be taken before and during the grouting process, and the steps to be taken if deviations are required.

WO 01337683-31. Alexander, O. "TK.12 Flush & Grout Intact Chromate Cooling Coils." Revision 1. November 2, 2015 [Initials and handwritten notes added during March 2016]. [ADAMS Accession No. ML20279A791]

This work order is for flushing contaminants inside intact Tank 12H chromate cooling water coils to Tank 10H, Riser 3, and for grouting intact coils. The work order describes personal protective equipment (PPE) used, and for which steps each PPE is used, lists chemicals employed, checklists for steps to be taken before and during the flushing and grouting processes, and the steps to be taken if deviations are required.

WO 01337683-31-A. “Attachment ‘A’ – Tank 12 Coil Flushing Spreadsheet.” [ADAMS Accession No. ML20279A792]

This work order attachment identified the 8 intact cooling coils flushed and grouted in Tank 12H (i.e., CRW-CCL-4, -17, -18, -22, -23, -30, -31, and -32), and recorded water levels before and after flushing, and the required flush volumes per coil (i.e., 94, 116, 147, 94, 104, 101, 112, and 102 gal).

WO 01337683-31-F. “Attachment F – Coil Grout Spreadsheet.” [ADAMS Accession No. ML20279A794]

This work order attachment identified 5 of the 8 intact cooling coils flushed and grouted in Tank 12H (CRW-CCL-4, -17, -18, -22, and -23), and the “100 percent” coil capacity (i.e., volume) of these coils (i.e., 102, 124, 154, 102, and 109 gal).

WO 01337683-33. Patton, G.W. “Placement of Bulk Fill Grout (Tank 12 Work Order).” Revision 2. [ADAMS Accession No. ML20279A795]

This work order is for placing grout in Tank 12H in support of tank closure, including operations such as removal of riser cover port plugs, tremie installation into risers and pumping of grout through slickline piping. Nine grout placements (i.e., lifts) are described, including their not-to-exceed volumes, necessary to fill the primary tank, annulus, and annulus inlet ventilation horizontal and vertical duct, and additional placements for each riser and riser cap (including annulus exhaust duct). The work order describes personal protective equipment (PPE) used, and for which steps each PPE is used, lists chemicals employed, checklists for steps to be taken before and during the grouting process, and the steps to be taken if deviations are required.

WO 01337683-33-A. “Attachment A – Tank 12 Tremie Installation Steps.” [ADAMS Accession No. ML20279A796]

This work order attachment is for installation of tremies used to place grout in the Tank 12H primary and annulus through risers, including operations such as removal of riser cover port plugs and installation of hammer valves. Checklists for steps to be taken during the processes are provided.

WO 01337683-33-B. “Attachment B – Tank 12 Cleaning/Pigging of Slickline.” [ADAMS Accession No. ML20279A797]

This work order attachment is for implementation at any time during grouting operations when it is deemed necessary to clean out the grout slickline. Checklists for steps to be taken during the process are provided.

WO 01337683-50. Alexander, O. “TK12 Grout Failed Coils.” August 12, 2015. [ADAMS Accession No. ML20279A798]

This work order is for grouting failed Tank 12H chromate cooling water coils. The work order describes personal protective equipment (PPE) used, and for which steps each PPE is used, lists chemicals employed, checklists for steps to be taken before and during the grouting process, and the steps to be taken if deviations are required.

WO 01337683-51. Patton, G.W. “TK 12 Closure Constr Perform Equipment.” [ADAMS Accession No. ML20279A799]

This work order is for construction to perform grouting of equipment for Tank 12H at the Riser 1, Riser 3, Riser 5 and Riser 8 spray chambers; Riser 2 steam jet (core), steam jet (jacket), and transfer line; North annulus conductivity probe #1 and #2 and South annulus conductivity probe #1 and #2; Riser 7 submersible transport pump, caisson lance, thermowell, and Riser 4 reel tape, HLLCP, TW insert plug, spray lance, and H&V riser drain. The work order describes personal protective equipment (PPE) used, and for which steps each PPE is used, lists chemicals employed, checklists for steps to be taken before and during the grouting process, and the steps to be taken if deviations are required.

## Appendix B

### NDAA WIR Monitoring of Tank Grouting Operations: Questions for DOE Related to Tank 12H and Tank 16H

The NRC provided DOE with a list of requested references via email on February 26, 2016, and updated the requested reference list via e-mail on March 30, 2016. Most of these references were provided by DOE prior to the May 17, 2016, teleconference. Due to time constraints during the May 17, 2016, teleconference, the NRC was unable to ask a few questions related to the new reference reviews and other lingering questions. Recent receipt and review of new DOE documents concerning grouting of Tanks 12H and 16H have given rise to some additional questions, as well. The NRC requests DOE to respond to the following questions via email or letter. Alternatively, interested parties could participate in a follow-up teleconference to discuss these questions, if preferable to DOE.

1. **Grout Specifications & Testing:** While the use of high-range water-reducer ADVA 575 has increased to achieve greater flowability, the viscosity modifying admixture (VMA), EXP 958 dosage has not changed, even though VMAs are used to counter-balance the use of high-range water-reducers, which at higher quantities can lead to excessive bleed water segregation. Why has EXP 958 dosage not changed with the increase in ADVA 575? Please provide the quantity or range of ADVA 575 and RECOVER in fluid ounces that were used to batch tank grout for Tank 12H (the 5 accepted and 5 rejected grout batch tickets for Tank 12H provided in SRR-CWDA-2020-00052 were illegible so NRC could not determine the dosages).
2. **Grout Specifications & Testing:** Tank 12H was grouted with two different types of grout. Lehigh Grade 120 slag cement was used in the mix to grout Tank 12H only starting on the second day and thereafter, but Holcim Grade 100 slag cement was used in the mix poured on the first day. Please explain the reasoning for using Grade 100 slag in the first 27 batches of tank grout that were placed into Tank 12H on the first and second grouting days. Was there a decision made to use all existing Grade 100 slag, even if it meant using two different types of slag in grout placed into one tank? Did DOE consider it important to use grout comprised of Grade 100 slag in immediate contact with the waste on the floor of Tank 12H? Please evaluate the differences in hydraulic conductivity between the Grade 100 and Grade 120 slag tank grout and any resulting performance impact). Consider using remaining untested samples of tank grout for late-term compressive strength testing.[9]
3. **Grout Specifications & Testing:** Please clarify if all testing of Lehigh Grade 120 slag is described in VSL-15R3740-1. DOE indicated that additional testing information is provided in SRR-CWDA-2015-00088, but testing results do not appear to be included in this document. What testing, if any, has been completed for tank fill, equipment, cooling coil, and clean cap grout prepared with Grade 120 slag? Has DOE evaluated other reducing tank-closure grouts such as equipment, cooling coil, and clean cap grout? Is there a document available that includes information about Grade 120 slag tank grout wet chemistry test, flow test, compressive strength, and bleed? [Requested References for May 2016 Teleconference (Question transmitted to DOE in March 2016)]
4. **Grout Specifications & Testing:** NRC requested the final specification for clean cap grout as a follow-up action to the May 17, 2016, teleconference. Could DOE clarify how it achieves the minimum flowability given that SRNL-STI-2012-00558 indicates that flowability would be compromised at a water-to-cement ratio of 0.51, and that the one most-relevant

[9] If any samples of tank grout remain available afterward, DOE should consider using them to conduct grout water-conditioning experiments, either at CNWRA or a DOE-selected laboratory or both.

sample tested in SRNL-STI-2012-00558 (sample WP023 with a water-to-cement ratio of 0.51) had slump flow of only 18.6 cm (7.5 in) and no sample had greater slump flow than 29 cm? Could DOE clarify if any Daratard or any admixtures were used in the Tank 16H clean cap specification, or if there is an option to use admixtures in the future?

5. **Grout Specifications & Testing:** With respect to SDDR No. 13307, the document has two attachments documenting the two highest bleed results, which were 8.9 percent (June 18, 2015) and 3.3 percent (June 19, 2015), but the deviation description states that none of the bleed tests resulted in zero bleed. Please indicate if this statement was true over a limited time-range, or for every batch placed into Tank 16H. On page 4 of the SDDR, DOE states that bleed test results varied from 0.0 to 8.9%, which isn't consistent with page 1 that states none of the bleed tests resulted in 0.0 bleed. DOE also stated that the initial grout mix qualification test results for these two batch tickets show that these batches met the zero bleed requirement (initially, but not after 24 hours). Please clarify.
6. **Grout Placement:** NRC recently reviewed DOE's Tank 16H grouting operations lessons learned document, which included the recommendation to devise grout placement sequence/lift height plans on real grout data for set-up time, specific gravity, etc., instead of on bounding values, to potentially provide more placement flexibility. Please indicate whether the Tank 12H lift height analysis was based on bounding values or realistic values, and if based on bounding values, will realistic values be utilized for Tank 15.
7. **Grout Transferability, Flowability & Mounding:** DOE estimated that 3,928 cubic yards (793,411 gal) of grout would be required to fill a generic, empty Type I tank (U-CLC-G-00001), excluding riser volumes. For Tank 12H specifically, DOE conservatively estimated that the actual volume of the tank was 3010 cubic meters (3,937 cubic yards or 795,082 gal), and that the volume of residual material remaining on the floor of the primary (**Figure 1**) and on cooling coils (**Figure 2**) totaled 6.9 cubic meters (9 cubic yards or 1,900 gal) (SRR-LWE-2016-00036; U-ESR-H-00125; M-CLC-H-03256). Accounting for the residual material volume, the final estimated Tank 12H grout volume (excluding risers) was 3,002 cubic meters (3,927 cubic yards or 793,182 gal). Please indicate what accounts for the difference between the generic Type I tank and actual Tank 12H volume estimates. Please provide an estimate of uncertainty for these volumes. Please confirm that DOE calculates grout volumes in advance of grouting so that the values provided are not biased.
8. **Grout Transferability, Flowability & Mounding:** Please provide information about the volumetric capacity of the grout trucks and about the limitations on the amount they can reasonably discharge. Does the batch plant meter "exactly" 6.1 cubic meters (8 cubic yards) (and with what uncertainty) into each truck? When a truck has fully discharged its load of grout into a tank, is there a certain amount of grout residue remaining on the interior of the truck, such that only approximately 6.04 cubic meters (7.9 cubic yards) are actually discharged per truck? Is it feasible for each grout truck to actually deliver its 6.1 cubic meters (8 cubic yards) of grout?
9. **Grout Transferability, Flowability & Mounding:** The Tank 16H lessons learned document addressed needs to (i) remove diversion valves from the grout slickline, because such use resulted in grout plugging and ineffective cleaning of the slickline, and (ii) develop a better method to ensure that the grout slickline is fully wetted/lubricated prior to grout introduction to minimize grout plugging (SRR-TCR-2015-00024). Please provide insight into whether this lesson learned represents a long-term issue that DOE has been tracking through multiple tank grouting operations.
10. **Grout Transferability, Flowability & Mounding:** The Tank 16H grout strategy indicated that having 8 to 10 cement mixer trucks in rotation was ideal (SRR-LWE-2014-00013),

whereas the Tank 12H grout strategy later clarified that a grout delivery rate of 8 to 10 trucks per hour (SRR-LWE-2014-00147) was ideal. Which of these two statements is correct?

11. **Grout Transferability, Flowability & Mounding:** Has DOE made an effort to establish a causative relationship or correlate ambient temperatures or grout placement rates with the Tank 16H mounding phenomenon (ADAMS Accession No. ML16167A237), which, if undertaken, would improve understanding of contributing factors or has DOE taken steps to study this phenomenon in the future? For example, DOE could monitor in-tank temperatures (ADAMS Accession No. ML16167A237), which are expected to be dominated by the heat of hydration during grouting operations. While the tanks are located underground and are insulated from surface temperature fluctuations, DOE indicates that ventilation of the tanks introduces ambient air into the tanks and could influence in-tank temperatures during grout hydration.
12. **Bleed Water Segregation:** Residual pools of flush water present on the floor of Tank 12H before grouting began were mapped by DOE contractors so that those areas could be purposefully avoided during initial grouting of Tank 12H (ADAMS Accession No. ML16111B174). Does DOE have such maps or further information available about where residual water remained in the tank for NRC review? DOE should provide additional information regarding the quantity and performance impact of the standing water that was present in Tank 12H during grouting.
13. **Groundwater In-Leakage:** As tank grout placed into Tank 12H primary approached the tank roof and risers, liquid perched on the grout surface was observed from several of the risers (SRR-CWDA-2016-00068; SRR-LWE-2016-00036). Has DOE considered that the rising liquid level could have been comprised, in part, of bleed water that was segregated from grout flow lobes, flowing to low spots near the tank wall? Tank grout comprised of Grade 120 slag may produce more bleed water than tank grout comprised of Grade 100 slag (VSL-15R3740-1). NRC recalls a water/liquid removal procedure being in place for Tanks 5F and 6F, but that it was not implemented for those tanks. When rising liquid levels were observed approaching the roof of Tank 5 or 6 (perhaps 1 ft of water), why was it unnecessary to pump out the excess (follow-up question from discussion during August 2018 OOV)? Was dry grout mix added to absorb the liquid, as mentioned in a recent work order? Is Tank 12H the first tank for which water was pumped out late in the process of grouting?
14. **Groundwater In-Leakage:** During the May 17, 2016, teleconference, DOE indicated that it is working with SCDHEC to enable original, operational ventilation systems to remain in place during future grouting operations (ADAMS Accession No. ML16167A237) to better manage water ingress. Would DOE please provide an update on the status of these discussions and plans?

15. **Groundwater In-Leakage:** It is NRC's understanding that DOE stopped work twice during Tank 12H grouting due to groundwater in-leakage into the annulus. First, initial planned grouting of the first annulus lift was delayed due to groundwater ingress and required pumping of 3785 L (1000 gal) of water. Then, water was also observed flowing into the vertical ventilation inlet duct of the Tank 12H annulus (SRR-CWDA-2020-00058) through a crack in the duct wall of the Tank 12H annulus (SRR-CWDA-2016-00068). DOE described that a clay ventilation pipe was a source of groundwater leaking into the annulus (August 2018 OOV). DOE contractors indicated that a vertical leg of the annulus ventilation duct required 1893 L (500 gal) of groundwater to be pumped out. Did this second event all occur on one day, from discovery to resolution of the issue and completion of ductwork grouting? On what date(s)/during which lifts did this second water ingress and pumping of another 1893 L (500 gal) of water occur?
16. **Groundwater In-Leakage:** Tank 12H is susceptible to groundwater intrusion due to its location below the water table. DOE should provide additional information about the anticipated performance impact on grout in Tank 12H of groundwater saturation. Will DOE undertake modeling to estimate the rate at which the grout monolith of Tank 12H will wet up due to in-leakage?
17. **Annulus & Ventilation Duct Grouting:** The Tank 12H closure module (SRR-CWDA-2014-00086) suggested that a more flowable grout might be used to grout future ventilation ducts, and DOE reiterated the potential use of a more flowable grout for ductwork during the February 2–3, 2016, OOV. The Tank 12H grout strategy document (SRR-LWE-2014-00147) did not address use of a more flowable grout for this purpose (ADAMS Accession No. ML16111B174). Work order WO 01337683-33 indicates that Lifts 5, 7, and 9 partially consisted of placement of cooling coil grout inside the annulus ventilation duct, addressing the issue of grout flowability within the ductwork. It is NRC staff's understanding that this is the first tank for which flowable cooling coil grout was placed into the annulus ventilation duct. Please indicate if DOE had a concern about filling the ductwork using the annulus grout that led to this new use of a more flowable grout. If there was a concern, please provide data or evidence from relevant grouted tanks that supports why this was a concern.
18. **Cooling Coil Flushing & Grouting:** Intact cooling coils of Tank 12H were flushed once prior to grouting to remove chromate water, which was sent through a hose to Tank 10H, Riser 3 (SRR-CWDA-2020-00052; WO 01337683-31-A; HTF-SKM-2015-00010). Intact cooling coils remained full of water at the conclusion of flushing (SRR-CWDA-2020-00052). After Lift 8 was complete and the primary had been filled with bulk grout (ML18247A080, Slide 21), flushwater remaining in the coils was flushed again on March 17 and 21, 2016, through hoses into stand-alone, 1135-L (300-gal) gray-water collection totes by grout pumped into the coils (HTF-SKM-2015-00010); this process minimized air entrainment and helped maintain the water-to-grout interface inside the coils (ADAMS Accession No. ML16167A237). Please indicate if chromate flushing into Tank 10 also occurred on these intact coil-grouting dates, or beforehand, and when it occurred.
19. **Cooling Coil Flushing & Grouting:** The 8 intact cooling coils of Tank 12H were grouted only from the coil inlet (SRR-LWE-2016-00036). When a solid stream of grout was visually detected at the coil outlet, a minimum surplus of 38 L (10 gal) of grout was introduced to the coil to ensure complete filling (ADAMS Accession No. ML15239A612; SRR-CWDA-2015-00159; SRR-LWE-2016-00036; WO 01337683-31-F). Does DOE measure the discharged grout volume to determine if more than 37.9 L (10 gal) was introduced to a coil, or does DOE know the coil capacity ahead of time (coil volume) and add 37.9 L (10 gal) to determine the volume of grout to be injected into the coil?

20. **Cooling Coil Flushing & Grouting:** With regard to work order WO 01337683-31-A (Tank 12H coil flushing spreadsheet), please explain the term "water buffalo level" and the disconnect between the water levels recorded before, after, and the volumes required (which do not appear to add up, even with adding a minimum of 37.9 L (10 gal) extra).
21. **Cooling Coil Flushing & Grouting:** With regard to work order WO 01337683-31-F (Coil Grout Spreadsheet), please explain why this spreadsheet addresses only 5 of 8 intact coils, and why the coil capacity noted here differs from the required flush volumes per coil (WO 01337683-31-A).
22. **Riser Grouting:** It was pre-estimated that 34 cubic meters (45 cubic yards or 9,089 gal) of tank grout would be required to fill the risers, including four spray chambers (SRR-LWE-2016-00036). However, only approximately 20 cubic meters (26 cubic yards of tank grout or 5,241 gal) were used to fill the risers and spray chambers and this is consistent with the grouting operation work order's description of the estimated riser fill volumes, which total 20 cubic meters (26.2 cubic yards) (WO 01337683-33). Please explain how explain how the total riser volume in SRR-LWE-2016-00036 was mis-estimated, when the total riser volume was accurately estimated in the WO.
23. **Riser Grouting:** During the final stages of riser grouting in the Tank 12H primary, a liquid spill onto the tank top occurred when liquid that had accumulated in the tank primary overtopped a riser. DOE thinks the liquid spill was from a riser that was not being monitored by a camera, but the specific riser that was overtopped was not identified in the lessons learned document (SRR-TCR-2016-00007). Please identify the specific riser involved in this liquid spill, and additional reports or documentation of the incident, as well as any video footage.

**Modeling Files, Reference, and Video Requests:**

1. Goldsim modeling files associated with SRR-CWDA-2015-00100 (evaluation of impact of clean cap grout in Tank 16H), if not already provided.
2. NRC requested and DOE provided Work Order No. 01324150-64. However, key attachment HTF-SKM-2014-00031 (Grout Placement Plan) was not provided (DOE provided attachments HTF-SKM-2015-00021 and HTF-SKM-2015-00010). Would DOE provide missing attachment HTF-SKM-2014-00031?
3. SRR-CWDA-2014-00102. Layton, M.H. "Disposal of Cooling Coil Grouting Liquid Within Tank 16." Revision 0. Aiken, South Carolina: Savannah River Site. November 2014.
4. SRR-CWDA-2012-00051 *Revision 3 or later*, said to contain directions referenced in a work order to: "PLACE/POUR GROUT; IF water is present Then add Dry Grout Per the guidance of SRR-CWDA-2012-00051 Revision 2 (Riser grouting)." NRC has Revision 2, which does not address application of dry grout mix to bleed water in risers.
5. SRR-LWE-2014-00162. Voegtlen, R. O. "Video Inspection Plan for Tank 12 During Tank Grouting Activities." February 2015.
6. SRR-LWE-2016-00020. Voegtlen, R.O. "Tank 12 Grout Cracks under Riser 1." 2016.
7. USQ-HTF-2015-00635 (Technical Review Package associated with grout cylinder laboratory temperature excursions).
8. USQ-HTF-2015-00686 (Technical Review Package associated with grout cylinder laboratory temperature excursions).
9. Any Tank 12H nonconformances.