

**Detailed Technical Discussion
NRC DOE Teleconference May 17, 2016
Regarding SRS Tank Grouting**

During the teleconference, Department of Energy (DOE) and U.S. Nuclear Regulatory Commission (NRC) discussed NRC questions e-mailed to DOE Savannah River Site (SRS) on February 26, 2016, following a February 2-3, 2016, onsite observation visit (OOV) at the site. The questions were primarily related to review of video of grouting of Tank 16H during the months of June through September 2015. Grout video was provided by DOE to the NRC in response to a follow-up action item to the July 28-29, 2015, OOV in late December 2015. The DVDs were reproduced and sent to NRC's contractor at the Southwest Research Institute in late January 2016 for review. Review of the Tank 16H grouting video was completed by NRC contractors and staff the beginning of February 2016. Although the NRC staff discussed some of its video observations at the February 2-3, 2016, OOV (see ML16111B174), the bulk of the discussion regarding the grouting of Tank 16H took place during this May 17, 2016, teleconference. The NRC staff explained that questions asked during this teleconference are akin to questions that NRC would raise in an onsite observation and no greater risk significance should be placed on the questions. However, due to the timing of completion of its review and NRC staff's desire to provide DOE with a list of questions well in advance of discussing the technical issues with DOE, the NRC determined the questions were better discussed following the February 2-3, 2016, OOV after DOE had an opportunity to think about and better respond to the questions. After DOE received the questions via email on February 26, 2016, DOE proposed the date of the May 17, 2016, for the teleconference.

In the e-mail that was sent to DOE SRS on February 26, 2016, the NRC staff provided DOE with a summary of the list of questions related to its review of Tank 16H grout video to help facilitate discussion at this teleconference. The NRC began the teleconference by providing an overall summary of the questions that focused on three topics:

- Mounding of grout in Tank 16H underneath risers used as grout entry points, which led to difficulty in filling remaining void space at the top of Tank 16H, and necessitated a switch in the grout formulation used to fill the remaining void space. Ambient temperatures were attributed by DOE as the primary cause of the mounding. The NRC staff hypothesized that grout discharge rates could also be a contributing factor. Additionally, the NRC staff also reviewed specifications for a more flowable clean cap grout (a formulation more commonly used at the saltstone disposal facility), which was used in Tank 16H to fill remaining void space at the top of the tank, and any detrimental impacts on H-Tank Farm performance associated with the change in grout formulation.
- Ability to stabilize waste in the Tank 16H ventilation duct. The NRC staff had technical concerns regarding the extent to which waste residing in the Tank 16H ventilation duct was grouted and the strategy used to fill the ventilation duct. The ventilation duct contains a significant quantity of relatively soluble waste from historical Tank 16H waste leakage.
- The causes of and extent of bleedwater segregation during tank grouting. The NRC staff had questions about sources of water in the tank that may exacerbate bleedwater segregation, and DOE's efforts to manage this water. Results of a grout drop test

reported in RPT-5539-EG-0016 showed excessive bleed water segregation when grout is dropped into a certain quantity of standing water. The NRC staff were also interested in better understanding mechanisms for bleedwater segregation observed during NRC staff's review of tank grouting operations.

Finally, the NRC reiterated its main technical concern regarding the potential for grout shrinkage, which could lead to the formation of preferential and by-passing pathways through the reducing tank grout, although this key technical issue is not a major focus of the teleconference call discussion. In addition to NRC staff's questions on the grout video, in the February 26, 2016, email forwarding NRC staff's video review questions, NRC staff requested a number of references to help complete its technical review. The list of references was updated and sent to DOE via e-mail on March 30, 2016, prior to the teleconference. DOE provided all *available* references to NRC prior to the May 17, 2016, teleconference (some references have not yet been completed and will be sent to NRC when they are available). The NRC indicated that the references were helpful in addressing NRC staff technical concerns particularly those references related to the change in slag grade (change from grade 100 to grade 120). The NRC will provide final review conclusions related to the change in slag grade and other technical issues related to tank grouting in a technical review report to be issued later this fiscal year. Review of both Tank 12H and 16H grouting operations and associated documentation will be documented in a single technical review report to increase efficiency in the technical review process. Any changes to the technical review findings necessary to accommodate the later schedule for completion of Tank 12H grout documentation will be made in a supplement to the technical review report at a later date.

The following is a summary of main discussion points during the teleconference:

Bleedwater Segregation

- The NRC initiated a line of questioning related to observation of bleedwater segregation during grouting operations and factors that may enhance the phenomena (e.g., grouting into standing water). Although DOE takes efforts to ensure that grout is not discharged into standing water that could lead to excessive bleedwater segregation, loss of strength and higher hydraulic conductivity grout (based on the results of RPT-5539-EG-0016), DOE indicated that tests run and reported in the grout drop test report, RPT-5539-EG-0016, are not expected to be representative of the real system. DOE only discharged seven cubic yards of grout in the test and in one case where "massive" bleedwater segregation was noted, DOE grouted into four inches of pooled water, which DOE stated is not typical of grouting operations at the tank farm facilities.
- DOE indicated that compressive strength testing required the use of specimens twice the diameter in height. With 2.75 inch diameter cores, DOE needed a core height greater than 5 inches, yet only had an approximately 5 inch thick sample closer to the edge of the test form. Therefore, DOE stated that the small quantity of grout poured into the test form influenced the testing results and may have biased the compressive strength tests low, particularly for the cores located at the outer diameter. For example,

the poor quality surface of the short core extracted from the outer diameter of the test form could not be removed prior to testing, and surface effects are expected to influence the test results.

- Although DOE indicated that grouting into standing water is generally not performed, the NRC staff raised technical concerns with accumulation of water in Tanks 5F and 6F that led to creation of a work order to remove standing water, and video observations of accumulated water in the tanks to varying extents. DOE indicated that sources of water in the tank and annuli include use of Slick Willie pump priming agent, which was historically discharged to the tank, groundwater in-leakage, bleed water segregation, flushing of cooling coils, and condensation associated with the ventilation system. DOE indicated that water that accumulated at the top of the tank under a Tank 5F/6F riser was incorporated or evaporated very rapidly (within about a day), and will confirm whether or not water was actually pumped from any of the Tank 5F/6F risers. Additionally, DOE thinks that it is the energy from the drop that causes mixing of the grout with water, when water is present, but that typically grout is not dropped into water but is dropped into grout. DOE thinks that grout moving away from the grout mounds below the risers towards lower points in the tank that may accumulate water, displaces the water, rather than mixes with the pooled water. DOE thinks that much of this water is eventually taken up in the grout or is evaporated during ventilation of the tanks which occurs throughout grouting operations. Although some bleedwater segregation and grout heterogeneity in the tank should be expected, DOE does not think that grout associated with ponded water at low points in the tank away from the grout mounds should necessarily be characterized as “low quality.” DOE expects differences in hydraulic conductivity to be less than an order of magnitude.
- DOE indicated that while higher discharge rates in the grout drop tests could have led to greater segregation, DOE did not think that the discharge rate would have a significant impact on the results reported in RPT-5539-EG-0016.
- DOE thinks grade 120 slag will produce less bleed water because it is more reactive, causing hydration reactions to initiate earlier and with faster kinetics.
- During Tank 16H grouting, DOE estimated 7 gallons/day x 25 days = 175 gallons of Slick Willie were added to Tank 16H. With respect to the annulus, DOE grouted 6 days and estimated, using the same logic, that approximately 42 gallons of Slick Willie were added to the annulus. NRC stated and DOE agreed that this is about 10 times less Slick Willie than was added to Tank 5F and Tank 6F. DOE confirmed that Slick Willie was used during Tank 18F/19F grouting.
- DOE indicated that probes were used to measure water levels during operations, and a camera is used to monitor water levels after the tanks are isolated and the probes are removed. DOE indicated that there was no water accumulation in the Tank 16H annulus, but they removed standing water from Tank 12H after the portable ventilation system, which forced unheated air through the annulus was shut off, and water was able to accumulate (otherwise the portable system was sufficient to keep water out). During

the time period of water accumulation in the Tank 12H annulus, DOE pumped air out of the annulus maintaining a negative pressure. DOE uses a dehumidification system in the primary. Tank 16H water accumulation observed at the beginning of grouting operations was related to cooling coil flushing. DOE indicated that it is working with SC DHEC to allow changes to the tank isolation/stabilization sequence which would allow DOE to keep the operational ventilation system in place during grouting operations.

- The NRC inquired whether DOE had any grouting constraints related to accumulation of water in the tanks. DOE indicated that it is a judgement call and is based on when they do work in the field. DOE indicated that they tried to measure the water level in Tank 12H, using what they described as “steel taping”. DOE took a measuring tape with a weight attached to the end of it, dropped the tape through the water, and used a camera to read the water level. DOE also has data on pumping volumes from Tank 12H. Therefore, two methods of estimating accumulated water are available.

Grout Mounding Below Risers

- Because the NRC is not convinced that grout mounding is attributable to high ambient temperatures alone, NRC inquired about DOE’s efforts to establish a causative relationship between grout mounding and ambient temperature. For example, DOE noted grout flowability issue days on Tank 16H grout status reports but it was not clear that the grout flowability issue days were correlated with high ambient temperatures. DOE indicated that grout flowability issue days (2 days) noted on the status reports were associated with the week at the end of July where mounding caused primary tank grouting work to slow down and two especially hot days around the beginning of August during equipment grouting. The last two grout flowability issue days were actually more related to heat impacts to workers who are more susceptible to heat during equipment grouting and less related to concerns regarding grout flowability. DOE has made no effort to correlate ambient temperatures and grout mounding. DOE agrees that grout discharge rates contribute to grout mounding. DOE also indicated that there are no constraints on grouting related to ambient temperatures.
- The NRC staff thinks that grout discharge rates influence the extent of mounding. DOE’s need to “slow roll” grout when an insufficient number of trucks are in rotation to keep the slick line from plugging, may exacerbate the mounding issue. Higher grout discharge rates will lead to more spreading and superior distribution of grout compared to slower grout discharge rates. When questioned by NRC, DOE indicated that it did not increase the pump discharge rate from that used during Tank 18F/19F grouting operations based on a DOE report recommendation. DOE said it had used the TK-70 pump for Tank 18F/19F grouting and will continue to use it in future tank grouting.
- DOE indicated that they have considered including contractual obligations with respect to the number of trucks in rotation during grouting operations; however, inclusion of this specification would lead to significantly higher costs. DOE attempts to work with the batch plant to schedule grouting during periods of time when it can supply a greater number of trucks to the effort.
- DOE noted that while they were short trucks during Tank 12H grouting, they did not have

the mounding issues they had when grouting Tank 16H. Likely several contributing factors such as temperature, discharge rates, and slick line length, contribute to mounding.

- Tremies were used in all tanks including Tank 12H. DOE does not anticipate dropping grout from the tank top directly into the tank with no tremie in the immediate future. Directional nozzles/tremies were only used in Tanks 5F/6F.
- NRC staff noted that to alleviate mounding, distribution pipe mobility within risers had been identified by DOE as an option for controlling placement of grout. When NRC asked DOE if they had ever exercised this option, and particularly for Tank 16H, DOE stated that this description pertained specifically to the potential use of directional nozzles, and not to where the tremie hung within the diameter of the active riser.
- NRC staff questioned the relevance of ambient temperatures when the tanks are located underground. DOE indicated that it does not measure temperature in the tanks as all of the equipment is removed prior to grouting but that ventilation exposes the tank to outside conditions.

Cooling Coil Grouting

- DOE clarified their strategy for flushing cooling coils. Historically, DOE flushed cooling coils well before grouting and flushed cooling coils just before grouting to establish liquid to liquid interface to minimize air entrainment. DOE has since determined that it is unnecessary to use three cooling coil volume flushes and flushed once early on and once prior to grouting in Tanks 16H and 12H. DOE also determined it is more efficient to flush just prior to grouting and listed this as a lesson learned that may be used in the future.
- Failed cooling coils are grouted shortly after an approximately 2 foot layer of grout is added to the primary to provide structural support.
- When NRC expressed concern with the timing of in-tact cooling coil grouting, after the primary had been nearly filled, and the potential for the grout to boil in the presence of the insulating tank grout, DOE indicated that there were no worker observations indicating potential boiling of grout in the cooling coils. Workers routinely work in the valve house with jobs related to installation, removal, and maintenance of the grout hoses, performing valve manipulations, etc. Workers have not observed increases in temperatures, etc., that might suggest excessive grout temperatures in the coils.
- DOE indicated that the Tank 16H Final Configuration Report would be completed within three weeks. DOE provided preliminary information on cooling coil grouting, and indicated that in Tank 16H the 5 failed coils were all grouted, and that 1 intact coil was known to be blocked prior to grouting, and approximately 70 percent of that coil was filled by grouting from both ends. Two other intact coils did not take the maximum amount of grout. DOE was less clear on specific details of the success of Tank 12H cooling coil grouting. Information on Tank 12H cooling coil grouting will be available in the Tank 12H Final Configuration Report when that report is complete.

Bulk Fill and Clean Cap Grout Performance

- The NRC inquired about the use of clean cap grout in Tank 16H to fill remaining void space at the top of the tank when significant mounding of grout occurred below grout delivery points. The NRC requested clarification regarding the actual specification that was used in Tank 16H (three specifications were provided in C-SPP-Z-00012 but it is unclear which of the three specifications was used), and specifically use of caustic in the formulation. The NRC also asked for clarification on the material “TEMPER” listed on one of two batch tickets for clean cap grout provided by DOE for Tank 16H. DOE indicated that caustic leads to faster dissolution, and greater reactivity, and therefore, would reduce flowability of the grout. DOE also indicated that Portland cement is more reactive than slag and introduction of finer grade slag would lead to earlier/faster reaction of the slag with the CaOH hydration products. Slag grade 100 was used in the clean cap grout used in Tank 16H.
- DOE was unable to definitively answer questions regarding the potential for differences in particle size or hydraulic conductivity, which may result in a capillary or permeability barrier in the tank between the grout pours of varying formulation or quality.

Cracking

- When questioned about cracks observed after the first day of annulus grouting in Tank 16H, DOE indicated that cracks were observed when the grout surface approached the top of the annulus due to drying out of the grout from the ventilation system. Cracks were also observed in the primary due to drying. DOE also associated cracks with “pour points” underneath risers (e.g., near pigs used to clean the slick lines, or near discarded tremies, or due to separation and settling of mounded grout as it cured).

Annulus Waste Stabilization

- The NRC indicated that it was unclear from review of the video that the waste in the annulus duct had been successfully stabilized with grout. The NRC inquired about the potential for grout to harden near register entry points before a sufficient quantity of grout was discharged into the annulus from outside the duct to fill the duct.
- In response to an NRC question regarding the number of registers in the duct, DOE indicated that the annulus duct had 16 rectangular registers, which are 14 inches x 6 inches in size, spaced 17 feet apart. A circumferential section of approximately 10-15 feet contained no duct.
- NRC asked DOE to provide additional supporting information on why it was confident that the ventilation duct had been filled. DOE indicated that there were a large number of openings in the duct to accept grout and it was able to observe grout entering and exiting the ventilation ducts in the Command Center. DOE’s strategy was to force grout to flow into larger diameter portion of the duct all the way up to the “pant legs” of vertical portion of the ventilation duct. Smaller diameter portions of the duct would fill with grout with two transitions to smaller diameter ducts: 18, 15, 12 inch diameter sections with the

largest diameter closest to the vertical inlet. A same small gap exists between the annulus floor and the bottom of each section of duct of different diameter (i.e., duct essentially rests on the annulus floor); therefore, as the duct transitions to smaller and smaller diameters away from the inlet, the center of the smaller diameter ductwork resides closer and closer to the floor of the annulus. Deterioration of the Tank 16H duct (e.g., corroded seams at the bottom of the duct) also created entry points into the duct that provided confidence that the duct had been filled.

- DOE clarified that regular tank fill grout was used to grout the Tank 16H duct. The majority of grout used in lift 6 was regular bulk fill (only 5-6 out of 31 trucks used clean cap grout at the end of the lift).
- When questioned about the change in strategy for filling the duct between Tank 16H and Tank 12H, DOE indicated that it did not see evidence of Tank 12H annulus duct deterioration and determined that they would grout the duct from the duct inlet in lieu of relying on grout entry from outside the duct through open registers and other openings. DOE also indicated that although it was worried about inlet ventilation duct collapse due to grouting the annulus before grouting this vertical section of the duct, they saw no evidence of this occurring in Tanks 5F and 6F. In an abundance of caution, DOE alternated grouting between the annulus and the vertical section of the duct for Tank 12H (although they did not do that for Tank 16H).
- DOE plans to fill the ventilation ducts for other H-Tank Farm tanks with significant annular inventories through the vertical inlet or “pants legs” of the duct in the future.

Shrinkage Testing

- The NRC staff expressed concern with representativeness of grout shrinkage tests based on differences in relative humidity between the tanks that use ventilation and the 100 percent humidity experimental conditions. In response to NRC’s inquiry, DOE indicated that the ventilation rates in the Tank 16H were approximately 24,000 cubic feet/hour, and 11,000 cubic feet/hour (measured) for the primary and annulus, respectively.
- In response to NRC’s question, DOE indicated that the Tank 16H bulk grout shrinkage testing report would be completed December and that the Tank 12H clean cap grout shrinkage testing report would be completed in June 2017. DOE clarified that use of clean cap grout in Tank 12H was listed as an alternative grout formulation, but that DOE did not have to use clean cap for Tank 12H. Still the shrinkage testing was paid for with Tank 12H funds. Tank 16H clean cap used grade 100 slag cement, not the grade 120 used in the clean cap grout shrinkage test. DOE used a water to cement ratio of 0.5 in Tank 16H clean cap grout; the clean cap grout shrinkage testing evaluated water to cement ratios of both 0.45 and 0.5.

A list of follow-up action items and list of follow-up questions from this May 17, 2016, teleconference is included below.

Follow-up Action Items from the May 17, 2016, teleconference:

1. DOE indicated that they did not measure the accumulated volume of water at the top of Tanks 5F/6F that led to creation of a work order to remove water from the tank top prior to grouting the risers. The NRC indicated that they seem to recall DOE reporting that about 12 inches of standing water was observed in one of the tank risers. DOE indicated that they may have pumped standing water out of one riser but they would need to go back and confirm the quantity of water pumped out of Tanks 5F/6F, if any.
2. DOE to provide follow-up information on how much water was pumped out of Tank 12H annulus and primary (DOE estimated about 1000 gallons was pumped out of the Tank 12H annulus).
3. DOE to provide information on the quantity of Slick Willie/water used in Tanks 18/19 as a pump priming agent and slick line lubricant (similar information was previously provided for Tanks 5F/6F but not for Tanks 18F/19F).
4. NRC to provide information from the literature that led to its question on the potential for bleedwater segregation based on slag grade (later indicated that it might be related to Portland cement substitution with various grades of slag).
5. DOE will provide the grout formulation used for clean cap grout in Tank 16H (3 formulations were provided in CSP-SPP-Z-00012 and it is not clear which was used). The design water to cement ratio listed on 2 batch tickets for clean cap grout was 0.5 (but two formulations had 0.5 in CSP-SPP-Z-00012). DOE will also look at the batch tickets for clean cap grout that were provided to NRC (042239 and 042345) and clarify differences between the two batch tickets (one included TEMPER in the mix and one did not). The NRC specifically asked if caustic was used in the formulation (DOE did not think caustic was added as that would speed up the hydration reactions and cause the cement to be less flowable) and to clarify what "TEMPER" is (TEMPER was listed on one of the batch tickets). DOE offered a description of "TEMPER" listed on one of the batch tickets but may have some additional follow-up information that they can provide to the NRC.
6. DOE to provide a figure illustrating the ventilation duct including riser locations, diameters, etc.

Follow-up list of questions from the May 17, 2016, teleconference

The NRC provided DOE with a list of requested references via email on February 26, 2016, and updated the list via e-mail on March 30, 2016. Most of these references were provided to the NRC 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. 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:

NRC requested the final specification for the clean cap grout as a follow-up action to the May 17, 2016, teleconference.

1. 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 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 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 them in the future?
2. Could DOE clarify why compressive strength measurements are not required for the clean cap grout?
3. Could DOE provide VSL-14R3330-1 that provides test results for clean cap grout mixed at varying water-to-premix ratios and adding NaOH solution (measures total bleed, reabsorption time, flowability, and uniformity).

NRC requested and DOE provided Work Order Nos. 01324150-64 and 01337683-33. However, key attachments were not provided.

4. Could DOE provide key attachments to the work orders? For example, attachments HTF-SKM-2014-00031 and HTF-SKM-2015-00021 to the work orders were not provided.

NRC requested references related to the change to and testing of Grade 120 slag.

5. Could DOE clarify if all testing of grade 120 slag is provided in VSL-15R3740-1 (DOE indicated that information is provided in SRR-CWDA-2015-00088 but testing results do not appear to be included). What testing, if any, has been completed for tank fill, equipment, cooling coil, and clean cap grout?

With regard to presence of standing water and water removal in Tank 12H,

6. SRR-LWE-2015-00048 indicates that DOE expected water levels in the annulus could be reduced to no more than 2 inches by the water removal system. DOE was also prepared to remove accumulated water from the annulus into decant totes after annulus grouting had begun. Could DOE clarify how much water remained in the Tank 12H annulus prior to grouting and if 2 inches represents the limit to how much water can be

removed by the water removal system (e.g., is the ventilation system used to remove additional water).

7. Could DOE clarify if there are any specifications with respect to how much water might remain in the primary or annulus prior to grouting?
8. Could DOE provide the following reference: Cozzi, A.D., and Pickenheim, B.R., "Impact of Pouring into Standing Water," Savannah River National Laboratory, September 2012. With regard to use of RECOVER,
9. Could DOE clarify why RECOVER dose was changed from 50 oz in Tanks 5F and 6F to either 30 oz or 60 oz in Tank 16H? Although a range is allowed to be used, it is unclear what necessitated the change.

Note: The following questions were emailed to DOE on February 26, 2016, following the February 2-3, 2016 onsite observation, and are the subject of this May 17, 2016, onsite observation.

Follow-up Questions for DOE Teleconference on Tank 16H Grouting Operations

The NRC staff identified three key technical issues during its review of DOE Savannah River Site Tank Farm Facility grouting documentation and video records. The majority of questions that follow are related to the following three issues:

- Mounding of grout that could lead to plugging of grout access points into the tank and make it difficult to fill remaining void space in the tank. Several questions are related to (i) the alternative grout formulation (i.e., clean cap grout) used to fill the remaining void space in Tank 16H and (ii) the primary mound-inducing mechanism(s) (e.g., grout discharge rates versus ambient temperatures). Mounding is risk-significant because it could make it difficult to fill void space at the top of the tank. Significant void space at the top of the tank and excessive use of clean cap grout to fill remaining void space could lead to enhanced infiltration and waste release, as well as structural instability. The NRC is in the process of evaluating of negative impacts associated with the use of clean cap grout including hydraulic conductivity, chemical properties, and compressive strength tests to ensure that the performance of clean cap grout is similar to the assumed performance of tank grout in DOE's performance assessment.
- Stabilization of waste in the Tank 16H annulus ventilation duct. Based on review of video records it is unclear if significant void space remains in the ventilation duct. Significant void space in the ventilation duct of Tank 16H is risk-significant because there is significant quantity of waste in the duct (a large fraction of the annular inventory resides in the duct and is generally more soluble than other waste). Incomplete grouting of the duct could lead to enhanced waste release.
- Endemic bleedwater segregation of tank grout, which may both cause and be exacerbated by the presence of aqueous ponds. Review of video records indicates a significant amount of bleedwater segregation. Additionally, grouting into an aqueous environment has been demonstrated in DOE testing to lead to excessive bleedwater segregation. Switching from Grade 100 to Grade 120 slag may also enhance segregation of fines from aggregate. Bleedwater segregation leads to poor quality grout that has higher porosity and hydraulic conductivity. Bleedwater segregation is risk-significant because it has the potential to lead to enhanced infiltration and waste release.

Comments on Grout Drop Testing Report RPT-5539-EG-0016

1. Could DOE provide grout drop testing video that documents the three tests performed? This question pertains to the statement in the grout drop test report (RPT-5539-EG-0016) "Record (still and video) the grout impact with the containment surface and subsequent spreading of the grout to the containment extremities, including any evidence of segregation effects."

2. The rates at which grout was pumped into the three grout drop test forms varied above and below the target range of 1.17 to 1.23 cubic yards per minute. Observations of grouting operation video supports a rough estimate of 1 yd³ per minute when grout is continuously discharged. What is the anticipated impact on test outcomes of placing grout at rates both above and below the targeted range? If the discharge rate into water had been faster (Test 2), would the observed bleedwater segregation have been further enhanced?
 - Test 1: The pumping rate was estimated to be 1.52 cubic yards per minute (no water).
 - Test 2: The pumping rate was estimated to be 0.80 cubic yards per minute (water).
 - Test 3B: The pumping rate was estimated to be 1.27 cubic yards per minute (no water).
3. Material property analyses were conducted of grout drop test samples removed from each monolith (Tests 1–3B) from positions located 1, 5, and 9 ft from the impact point (at the center of each mold). Could DOE comment on resulting evidence contained in the grout drop test report that compressive strength and hydraulic conductivity are functions of distance, typically exhibiting high quality properties nearest the drop point and lower quality properties further away (see Figs. 24–28, 30)? Does DOE expect similar heterogeneities in the grouted waste tanks?
4. The grout drop test report documented the effects of bleed water segregation in a sample removed from the monolith of Test 1 (Sample T1-9-O-1; see Page 44 and Fig. 32). During Test 1, grout was discharged by tremie into a dry mold, therefore this grout drop test case was most similar to current tank grouting operations when and where aqueous pools are not present. Based on video observation of tank grouting, bleed water segregation like this may be endemic to the tank grout mix in use (e.g., see summary of video observations found in the May 1, 2013, teleconference call meeting minutes, ML13127A291). When grout is discharged from a tremie into a ponded aqueous environment (Test 2; see Pages 20 & 44 and Fig. 33), the grout drop test results suggest that this endemic bleed water segregation is further enhanced and exacerbated. The grout drop test report described significant segregation of aggregate from fines, with aggregate remaining near the drop point and also stratifying at low levels due to gravitational effects, while fines and water were rapidly swept out to the tank perimeter. Please comment on the likelihood that the segregation of aggregate from fines observed in Samples T2-5-O-1 and T2-9-O-1 (Fig. 33) is representative of the segregation that occurs inside grouted waste tanks where excess water collects in aqueous pools at topographically low points.

These visual results and the aforementioned material property results suggest that efforts should be made to remove excess ponded water from the tank before, during, and after grouting operations whenever aqueous ponds are present, to ensure that only high-quality grout is placed into tanks and annuli. Video records of tank grouting operations indicate that aqueous ponds were commonly noted to form at low points in Tank 16-H during grouting operations, typically at the tank wall at locations far from the active riser. Tank grout that

hydrates and hardens in a subaqueous environment will likely be of low quality relative to that forming subaerially (e.g., may have higher permeability and higher porosity due to relatively high water-to-cement ratio). In contrast, high-quality grout was typically emplaced near the tank wall close to the active riser, probably due to relatively high elevations associated with mounding that would locally preclude ponding. Four risers were employed in round-robin style, suggesting a layered structure developed in the tank with high quality grout layered between low-quality grout associated with aqueous ponds. Could DOE please comment on this conceptual model of grout heterogeneity within Tank 16-H?

5. A cursory review of literature suggests switching from Grade 100 slag cement to finer grained Grade 120 may further enhance production of bleed water. Please discuss any evaluations or video observations during the ongoing Tank 12-H grouting operations that would confirm or refute the concern that using finer slag in the grout mix (Grade 120) may lead to more bleed water production than has been observed previously using Grade 100.
6. Could DOE discuss how the results of the grout drop test report are being considered in the grout delivery design for current and future grouting operations?

Comment on Thermal Conditions During Tank 16-H Grouting Operations

1. Could DOE clarify the dates of the four grout flowability issue days that were attributed to heat, which were noted on the SRS weekly status report for Tank 16-H grouting (“Grout Flowability Issues—heat impacts...” noted under “Grout Risk Tracking”). Two days in July and two days in August were noted as heat impact days. Daily maximum temperatures in nearby Augusta, Georgia, indicated there were two triple-degree days in June, two triple-degree days in July, but none in August or September. Were any specific grouting operation actions taken as a direct result of the high temperatures on those four dates?

Comments on Tank 16H and 12H Grouting Operations

1. Could DOE clarify the extent of groundwater in-leakage into Tanks 16-H and 12-H? How does DOE manage groundwater in-leakage during operations and after isolation of the tanks? Does DOE have information on accumulation and removal rates? For example, during the February 2016 onsite observation, DOE noted that grout Lifts 2 and 3 were delayed during Tank 12H grouting due to accumulated groundwater in the annulus of the tank, and that approximately 6 inches of ground water had accumulated in Tank 12H over 5 days.
2. Could DOE provide the *total* volume of water (used to lubricate slicklines/tremies) discharged into (i) the primary tank and (ii) the annulus of Tank 16-H? During the July 2015 onsite observation, DOE approximated that 6 to 7 gallons of water are used to lubricate the slicklines/tremies per grout day. Could DOE also clarify whether Slick Willie was used in Tanks 18-F and 19-F, and if so, the quantities used?

Could DOE clarify the source of standing water in the primary of Tank 16-H on the morning of June 2, 2015, before grouting commenced (e.g., residual liquid waste, ground water

in-leakage, lubrication water, etc.)?

Could DOE clarify if there were aqueous ponds of standing water near and at the top of the Tank 16H primary (as previously observed in Tanks 5F and 6F) when tank grout was being placed in Lift 5? If so, how did project personnel respond to the presence of such ponds?

Could DOE discuss the sources of ponded or excess water present in Tanks 18-F, 19-F, 5-F, 6-F, 16-H, and 12-H during grouting operations and what efforts DOE took to remove it? Could DOE discuss lessons learned from previous grouting operations with respect to limiting entry and removing excess water from tanks that can be applied during future grouting operations to maximize and homogenize the quality of grout placed throughout each tank?

3. In video footage reviewed to date, rapidly migrating dark water was commonly observed to exude from slowly flowing, light-colored grout lobes. Dark water emerged distinctly from the free surfaces of freshly flowing light-colored grout lobes: from their front edges, side edges, and top surfaces. Numerous examples of the aqueous separation phenomenon (or what is referred to as “bleedwater segregation”) were documented both in the primary and in the annulus by the video cameras. Camera operators seemed interested in this phenomenon, based on cameras that focused on and zoomed into such occurrences, and that focused on pools of water forming at tank edges. Does DOE agree that video evidence supports the finding that excess water was exuding from the bulk mass of flowing tank grout when it was being distributed throughout the tank, and that this exuded water increased the overall volume of water that collected in pools (i.e., increased the overall volume of water in pools beyond the quantity of lubrication water introduced in the tank)? If DOE does not agree, please provide DOE’s interpretation of these observations and a technical basis to support that interpretation.
4. An observation made during review of Tank 16-H grouting video was that many grout truckloads took longer to discharge than the approximate (and typical) 7 minutes, apparently due to temporary shut-downs or what DOE calls *slow rolling*¹. Allowing grout to flow only for one minute or two, followed by a temporary shutdown results in the premature halt of currently forming grout flow lobe(s) that would otherwise have continued to flow until they reached a barrier. If each truck would discharge continuously at an optimal rate, there would be less grout buildup around the discharge zone and grout would be more evenly distributed throughout the tank. Mounding may be exacerbated when grout discharge from a single truck starts, stops and restarts. Langton, Stefanko, and Hay (“Relationship Between Flowability and Tank Closure Grout Quality”, SRNL-STI-2012-00578) indicated that “increasing the delivery rate of grout into Tanks 5-F and 6-F by using a higher capacity concrete/grout pump will result in better grout spread/flow inside the tanks. While high temperatures may play a role in reducing the set time of grout, it has yet to be determined what the relative contributions of grout temperature and discontinuous grout discharge are with respect to the mounding issue.

¹ Slow rolling is a term used by DOE to describe the intentional intermittent flow of grout intended to maintain relatively fresh grout in the slickline, particularly on days when an insufficient number of grout trucks are in rotation.

On which days did DOE observe the most significant issues related to mounding? What were the outdoor air temperatures when significant mounding was observed? Has a maximum outdoor air temperature been established above which DOE thinks mounding may become an issue (i.e., are there constraints on grouting related to ambient temperatures)? Did more slow-rolling occur on days when significant mounding was observed? Is there a record available for review of the number of cement trucks that were in rotation on each grouting day?

Could DOE clarify (1) the capacity of the grout pumps used during grouting of Tanks 18-F and 19-F, and (2) if the capacity of the grout pumps increased during grouting of Tanks 5-F, 6-F, 16-H, and 12-H as a result of the recommendation in SRNL-STI-2012-00578, and if so what they increased to?

Please discuss the feasibility of establishing contractual obligations to have a minimum number of trucks in rotation during grouting operations (8 to 10 cement trucks *in rotation* were said to be optimal in the Tank 16H Grout Strategy; a grout delivery rate of 8 to 10 trucks *per hour* was said to be ideal in the Tank 12H Grout Strategy), and any other options available for optimizing the continuous placement of grout to the extent practicable.

5. Please discuss DOE's understanding of the potential for a capillary or permeability barrier to be present at the interface between tank grout and clean cap grout inside the primary and annulus of Tank 16H. This discussion would include consideration of the anticipated differences in pore size (including microfractures and separation gaps around aggregate) and hydraulic conductivity between the two materials.
6. Please clarify the strategy used to fill the Tank 16-H ventilation duct with grout from outside the duct that enters through open registers, which differs from the approach used to grout the ventilation ducts in other tanks. For example, while grout entered the duct through the open registers from outside the duct, grout was also pumped directly into the ventilation duct inlet for Tanks 5F, and 6F to grout the horizontal portion of the ventilation duct, and the same approach is planned for Tank 12H. The Closure Module suggests that the exhaust vent openings (or registers) could be used as openings to fill the ventilation duct with grout placed outside the duct, while the Grout Strategy document indicates that waste inside the duct may block the flow of grout. During the February 2016 onsite observation, DOE indicated that (1) degradation of the duct, and (2) the presence of waste in the duct factored into the decision to initially grout from outside the duct. Could DOE also clarify if the distance between registers/exhaust vent openings is constant? What is the distance(s) between registers and how many register openings are in the duct? Were other pathways for grout entry present in the duct in addition to the open registers (e.g., holes from degradation or sampling)? If so, were such openings relied on as grout entry points? Could DOE discuss the pros and cons of directly discharging grout into the ventilation duct inlet versus grouting from outside the ventilation duct? For the vertical inlet and exhaust risers (pantlegs) of the ventilation duct, at what point were they filled with grout, and were they filled with tank grout, clean cap grout, or some other more flowable grout?

During the February 2016 OOV and in the Tank 16H Closure Module, DOE suggested that a grout more flowable than tank grout (e.g., cooling coil grout) may be used to fill portions of the annulus such as the ventilation duct. Could DOE clarify if bulk fill grout or a more flowable grout was used to fill the ventilation duct in the Tank 16H annulus and if DOE has plans to use more flowable grout than bulk fill tank grout in the annuli of other tanks in the future? Could DOE confirm if all or part of Lift 6 in the Tank 16H annulus consisted of clean cap grout?

7. During review of annulus video, the NRC staff noted the presence of numerous cracks in grout placed beneath the West riser. This cracked grout had been placed via the West riser on June 11, 2015, and was inspected on the mornings of June 15 and 16, 2015, which is when the cracks were first noted. Although grout was placed via the East riser during operations that lasted approximately 1.5 hours on June 15, 2015, this fresh grout did not overflow the cracks located in proximity to West riser, thus, they remained viewable on June 16, 2015. Camera operators seemed interested in these cracks, based on cameras that focused on and zoomed-in to view them. The aperture of the cracks appears to be significant. Many of the cracks seem to be oriented radially, but one system of cracks is an echelon parallel to the inner wall rotating to radial. One crack is beneath a pig released on June 11, 2015. Other cracks were noted on either side of a tremie dropped onto the grout surface on June 11, 2015. Please comment on DOE's observations and interpretations of these and similar cracks. How often are such cracks noted to occur in the annulus of this and previously grouted tanks? Is the radial orientation of these cracks typical? Does DOE associate the development of these cracks with the presence of the horizontal portion of the ventilation duct below this surface? Does DOE associate the development of these cracks with the impacts of objects dropped onto it (i.e., pig, tremie, directional nozzle)? What is the likelihood that the surface tension of fresh grout that later overflowed these cracks would prohibit fresh grout from entering into and sealing the open cracks?
8. WSRC-STI-2008-00298 demonstrated that internally grouted piping surrounded by an insulating material underwent significant temperature rise during hydration. Vertical cooling coils are externally grouted at their base to provide physical support prior to internal placement of coil grout; likewise, low-lying horizontal cooling coils are externally grouted prior to internal placement of coil grout. The NRC staff previously raised the issue of the potential for coil grout to boil during hydration due to the additional insulation provided by external grout (March 2014 OOV and ML14342A784). Could DOE please discuss efforts taken to ensure that insulation provided by massive amounts of external tank grout surrounding the cooling coils does not result in boiling of coil grout during its hydration process and associated effects that would negatively impact the performance of cooling coil grout and adjacent tank grout?

Harbour et al. ("Closure of HLW Tanks—Formulation for a Cooling Coil Grout", WSRC-STI-2008-00172) recommended laboratory-scale investigations to determine the impact of operational variations such as temperature and mixing time on cooling coil grout properties. Were any such investigations performed, and if so, could DOE provide documentation of the results of the investigations?

9. For Tank 16H (and Tank 12H, if timely) please discuss the extent to which intact and failed cooling coil grouting was successful and whether there were coils that failed to take the anticipated amount of coil grout. Please provide specific details, including the number of coils, if any, for which coil grouting was not successful. Following unsuccessful grouting of five intact cooling coils in Tanks 5F and 6F, process changes (e.g., more flushing, addition of screens to capture debris and larger diameter line cleaning device) may have been implemented to mitigate similar failures. Please comment on any implemented process changes and discuss whether a backup grout addition line was one of the changes implemented. Could DOE provide related document(s) for review that describe the implemented process changes or indicate where detailed information like this is already available?
10. *The continuity of grout placement is particularly important when contaminated ducts are being filled.* Uninterrupted flow of grout is desirable to ensure that permanent porosity does not develop. Could DOE please discuss the potential for open voids to have formed inside the duct due to incomplete filling and/or blockage by grout that had begun to set during long lapse periods between active grouting of the duct or due to the presence of waste in the duct? As part of this discussion, could DOE please present the estimated volume of grout that the Tank 16-H annulus theoretically could receive in contrast with the actual volume of grout that it did receive? This should include information on the estimate of void volume in the duct versus the void volume in the annulus for that portion of Lift 2 when DOE attempted to fill the ventilation duct (i.e., grout volume received up to the point when grout covered the ventilation duct). See attachment 1 describing staff's observation of Tank 16H annulus ventilation duct grouting.
11. For tanks with significant duct inventories that are grouted in the future, could DOE please discuss the pros and cons of intentionally creating more duct openings to facilitate complete filling of the duct?
12. Please discuss results obtained from DOE's ASTM C157 tank grout shrinkage testing, which included tests of fully submerged samples and those that set up in ~100 percent relative humidity. Shrinkage may increase significantly as relative humidity decreases below 100 percent. Shrinkage in the tanks could be greater than implied by these test results due to ongoing ventilation, which would reduce relative humidity by an unknown amount. Could DOE provide the ventilation rate(s) used during (i) operations, (ii) preparation for grouting, and (iii) grouting? American Concrete Institute documents exist for modeling and calculating shrinkage, based on the specific characteristics of cementitious materials. Please address how DOE is extrapolating test results to in-tank conditions that are significantly different from those tested.
13. Please discuss if any changes have been implemented to improve grout volume estimates that would help ensure void space is fully grouted and to better understand remaining void space as recommended in ML14342A784.

14. Please summarize results of compressive strength tests performed on Tank 16-H test specimens.

15. Could DOE provide NRC with the following documents?

- C-SPP-F-00057. McCord, J.B. "Furnishing and Delivery of Cooling Coil Grout Dry Feeds." Revision 2. Aiken, South Carolina: Savannah River Remediation, LLC. July 2014.
- C-SPP-Z-00012. "Vault 4 Clean Cap Grout (Procurement Specification)." Revision 1. Aiken, South Carolina: Savannah River Remediation, LLC. March 2014.
- Documentation for the anticipated compressive strength of clean cap grout, if not already provided in another requested report.
- Tank 16-H Grout Placement work order
- Tank 12-H Grout Placement work order
- Tank 16-H Grouting Project Lessons Learned (if and when completed)
- Shrinkage test report (if and when completed)

16. February 2016 OOV *outstanding* follow-up action items related to grouting operations:

- DOE to provide Tank 16H Final Configuration report when completed
- DOE to confirm the date of the rejected Tank 6F load
- DOE to provide 5 accepted and rejected batch tickets for Tank 16H grouting

Completed action items include the following:

- DOE to provide grout documents unique to Tank 12H.
- DOE to provide unresolved waste management question evaluation (UWMQE) for use of clean cap grout in Tank 16.
- DOE to provide UWMQE associated with the slag grade 120.
- DOE to confirm the date(s) when clean cap grout was placed in the primary tank and annulus of Tank 16H. Video dated August 31, 2015, may document the placement of highly flowable clean cap grout days earlier than discussed in e-mail communication between NRC and DOE that occurred over the course of January 20–21, 2016.

Attachment 1 to Enclosure 4

During the early minutes of annulus grouting on June 11 (11:33 am+), the Western Riser camera pointed straight down rather than to where it could have observed grout directly entering nearby ventilation duct register(s). By the time the camera panned downstream (11:36 am), any nearby duct(s) were covered with grout and no longer visible. It is unknown the extent to which the ventilation duct is fully filled with grout.

At 12:18 pm, the Eastern Riser camera first glimpsed stagnant, non-flowing grout already at rest inside the duct via a register in its field of view. A few minutes later (12:21 pm), fresh grout was observed flowing inside the duct as viewed through this register. Upstream, the duct was not completely full of grout; flow in the duct was under open channel conditions, not conduit flow/plug flow conditions. By 12:23 pm, grout had ceased flowing through the duct. Subsequent truckloads of grout did not continue to fill the interior of the duct (e.g., still stagnant at 12:42 pm) in this location until, as head in the annulus increased, a fresh batch sent grout flowing *from above* down into the partially filled duct via the register observed by the Eastern Riser camera (1:00 pm). Grout had been immobile and setting up inside the partially filled duct for almost 40 minutes before fresh grout entered this part of the duct again, this time from above. This new batch of fresh grout pouring into the open register may or may not have expired (i.e., truck emptied or discharge ceased) before the partially filled duct became completely filled up to that register location. Because grout placed earlier had been flowing in the duct under open channel conditions, some of the fresh grout filling the register from above had to reverse course and flow backward in the duct to backfill the remaining empty porosity. If the truckload of grout expired while filling was ongoing, empty space may be preserved inside the duct away from the register opening because hardening grout had now been placed around this register opening on all sides; additional truckloads of grout would not necessarily have been able to overcome the inertia of the setting grout.

Meanwhile, on the other side of the Eastern Riser camera's field of view, it took until 12:52 pm for grout to be observed flowing *inside* the duct (as viewed from a register). The initial pulse of grout flowing inside the duct from this other direction stopped flowing by approximately 12:54 pm. Then, 14 minutes later at 1:08 pm, grout flowing in the annulus from the original direction overtopped this register opening and flowed into that part of the duct from above.