Keywords:
Sludge Batch 9, DWPF,
Tank 51, WAC Compliance

X-ESR-S-00294
Rev. 1

Evaluation of Sludge Batch 9 Qualification with ISDP Salt Batches 8 and 9 Compliance to DWPF Waste Acceptance Criteria

DISTRIBUTION:

J. K. Fortenberry, 766-H
R. E. Edwards, Jr., 766-H
B. E. Long, 704-S
M. A. Rios-Armstrong, 766-H
J. S. Contardi, 704-56H
R. T. McNew, 707-4E
J. M. Bricker, 766-H
H. B. Shah, 766-H
F. D. Vick, 210-S
P. D. Schneider, 210-S
F. M. Pennebaker, 773-42A
A. Samadi-Dezfouli, 704-27S
J. D. Townsend, 766-H
A. R. Shafer, 766-H
T. L. Fellinger, 766-H
M. M. Potvin, 704-27S
M. N. Borders, 704-56H
E. J. Freed, 704-S
D. J. Martin, 766-H
D. C. Bumgardner, 704-56H
C. B. Sherburne, 707-7E
J. P. Arnold, 707-3E
J. F. Iaukea, 704-S
K. M. Brotherton, 704-27S
T. A. Le, 766-H
D. E. Snyder, 707-3E
T. C. Baughman, 241-121H
A. G. Garrison, 241-121H
I. P. Amidon, 704-56H
E. A. Brass, 241-121H
H. P. Boyd, 707-7E
C. I. Aponte, 241-119H
D. Morgan, 704-56H
B. A. Gifford, 704-56H
J. P. Schwenker, 241-156H
J. M. Gillam, 766-H
J. J. Jordan, 707-4E
J. R. Cantrell, 704-S
J. W. Ray, 704-27S
L.C. Jamison 704-27S
DCC, 766-H

Prepared by

A. Samadi signing for J.J. Jordan per telecon
J .J. Jordan, Flowsheet Development & Facility Integration — Date: 8/15/16

Technical review by

A. Samadi
A. Samadi-Dezfouli, DWPF and Saltstone Facility Engineering — Date: 8/15/16

Design Verification method: Document Review

Celia I. Aponte
C. I. Aponte, MCU and Salt/Sludge Engineering — Date: 8/15/16

Design Verification method: Document Review

Approvals

Eric J. Freed
E. J. Freed, Manager, DWPF and Saltstone Facility Engineering — Date: 8-15-16

J. S. Contardi, Manager, Tank Farm Facility Engineering — Date: 8/15/2016

R E Edwards
R. E. Edwards, Manager, Nuclear Safety and Engineering Integration — Date: 8/15/2016

TABLE OF CONTENTS

1.0 PURPOSE

Prior to receipt of new material (i.e., salt or sludge) in the Defense Waste Processing Facility (DWPF), the material must be evaluated for acceptability. Acceptability of material for feed to DWPF is based upon demonstration that the material will meet requirements specified in the DWPF Waste Acceptance Criteria (WAC) [X-SD-G-00008]. The requirements include processing and safety limits and targets. This report was prepared to demonstrate compliance with the requirements listed in the DWPF WAC, and thus meets requirements specified in DWPF Technical Safety Requirements (TSR) Specific Administrative Control (SAC) 5.8.2.11 [S-TSR-S-00001], Waste Acceptance Criteria Program, which ensures that the composition of waste streams to be received into DWPF are within the Documented Safety Analysis (DSA) analyzed limits prior to transfer to the facility. This report also evaluates effluent material back to H Tank Farm in the DWPF recycle stream.

The purpose of this report is to document the acceptability of Sludge Batch 9 Tank 51 material coupled with Interim Salt Disposition Project (ISDP) Salt Batches 8 and 9 for processing at DWPF. The Sludge Batch 9 evaluation was coupled with both Salt Batches 8 and 9 because the transition from Salt Batch 8 to Salt Batch 9 is fluid. Currently, Salt Batch 9 has been transferred to Tank 49 to feed ARP/MCU, but Salt Batch 8 material is still present in the processes. This evaluation also serves to implement requirements in the Tank Farm to DWPF Waste Compliance Plan (WCP) [X-WCP-H-00019].

2.0 BACKGROUND AND SUMMARY

Sludge Batch 9 will consist of the heel in Tank 40 (Sludge Batch 8 material) and the material compiled in Tank 51. Tank 51 received sludge from Bulk Oxalic Acid (BOA) cleaning in Tank 12 and from Tank 13 and Tank 22 sludge. In addition, Sodium Reactor Experiment (SRE) material from H Canyon was transferred into Tank 51 to be processed as part of Sludge Batch 9.

A qualification sample was pulled from Tank 51 on July 23, 2015, and transported to the Savannah River National Laboratory (SRNL). After sampling, the material in Tank 51 was washed several times using inhibited water and well water to remove the soluble salts from the sludge slurry. Since the qualification sample was pulled before field washing started, SRNL washed the qualification sample to the desired endpoint in the Shielded Cells Facility. SRNL then analyzed the SRNL-washed qualification sample as requested in the Technical Task Request (TTR) [U-TTR-S-00009] and Task Technical and Quality Assurance Plan (TTQAP) [SRNL-RP-2015-00120] for Sludge Batch 9.

ISDP consists of two processes that have been developed to remove strontium, actinides, and cesium from alkaline waste: the Actinide Removal Process (ARP) and the Modular Caustic-Side Solvent Extraction Unit (MCU). The ARP process involves two strike tanks where Monosodium Titanate (MST) can be added if needed to the salt solution in order to remove the majority of the soluble strontium and actinides. The MST/salt solution is transferred to 512-S for filtration. Two streams are generated as a result of filtration: MST/sludge solids slurry and a Clarified Salt Solution (CSS). The MST/sludge solids slurry is accumulated and concentrated over multiple batches. The concentrated solids are then washed to remove sodium and transferred to DWPF.

The CSS is transferred to MCU where it is processed through a solvent extraction process. The byproducts of MCU are a cesium-laden boric acid solution called Strip Effluent (SE) and a Decontaminated Salt Solution (DSS). The SE is transferred to DWPF; the DSS is transferred to the Saltstone Production Facility (SPF). All salt batches processed to date have been struck with MST even though the SPF WAC limits for strontium and actinides have been met without the need to strike with MST. Current plans are to only perform the MST strike if the salt batch does not meet requirements in the SPF WAC. A demonstration with no MST is ongoing during processing of Salt Batch 8 with Sludge Batch 8.

In this report, the sludge contribution is evaluated using the Sludge Batch 9 Tank 51 qualification sample (referred to as "Sludge Batch 9").

"The sludge batch qualification work is typically performed on the qualification tank (e.g. Tank 51) prior to blending with the DWPF feed tank (Tank 40). For the functional requirements discussed above, if the WAC limits have been met on the sample from the qualification tank and this material is then transferred to the feed tank (which was qualified in the last sludge batch qualification work), the blend of the two materials will also meet all the WAC requirements" [WSRC-SA-6, Ch. 11].

Qualification work conducted at SRNL was performed on a blend of the SRNL-washed Tank 51 qualification sample and the Sludge Batch 8 Waste Acceptance Product Specification (WAPS) sample pulled from Tank 40. The samples were blended at a ratio of 44% Tank 51 to 56% Tank 40 on an insoluble solids basis.

The salt contribution is evaluated by taking advantage of the most recent information on Salt Batches 8 and 9 and utilizing compositional data from the final salt batch qualification reports; where applicable, analysis obtained directly from the facility (samples retrieved from the Precipitate Reactor Feed Tank [PRFT] at DWPF) is used. These compositional analyses are coupled with bounding flow rates for salt processing [X-CLC-S-00113]. Deviation from this strategy, if required, will be described separately in the applicable section.

From this evaluation of Sludge Batch 9 analytical results, it is determined that all WAC criteria regarding the DWPF receipt of the new sludge material coupled with ARP/MCU waste material have been met.

3.0 DISCUSSION OF RESULTS

512-S is used to filter MST and sludge solids for further processing in DWPF. Typically salt solutions are low in sludge solids based on settling of salt batches prior to transfer to Tank 49. Since 512-S is used for filtering only, any feed that is sent to 512-S must also meet the requirements of the downstream facilities. Meeting the requirements listed in the 512-S sections of the WAC ensures that feed sent through 512-S meets the DWPF waste acceptance requirements.

MST/sludge solids from ARP and SE from MCU are transferred to DWPF for processing. These waste streams are added to Tank 40 sludge in the Sludge Receipt and Adjustment Tank (SRAT).

Compliance with the DWPF WAC is being evaluated using Tank 51 material coupled with ARP/MCU material from Salt Batches 8 and 9.

The following assumptions were applied to the analytical data: (1) if only a detection limit was reported, the detection limit was used as the actual value and analytical uncertainty is not applied; (2) for actual measured values, the average was reported by SRNL and credited in calculations and comparisons except where noted; (3) if analytical uncertainty is required by the WAC to demonstrate compliance, the average plus two standard deviations (in the most conservative direction) are used unless the analytical result is used in the denominator, then the average was utilized; and (4) Laboratory analysis from the PRFT is used where appropriate.

X-SD-G-00008 applies to transfers made to 512-S and to DWPF. There are specific requirements for transfers into 512-S (Section 5.3 of the WAC) and for transfers into DWPF (Section 5.4 of the WAC); all of the WAC criteria listed in Section 5.3 and 5.4 are evaluated in this section. The Tank Farm 2H enrichment criteria are evaluated in Section 3.3 of this report.

3.1 Compliance with 512-S WAC

The 512-S feed consists of MST/sludge solids from ARP which are processed along with the sludge batch in DWPF. WAC compliance of coupled sludge processing in the DWPF must be demonstrated. WAC compliance of Salt Batch 8 material currently being transferred from Tank 49 to 512-S is documented in X-ESR-H-00739, X-ESR-H-00759, X-ESR-H-00763, X-ESR-H-00784, X-ESR-H-00806, X-ESR-H-00827, and X-ESR-H-00833. 512-S WAC compliance for Salt Batch 9 is demonstrated in X-ESR-H-00807 and X-ESR-H-00825. Compliance of this material is referenced in the sections regarding each of the 512-S WAC criteria (i.e., gamma shielding, inhalation dose potential, nuclear criticality safety, radiolytic hydrogen generation, organic concentration, and temperature).

3.2 Compliance with DWPF WAC

Compliance with the DWPF WAC will be demonstrated by evaluating Tank 51 material coupled with Salt Batches 8 and 9. In the following sections, each of the DWPF WAC criteria are addressed individually; input utilized for each of the criteria will also be discussed in these sections or accompanying attachments.

3.2.1 NO_x Emissions (DWPF WAC 5.4.1)

The estimated annual NO_x emissions from DWPF shall not exceed 103.52 tons/year.
Potential NO_x emissions for the batch were determined using the algorithm provided in X-SD-G-00008. The estimated NO_x emission for Tank 51 is 36.97 tons per year. Tank 51 emissions are 35.72% of the DWPF WAC target of 103.52 tons per year.

For Salt Batch 8, the NO_x emission for the ARP contribution was derived using PRFT sample results for the anions and the Tank 21 qualification sample results for the cations [SRNL-STI-2014-00561]. The NO_x emission was calculated to be 17.01 tons per year. The estimated NO_x

emission for Tank 51 material with the ARP contribution from Salt Batch 8 is 53.98 tons per year. This is 52.15% of the DWPF WAC target of 103.52 tons per year.

For Salt Batch 9, the NO_x emission for the ARP contribution was derived using PRFT sample results for the anions and the Tank 21 qualification sample results for the cations [SRNL-STI-2015-00622]. The NOx emission was calculated to be 16.24 tons per year. The calculated NO_x emission for Tank 51 material with the ARP contribution from Salt Batch 9 is 53.21 tons per year. This is 51.40% of the DWPF WAC target of 103.52 tons per year.

The MCU contribution to NO_x emission is expected to be negligible [X-SD-G-00008].

Projected NO_x emission calculations for Tank 51 material coupled with Salt Batch 8 or 9 can be found in Attachment 1.

3.2.2 Canister Heat Generation (DWPF WAC 5.4.2)

The heat generation per canister produced in the DWPF shall not exceed 792 watts/canister as calculated from the radionuclide content of the glass [X-SD-G-00008]. The projected canister heat generation from Tank 51 is 52.47 watts per canister, which is 6.63% of the WAC limit.

For Salt Batch 8, the contribution of MST/sludge solids to the canister heat generation is 57.79 watts per canister, while the contribution of SE to the canister heat generation is 122.70 watts per canister. The canister heat generation for Tank 51 material coupled with Salt Batch 8 is then 232.96 watts per canister. The calculated value is approximately 29.41% of the DWPF WAC limit of 792 watts/canister.

For Salt Batch 9, the contribution of MST/sludge solids to the canister heat generation is 53.67 watts per canister, while the contribution of SE to the canister heat generation is 140.56 watts per canister. The canister heat generation for Tank 51 material coupled with Salt Batch 9 is then 246.70 watts per canister. The calculated value is approximately 31.15% of the DWPF WAC limit of 792 watts/canister.

Calculations for canister heat generation can be found in Attachment 2.

3.2.3 Gamma Shielding (DWPF WAC 5.4.3)

The sludge to be transferred to DWPF shall not exceed specific gamma source strength values of 4070 mR/hr/gallon and 3.7 mR/hr/gram insoluble solids. Also, transfers of MCU SE are limited to 16.5 Ci/gallon for Cs-137. A list of radionuclides, which were previously determined to be all inclusive of the radionuclides that contribute to 1% or more of the total gamma dose in the sludge slurry, is used to show that the design basis for shielding is not exceeded. The radionuclides are Co-60, Ru-106, Sb-125, Cs-134, Cs-137, Ce-144, Eu-154, Eu-155, and Pu-238.

The reported μCi/g dried solids for each radionuclide from the washed Tank 51 sample analytical results have been multiplied by a conversion factor and the specific isotope gamma dose constant to obtain the contribution of each radionuclide. The computed gamma source strength values for the nine radionuclides are then summed together. In addition, the gamma source strengths were converted to a slurry gallon basis.

The calculated values for Tank 51 are 0.599 mR/hr/g insoluble solids and 381 mR/hr/gal slurry. Tank 51 represents 16.20% of the WAC limit of 3.7 mR/hr/g insoluble solids and 9.37% of the WAC limit of 4070 mR/hr/gallon.

The contribution from Cs-137 in Salt Batch 8 was determined to be 12.09 Ci/gallon, which corresponds to 73.29% of the limit.

The contribution from Cs-137 in Salt Batch 9 was determined to be 13.85 Ci/gallon, which corresponds to 83.96% of the limit.

MCU continues to conduct periodic sampling of the SE in order to monitor cesium concentration in accordance with the Tank Farm to DWPF WCP [X-WCP-H-00019].

Calculations for gamma shielding can be found in Attachment 3.

3.2.4 Neutron Shielding (DWPF WAC 5.4.4)

The total alpha curie per gram of solids value for the sludge feed to DWPF shall not exceed 1.5E-03 Ci/gram insoluble solids. The neutron production rate is related to the total amount of alpha emitters. The total alpha concentration in Tank 51 is 2.64E-04 Ci/g insoluble solids, which is 17.61% of the DWPF WAC limit.

The neutron production rate from the MST/sludge stream is insignificant compared to sludge based on the much lower alpha content and weight percent solids of MST/sludge solids.

Calculations for neutron shielding are shown in Attachment 4.

3.2.5 Inhalation Dose Potential (DWPF WAC 5.4.5)

The inhalation dose potential (IDP) for the sludge stream to be transferred to DWPF shall have a total rem/gallon value less than or equal to 8.0E+07 rem/gallon for the sludge stream accounting for analytical uncertainty and the sludge stream Cs-137 concentration is to be less than or equal to 1.34 Ci/gallon after applying analytical uncertainty. Also, Cs-137 concentration for strip effluent (SE) transfers is to be less than 16.5 Ci/gallon accounting for analytical uncertainty.

Two methods have been specified in the WAC for IDP calculation. The first method evaluates the dose by determining the total alpha and Sr-90 content of the sludge feed from Tank 51. The reported Ci/gallon values are multiplied by the dose conversion factors to obtain a final rem per gallon value. For total alpha, the dose conversion factor is the conversion factor for Pu-238. The rem per gallon values for total alpha and Sr-90 are then summed and compared to the WAC limit.

The second method compares the eleven major inhalation dose radionuclides in the Tank 51 feed. These radionuclides are Sr-90, Ru-106, Cs-137, Ce-144, Pm-147, Pu-238, Pu-239, Pu-240, Pu-241, Am-241, and Cm-244. Similar to the first method, rem per gallon values are calculated for each radionuclide and then summed together. The rem per gallon value is then compared to the WAC limit.

The first method results in an IDP of 2.98E+07 rem/gallon for Tank 51 material, which is 37.20% of the DWPF WAC limit. The second method results in an IDP of 3.01E+07 rem/gallon for Tank 51, which is 37.59% of the WAC. Both methods of calculation show compliance with the DWPF WAC limit for total IDP.

The Cs-137 concentration in the sludge stream is 1.02E+00 Ci/gallon for Tank 51. The concentration is 76.12% of the DWPF WAC limit of 1.34 Ci/gallon.

The Cs-137 concentration shall be less than or equal to 16.5 Ci/gallon for SE transfers. The concentration of 12.63 Ci/gallon for Salt Batch 8 is 76.55% of the WAC limit. The concentration of 13.93 Ci/gallon for Salt Batch 9 is 84.42% of the WAC limit.

Calculations for IDP are included in Attachment 5.

3.2.6 Nuclear Criticality Safety (DWPF WAC 5.4.6)

The nuclear criticality criteria for the DWPF facility will be met as long as sludge transfers from the Tank Farm meet four requirements, and the ARP/MCU process meets the requirement for the Nuclear Criticality Safety Evaluation (NCSE) (which has already been addressed as part of Section 3.1 and is evaluated by documents X-ESR-H-00739 and X-ESR-H-00807).

Four limits must be satisfied by the sludge feed in order to comply with this requirement.

1. The Pu-240 concentration shall exceed the Pu-241 concentration accounting for analytical uncertainty. For Tank 51, the concentration of PU-240 exceeds the Pu-241 concentration. It should be noted that for conservatism, the Pu-240 Wt% - 2 Standard Deviations was used while the Pu-241 Wt% + 2 Standard Deviations was used.
2. The overall Fe to Equivalent Pu-239 weight ratio shall be greater than or equal to 160:1 accounting for analytical uncertainty and only Fe from the Tank Farm material shall be included in the calculation of the ratio. The Tank 51 ratio is 444:1. Again, for maximum conservatism, the Wt%- 2 standard deviations was used.
3. The Equivalent Pu-239 concentration shall be $\leq$ 0.59 g/gallon if non-Tank Farm Plutonium is included in the sludge batch. Equivalent Pu-239 in Tank 51 is 0.0658 g/gallon.
4. The Equivalent U-235 enrichment in sludge shall be $\leq$ 0.93 Wt% or $\leq$ 5 Wt% with a Mn:U-$235_{(eqSLU)}$ mass ratio of $\geq$ 70:1 accounting for analytical uncertainty. For Tank 51 material, the equivalent U-235 enrichment is 1.47 Wt%. Because the U-235 enrichment Wt% was greater than the first criterion, the mass contribution of Manganese in the slurry was calculated and evaluated in comparison to the slurry mass contribution of U-$235_{(eqSLU)}$. Mn:U-$235_{(eqSLU)}$ mass ratio is 121:1.

Calculations for nuclear criticality safety are included in Attachment 6.

3.2.7 Glass Solubility (DWPF WAC 5.4.7)

The concentration of the elements shown below shall not be exceeded.

Species	Weight Percent in Glass
TiO_2	2.00
Cr_2O_3	0.30
PO_4	3.00 [SAC]
NaF	1.00 [SAC]
NaCl	1.00 [SAC]
Cu	0.50
SO_4	0.65 [SAC]

The maximum waste solubility of certain components is vital to the longevity and efficacy of DWPF melter operations. If the concentrations listed above are exceeded, secondary glass phases or salt layers may be formed. Analytical uncertainty will be accounted for only when demonstrating compliance with the phosphate limit [X-SD-G-00008].

The PRFT volume capable of being transferred per SRAT batch was derived using Product Composition Control System (PCCS) case studies at varying PRFT volumes and the waste loading range of 28%-40%. From a glass solubility standpoint, the Tank 51 material meets PCCS criteria for waste loadings between 28%-40% at 10,500 gallons of sludge coupled with a PRFT volume of 5,300 gallons.

The sulfate limit is reevaluated during each sludge batch qualification due to its dependence on glass composition. Per SRNL-L3100-2016-00044, the sulfate limit of 0.65 weight percent is still valid for Sludge Batch 9 and the limit remains unchanged.

Sludge Batch 8 WAPS results show a higher sulfate weight percent than the Sludge Batch 9 Tank 51 qualification sample. Hence, in order to maintain conservatism following the transfer of Tank 51 material to Tank 40, the maximum allowable PRFT volume to be added to each SRAT batch should be limited to 4,860 gallons [X-ESR-H-00807].

Refer to Attachment 7 for calculations.

Table 1- DWPF WAC analysis of Sludge Batch 9 Coupled Operations at 40% Waste Loading (10,500 gal Sludge) and 5,300 gallons of PRFT

Species @ 40% Waste Loading	Wt% WAC Limit (%)	Sludge Only Wt% (%)	Coupled Wt% (%)	Sludge Only % of WAC Limit (%)	Coupled % of WAC Limit (%)
TiO_2	2	0.028	**0.687**	1.39	34.37
Cr_2O_3	0.3	0.090	**0.078**	29.96	26.10
PO_4	3	0.376	**0.388**	12.55	12.94
NaF	1	0.113	**0.215**	11.32	21.52
NaCl	1	0.084	**0.160**	8.45	16.05
Cu	0.5	0.021	**0.018**	4.22	3.68
SO_4	0.65	0.270	**0.353**	41.57	54.29

3.2.8 Corrosive Species (DWPF WAC 5.4.8)

The SO_4 concentration in washed sludge shall not exceed 0.058M slurry and the Hg concentration shall not exceed 21 g/L slurry [X-SD-G-00008]. The sludge only sulfate concentration is calculated to be 0.012 M while the sulfate concentration for PRFT coupled operations is calculated to be 0.019 M. Sludge only concentration is 21.33 % of the WAC while the coupled concentration is 31.98% of the WAC limit. For sulfate concentration, the coupled concentration evaluation is not salt batch specific.

The sludge only mercury concentration is derived from the reported weight percent value of the qualification sample memo [SRNL-STI-2015-00693]. The mercury concentration is 7.03 g/L and 33.48% of the WAC limit.

The Salt Batch 9 total mercury concentration used in the evaluation of the Sludge Batch 9 coupled operations total mercury concentration is 0.0628 g/L where Sludge Batch 9 refers to Tank 51 material.

The Coupled Sludge/PRFT mercury concentration with a PRFT volume of 5,300 gallons is calculated to be 18.9 g/L and 90.08 % of the WAC limit. A conservative ARP concentration factor of 375 is incorporated into the calculation based on methodology described in N-ESR-S-00004 to account for concentration due to filtration in 512-S. The concentration factor is Salt Batch specific and the calculation is illustrated in Attachment 1 of X-ESR-H-00807.

The Salt Batch 8 total mercury concentration used in the evaluation of the Sludge Batch 9 total mercury concentration is 0.129 g/L [SRNL-STI-2014-00561]. The higher mercury concentration limits the amount of PRFT that can be incorporated into each SRAT batch. The higher mercury concentration and larger ARP concentration factor of 377.1 for Salt Batch 8 constrains the PRFT volume to 3,000 gallons. The Coupled Sludge/PRFT mercury concentration with 3,000 gallons of PRFT material is 20.93 g/L and 99.66 % of the WAC.

Further discussion on the degree of conservatism that is built into the corrosive species calculation and the calculations are found in Attachment 8.

3.2.9 Sludge Solids Content (DWPF WAC 5.4.9)

The sludge feed sent to DWPF has a target range of 12-19 Wt% dry total solids. The Tank 51 weight percent dry total solids was determined to be 19.59 Wt% for the qualification sample [SRNL-STI-2016-00026].

The confirmatory sample shows the weight percent dry total solids was determined to be 12.9% after washing in Tank 51 [SRNL-L3100-2015-00195]. This meets the WAC target.

DWPF Facility Engineering will perform calculations on each SRAT and Slurry Mix Evaporator (SME) batch to ensure the product is consistent with the design basis. Therefore, the target weight percent of 12-19 will be monitored on a SRAT batch basis.

3.2.10 Glass Quality and Processability (DWPF WAC 5.4.10)

SRNL verified the quality and processability of a projected blend of Tank 40 for Sludge Batch 9 (In this section, Sludge Batch 9 refers to a blend of Tank 51 and Tank 40 material). The washed qualification sample was processed at SRNL to current waste processing practices at DWPF. A glass variability study was performed for Sludge Batch 9 by Vitreous State Laboratory (VSL) prior to vitrifying the glass at SRNL [VSL-16R3370-1]. The study demonstrated applicability of the current durability models to the Sludge Batch 9 composition region of interest.

Similar to Sludge Batch 8, it was challenging for the SRNL frit development team to identify candidate frits for Sludge Batch 9 based on the elevated sodium content in the sludge projections from washing and additions from ARP. In order to compensate for the elevated sodium levels in the sludge and ARP streams, the available sodium content for the frit must be reduced to keep the total alkali content of the glass waste form below a critical value so that PCCS durability related constraints are not challenged [SRNL-L3100-2015-00155].

Frit 803 was the recommended frit to use for Sludge Batch 9 processing [SRNL-L3100-2016-00010] and was used to make glass in the Shielded Cells based on the SRNL recommendation for qualification [SRNL-L3100-2015-00155]. The targeted waste loading was 36 weight percent sludge oxides [SRNL-L3100-2016-00099].

Leach rates were measured using the standard Product Consistency Test (PCT-ASTM 2002) as required by the DWPF Glass Product Control Program (GPCP) [WSRC-IM-91-116, WSRC-STI-2006-00014] and met the durability standards by a wide margin. The other quality and processability limits were met as seen in the table below [SRNL-L3100-2016-00099].

Table 2- Comparison of DWPF Glass Quality and Processability

Attribute	Limit	Value	Evaluation
Boron Leach Rate	≤ 16.70 g/L	0.93	Passes
Lithium Leach Rate	≤ 9.57 g/L	0.93	Passes
Sodium Leach Rate	≤ 13.35 g/L	0.91	Passes
Liquidus Temperature -	≤1050° Celsius	846	Passes
High Viscosity	≤ 110 poise	69	Passes
Low Viscosity	≥ 20 poise	69	Passes
Homogeneity Constraint	$Al_2O_3 \geq 4$ Wt% **OR**	5.95	Passes
Homogeneity Constraint	$Al_2O_3 \geq 3$ Wt% **AND** $\sum M_2O < 19.3$ Wt% where $\sum M_2O = Na_2O + Li_2O + Cs_2O + K_2O$ Wt%	Not Required, Primary Constraint Met	Not Required
Nepheline (Mass) Ratio	$SiO_2 / (SiO_2 + Na_2O + Al_2O_3) > 0.62$	0.74	Passes

The impact of the ARP stream and the MCU strip effluent stream on glass quality and the DWPF operating window has been evaluated for Sludge Batch 9 [VSL-16R3370-1]. Further ARP/MCU impact was determined by running PCCS test cases at varying PRFT volumes to determine conditions at which the most efficacious composition of sludge and ARP material occurs.

3.2.11 H_2 Generation/N_2O Concentration (DWPF WAC 5.4.11)

The hydrogen generation rate in the SRAT shall not exceed 0.65 lb/hr for 6000 gallons of SRAT product and the SME shall not exceed 0.22 lb/hr for 6000 gallons of SME product accounting for analytical uncertainty. The nitrous oxide concentration in the SRAT vapor space shall not exceed 15 volume percent accounting for analytical uncertainty.

The criteria were met during Shielded Cells testing at SRNL for Sludge Batch 9 [SRNL-L3100-2016-00076, SRNL-L3100-2016-00088]. The SRAT cycle during the Shielded Cells run yielded a hydrogen generation rate of 0.063 lb/hr and a nitrous oxide concentration of 3.64 volume percent [SRNL-L3100-2016-00076]. The SME cycle during the Shielded Cells run yielded a hydrogen generation rate of 0.12 lb/hr [SRNL-L3100-2016-00088].

SRNL has performed a projected blend of Tank 40 Sludge Batch 9 SRAT/SME runs with the latest estimates of the ARP/MCU compositions (without entrained organics from MCU). The results showed no processing changes for Sludge Batch 9. Also, simulated DWPF runs with ARP/MCU additions did not negatively impact DWPF processing [SRNL-STI-2016-00281].

3.2.12 Radiolytic Hydrogen Generation (DWPF WAC 5.4.12)

The total radiolytic hydrogen generation rate (HGR) shall not exceed 8.95E-05 ft^3 H_2/hr/gal at 25 °C. The total hydrogen generation rate is based on the cumulative sum of a mixture of radionuclide hydrogen generation conversion factors multiplied by the radionuclide heat rate. The value of hydrogen generated is 7.08E-06 ft^3 H_2/hr-gallon for Tank 51, which is 7.91% of the WAC limit.

The contribution from Salt Batch 8 is 6.35E-07 ft^3 H_2/hr-gallon [X-ESR-H-00739]. The total generation coupled with Salt Batch 8 is 7.71E-06 ft^3 H_2/hr-gallon and is 8.62% of the DWPF WAC limit of 8.95E-05 ft^3/hr-gallon.

The contribution from Salt Batch 9 is 7.27E-07 ft^3 H_2/hr-gallon [X-ESR-H-00807]. The total generation coupled with Salt Batch 9 is 7.81E-06 ft^3 H_2/hr-gallon and is 8.72% of the DWPF WAC limit.

Refer to attachment 9 for calculations.

3.2.13 Organic Contribution (DWPF WAC 5.4.13)

Organic material present in sludge feed transferred to DWPF shall contribute less than 0.1% to the hydrogen LFL except for transfers from MCU.

Transfers of strip effluent from MCU shall be tracked and characterized by the sending facility prior to entering the DWPF Chemical Process Cell (CPC):

a) Transfers of strip effluent from MCU shall not exceed 87 mg/L Isopar L accounting for analytical uncertainty.
b) In the event of a process upset, transfers of strip effluent from MCU may be greater than 87 mg/L Isopar L but shall not exceed 600 mg/L Isopar L accounting for analytical uncertainty.
c) MCU may transfer a maximum of 1689 gallons of strip effluent prior to being characterized.
d) Transfers of strip effluent from MCU shall not result in a specific gravity exceeding 1.06 in the SEFT.

Based on Tank Farm operational history and sludge processing, the potential volatile organic content in the waste for DWPF sludge processing will not be a significant contributor to vapor space flammability [X-ESR-G-00016, X-CLC-H-00581, and X-ESR-H-00453]. The organic material is negligible for both Salt Batch 8 and Salt Batch 9, as shown in Section 3.1.5 of the Salt Batch 8 and 9 reports [X-ESR-H-00739, X-ESR-H-00807].

The criterion for Strip Effluent will be tracked and characterized by MCU prior to entering the DWPF CPC [X-WCP-H-00019].

3.2.14 pH (DWPF WAC 5.4.14)

Transfers from MCU must meet the following pH constraints:

a) Strip effluent with the BOBCalix-based solvent (based on a nominal 0.001 M nitric acid concentration and a bounding 0.006 M nitric acid concentration) shall have a pH ≥ 2 and ≤ 4 accounting for analytical uncertainty. NOTE: Compliance with the upper pH limit of 4 shall be shown by the sending facility prior to the strip effluent batch entering the DWPF CPC.
b) Strip effluent with the NGS solvent (based on a nominal 0.01 M boric acid concentration and a bounding 0.0125 M boric acid concentration) shall have a pH ≥ 2 and ≤ 11 accounting for analytical uncertainty. NOTE: Compliance with the upper pH limit of 11 shall be shown by the sending facility prior to the strip effluent batch entering the DWPF CPC.
c) The boric acid concentration for the Strip Effluent with NGS or a blend of the two solvents shall be ≤ 0.0125 M.
d) A full line volume water or SE flush shall be transferred through the Strip Effluent Transfer Lines within 2 weeks after Contactor Cleaning Solution (nominally 3 M HNO_3) is transferred.
e) The sodium concentration for the Strip Effluent with either the BOBCalix-based solvent, NGS, or a blend of the two solvents shall be ≤ 265 mg/L accounting for analytical uncertainty and shall be tracked and characterized by the sending facility prior to entering the DWPF CPC.

Each Strip Effluent Hold Tank (SEHT) transfer produced will be verified to ensure that the equivalent volume nearest to entering DWPF (physical 221-S building) has been characterized to have a pH concentration from ≥ 2 to ≤ 11 and a sodium concentration no greater than 265 mg/L accounting for analytical uncertainty [X-WCP-H-00019]. Chemical concentrations for nitric and boric acid are verified prior to chemicals entering the MCU process [X-WCP-H-00019]. The full line volume water or SE flush will be controlled by procedural measurement [X-WCP-H-00019].

3.2.15 Temperature (DWPF WAC 5.4.15)

Wastes entering the DWPF facilities shall meet the following temperature Limits:

a) Sludge transfers from Tank 40 shall be ≤ 45°C
b) Strip Effluent transfers from MCU shall be ≤ 40°C

The temperature limit for sludge transfers from Tank 40 will be met by direct measurement and process knowledge [X-WCP-H-00019]. The temperature limit for MCU strip effluent will be met by process control [X-WCP-H-00019].

3.2.16 Particle Size (DWPF WAC 5.4.16)

New product streams entering the DWPF facilities shall have a maximum particle size of 80 mesh sieve or equivalent. This criterion is for future non-sludge and non-salt streams (e.g., product stream from treatment of Tank 48 material) that may be transferred to DWPF for disposal.

3.2.17 Fissile Concentration in Glass (DWPF WAC 5.4.17)

The sum of the concentrations of ^{233}U, ^{235}U, ^{239}Pu, and ^{241}Pu shall not exceed 897 grams per cubic meter of glass. The Department of Energy required that DWPF control waste loading such that the total concentration of the specified radionuclides is less than 897 grams per cubic meter [MGR-10-037]. This limit was set to be consistent with the License Application for the Geological Repository at Yucca Mountain. The SRNL has developed a method by calculation that ensures that this criterion is met, allowing for uncertainties in the analytical measurements and the density of the glass.

The fissile glass concentration was evaluated by DWPF facility engineering based on the Tank 51 qualification sample results for initial Sludge Batch 9 processing until the WAPS sample results are received. The evaluation provides a fissile to iron mass ratio that can be used with the SME sample concentration for iron to determine the fissile mass of the batch. The fissile mass in the batch can then be used to determine the fissile concentration in the glass using the methodology of X-ESR-S-00280. The fissile concentration calculated is 759 g/m^3 and the fissile to iron mass ratio is 2.89E-03, which will not exceed the limit of 897 g/m^3 [X-ESR-S-00280]. The fissile content of the MST/SS stream is insignificant compared to the sludge stream.

3.3 Compliance with Tank Farm (TF) WAC [X-SD-G-00001]

These measures of compliance with the TF WAC are included to show batch specific compliance regarding transfers of Sludge Batch 9 material back to the Tank Farm via the Recycle Collection Tank (RCT). The remaining chemical characterization of the material is to be addressed with a revision to the WCP that is coupled with the Sludge Batch 9 evaluation report [X-WCP-H-00019].

3.3.1 Criticality Safety in 2H Evaporator System (TF WAC 11.6.1)

External transfers to HTF that may proceed directly into Tanks 43, 38, or 22 must meet the following conditions:

- ≤ 5.5 Wt% U-235 (eq) enrichment (DWPF must re-evaluate enrichment upon changing sludge batches)
- U-235 (eq) is to be calculated per the formula:
  U-235(eq) = U-235 +1.4*U-233 + 2.25*(Pu-239 + Pu-241)
  U (eq) = U + 2.25*(Pu-239 + Pu-241)
- The plutonium content of the fissionable elements in the waste transfers into the 2H Evaporator System shall not exceed 2 Wt% [X-SD-G-00001].

DWPF recycle waste is transferred to H Tank Farm. This material could contain sludge batch and/or salt batch material. U-235 (eq) enrichment and the ratio of plutonium to fissionable elements are calculated in Attachment 10.

The U-235 (eq) Wt% for the Tank 51 material was calculated to be 2.02 Wt% or 36.71% of the WAC Limit of 5.5 Wt%. The Pu (eq) Wt% ratio for the Tank 51 material was calculated to be 0.226 Wt% or 11.30% of the WAC Limit of 2.00%.

For Salt Batch 9, the U-235 (eq) Wt% was calculated to be 1.44 Wt% or 26.10% of the WAC Limit of 5.5 Wt%. The Pu (eq) Wt% for Salt Batch 9 was calculated to be 0.153 Wt% or 7.65% of the WAC Limit of 2.00 Wt%.

For Salt Batch 8, the U-235 (eq.) Wt% was calculated to be 1.02 Wt% or 18.63% of the WAC Limit of 5.5 Wt%. The Pu (eq.) Wt% for Salt Batch 8 was calculated to be 0.11 Wt% or 5.38% of the WAC Limit of 2.00 Wt%.

Since both salt batches and sludge batch meet these requirements, then either combination of salt batch and Tank 51 material will meet them. Therefore, the U-235 eq. enrichment and ratio of plutonium to fissionable elements limit is met.

Attachment 10 shows Sludge Batch 9 with the Salt Batch 8 and 9 calculations.

4.0 REFERENCES

CBU-PED-2004-00003, January 2004, "NO_x Emission Limit for DWPF Sludge Batch 3."

DOE/RW-0006, Rev. 13, October 2010, Integrated Data Base Report—1996: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics

MGR-10-037, April 2010, "Letter to J. W. French, S. D. Langston, Contract DE-AC09-09SR22505—Fissile Limits in Defense Waste Processing Facility Canister (Letter Spears to French, WDPD-10-20, dated February 4, 2010)."

N-CLC-S-00099, Rev. 0, March 2006, "Gamma Source Strength, Inhalation Dose Potential, Heat Rate and Hydrogen Generation Rate for DWPF Processing."

N-ESR-S-00004, Rev. 0, October 2, 2012, "Inhalation Dose Potential (IDP) Limit for 512-S MST/Sludge Solids."

S-CLC-S-00070, Rev. 8, May 2015, "Input Deck for use in DWPF Safety Analyses."

S-TSR-S-00001, Rev. 59, April 2016, "DWPF's Technical Safety Requirements."

SRNL-L3100-2015-00155, Rev. 0, October 2015, "Confirmation of Frit 803 for Sludge Batch 9."

SRNL-L3100-2015-00195, Rev. 0, November 2015, "Analytical Results of the Tank 51H Sludge Batch 9 Confirmation Samples (HTF-51-15-114)."

SRNL-L3100-2016-00010, Rev. 0, February 2016, "Reconfirmation of Frit 803 Based on the January 2016 Sludge Batch 9 Reprojection."

SRNL-L3100-2016-00044, Rev. 0, March 2016, "Recommendation for the Sludge Batch 9 Sulfate Solubility Limit."

SRNL-L3100-2016-00099, Rev. 0, July 2016, "Sludge Batch 9 Qualification- Summary of Results from Glass Analysis and Testing."

SRNL-RP-2015-00120, Rev. 1, May 2015, "Task Technical and Quality Assurance Plan for Sludge Batch 9 Qualification, Confirmatory, and Waste Acceptance Product Specification Samples."

SRNL-STI-2014-00561, Rev. 0, December 2014, "Sample Results from the Interim Salt Disposition Program Macrobatch 8 Tank 21H Qualification Samples."

SRNL-STI-2015-00622, Rev. 0, November 2015 "Sample Results from the Interim Salt Batch Disposition Program Macrobatch 9 Tank 21H Qualification Samples."

SRNL-STI-2015-00693, Rev. 0, January 2016, "Characterization of the SRNL-Washed Tank 51 Sludge Batch 9 Qualification Sample."

SRNL-STI-2016-00026, Rev. 0, Sludge Batch 9 (SB9) Acceptance Evaluation: Radionuclide Concentrations in Tank 51 SB9 Qualification Sample Prepared at SRNL."

SRNL-L3100-2016-00076, Rev. 1, June 2016, "Preliminary Results for Sludge Batch 9 Sludge Receipt and Adjustment Tank Run SC-17."

SRNL-L3100-2016-00088, Rev. 1, June 2016, "Sludge Batch 9 SME Offgas, Weight Percent Solids, Density, and SRAT and SME Rheology."

SRNL-STI-2016-00281, Rev. 0, August 2016, "Defense Waste Processing Facility Simulant Chemical Processing Cell Studies for Sludge Batch 9"

U-TTR-S-00009, Rev. 1, "Sludge Batch 9 Qualification, Confirmatory, and Waste Acceptance Product Specification Samples."

VSL-16R3370-1, Rev. 0, June 2016, "Sludge Batch 9 Variability Study with Frit 803."

WSRC-IM-91-116-6, Rev. 8, July 2016, "DWPF Glass Product Control Program (U)."

WSRC-SA-6, Rev. 34, "Final Safety Analysis Report Savannah River Site Defense Waste Processing Facility."

WSRC-STI-2006-00014, Rev. 0, June 2006, "The Nepheline Discriminator: Justification and DWPF PCCS Implementation Details."

X-CLC-H-00581, Rev. 3, December 2007, "Impact of CSSX Organic Carry-Over on Tank Farm Operation."

X-CLC-S-00113, Rev. 0, October 2004, "Actinide Removal Process Material Balance Calculation with Low Curie Salt Feed."

X-ESR-G-00016, Rev. 0, October 2006, "Estimated Impact of Tank Farm Organics on Flammability in the Vapor Spaces of DWPF Receipt Vessels."

X-ESR-H-00453, Rev. 0, December 2012, "Flammability Potential of Next Generation Solvent in the Tank Farm and Saltstone."

X-ESR-H-00739, Rev. 0, February 2015, "Evaluation of ISDP Batch 8 Qualification Compliance to 512-S, DWPF, Tank Farm, and Saltstone Waste Acceptance Criteria."

X-ESR-H-00759, Rev 0, June 2015, "Deviation to the Tank Farm WAC Downstream Facility Mercury Limit at Saltstone for Salt Batch 8 ARP/MCU Transfers to Tank 50."

X-ESR-H-00763, Rev. 0, June 2015, "Evaluation of ARP Filtration only Operations and Additional Mercury Requirements for the Saltstone WAC on the Qualification of ISDP Salt Batch 8"

X-ESR-H-00784, Rev. 0, September 2015, "Evaluation of Impacts to Salt Batch 8 Qualification due to Transfer Line Flush Inhibited Water Addition to Tank 49H."

X-ESR-H-00806, Rev. 0, December 2015, "Evaluation of WAC Changes to Support the Annual Documented Safety Analysis Update for DWPF, Tank Farm, and Saltstone on the Qualification of ISDP Salt Batch 8 and Sludge Batch 8."

X-ESR-H-00807, Rev 0. March 2016. "Evaluation of Sludge Batch 8 with ISDP Salt Batch 9 Qualification Compliance to 512-S, DWPF, Tank Farm, and Saltstone Waste Acceptance Criteria."

X-ESR-H-00825, Rev. 1, May 2016, "Evaluation of WAC Changes in Support of the Saltstone 2015 Documented Safety Analysis Update on the Qualification of ISDP Salt Batch 9 and Sludge Batch 8."

X-ESR-H-00827, Rev. 0, April 2016, "Tank 50 Material Balance Update Showing Saltstone WAC Compliance Through May 6, 2016."

X-ESR-H-00833, Rev. 0, May 2016, "Evaluation of Impacts to Salt Batch 8 Qualification due to Transfer Pump Flush Water Addition to Tank 49H."

X-ESR-S-00279, Rev. 1, May 2016, "Phase 2 Report- Mercury Behavior in the Defense Waste Processing Facility."

X-ESR-S-00280, Rev. 0, May 2016, "Control of Fissile Concentration in Sludge Batch 9 Glass."

X-SD-G-00001, Rev. 38, April 2016, "Waste Acceptance Criteria for Liquid Waste Transfers to the 241-F/H Tank Farms."

X-SD-G-00008, Rev. 21, August 2016, "Waste Acceptance Criteria for Sludge, ARP, and MCU Process Transfers to 512-S and DWPF."

X-WCP-H-00019, Rev. 21, August 2016, "Waste Compliance Plan for Tank Farm Transfers to DWPF (U)."

Attachment 1: NO_x Emissions (DWPF WAC 5.4.1)

The computational technique for sludge processing for total NO_x emission is described in the WAC [X-SD-G-00008]. The Tank 51 washed qualification sample reported the necessary analytes on a supernate basis [SRNL-STI-2015-00693]. Using the reported soluble and insoluble densities, the concentrations were subsequently converted to a slurry basis. All NO_x concentrations are moles per liter, slurry basis.

NO_x total

$$=19.1\ (0.70\ [OH^-]s + 1.40[CO_3^{=}]s + 1.86[NO_2^-]s + [NO_3^-]s + 0.84[Mn^{4+}]s + 0.70[Hg^{2+}]s)$$

	Analyte	Molar Mass g/mol	Wt %	M (Supernate Basis)	M (Slurry Basis)	N_T Coeff	NO_x Contribution
Slurry	**Base Eq**	---			1.32E+00	0.7	9.23E-01
Supernate	**$[OH^-]$**	---		2.47E-01	2.33E-01	0.7	---
Supernate	**$[CO_3^{-2}]$**			9.87E-02	9.32E-02	1.4	1.31E-01
Supernate	**$[NO_3^-]$**			1.38E-01	1.30E-01	1	1.30E-01
Supernate	**$[NO_2^-]$**			2.96E-01	2.80E-01	1.86	5.20E-01
Slurry	**$[Mn^{+4}]$**	5.49E+01	6.03E+00	---	2.47E-01	0.84	2.08E-01
Slurry	**$[Hg^{+2}]$**	2.01E+02	3.12E+00	---	3.50E-02	0.7	2.45E-02
						Total NO_x (M)	1.94E+00
						N_T (tons/yr)	36.97
						WAC Limit (tons/yr)	103.52
						% of WAC	35.72
						Salt Batch 9 Contribution (g/L)	86.71
						Salt Batch 9 NT (tons/year)	16.24

Data from SRNL-STI-2015-00693

Mn = 6.03 Wt% dry solids TS (Total Solids) = 19.6 Wt% IS (Insoluble Solids) = 14.6 Wt %
Hg = 3.12 Wt% dry solids Density (Slurry) = 1.15 g/mL Density (Supernate) = 1.04 g/mL

Convert Molarity from Supernate to Slurry Basis

- Assume 1 kg of slurry.

$$1\ \text{kg slurry} * \frac{14.6\ \text{kg Insoluble Solids}}{100\ \text{kg slurry}} = 0.146\ \text{kg Insoluble Solids}$$

1 kg slurry – 0.146 kg IS = 0.854 kg Soluble Solids (SS)

Supernate/Slurry Mass Ratio

$$\frac{0.854 \text{ kg SS}}{1 \text{ kg Slurry}} = 0.854$$

[OH.]

$$= 0.247\frac{\text{mol}}{\text{L}} * 17.008\frac{\text{g OH}}{1 \text{ mol}} * \frac{1 \text{ mL}}{1.04 \text{ g supernate}} * \frac{1\text{L}}{1000\text{mL}} * 0.854$$

$$= 3.42\text{E-03}\frac{\text{g OH} -}{\text{g slurry}}$$

$$= 3.42\text{E-03}\frac{\text{g OH} -}{\text{g slurry}} * 1.15\frac{\text{g}}{\text{mL}} * \frac{1000 \text{ mL}}{1\text{L}} * \frac{1 \text{ mol}}{17.008 \text{ g OH} -} = 0.233\frac{\text{mol}}{\text{L}} \text{ [OH]}$$

Per the DWPF WAC, the base equivalence is to be used to calculate the hydroxide contribution to the NO_x emissions. SRNL reported OH^- as free hydroxide. Therefore, the summation of the OH^-, $CO_3^=$, and NO_2^- is a conservative representation of the Base Equivalence on a slurry Basis.

Analyte	M (Slurry Basis)	Mass Contribution (g/L)	Total Base Eq (M)

$[OH^-]$	2.33E-01	3.97E+00	---
$[CO_3^{-2}]$	9.32E-02	5.59E+00	
$[NO_2^-]$	2.80E-01	1.29E+01	
Base Eq	---	2.24E+01	1.32E+00

Assuming 1 liter of slurry.

Mass Contribution of OH^-

$$\frac{0.233 \text{ mol OH}}{1\text{L slurry}} * \frac{17.008 \text{ g OH}}{1 \text{ mol}} = 3.97\frac{\text{g}}{\text{L}} \text{ OH}$$

Total Base Equivalence Concentration $[OH^-]$

$$\frac{22.4 \text{ g OH}}{1\text{L slurry}} * \frac{1 \text{ mol OH}}{17.008 \text{ g OH}} = 1.32\ M\ OH$$

Convert Wt% dry solids to Molarity in slurry

Mn (mol/L)

$$= \frac{6.03 \text{ g Mn}}{100 \text{ g Dried Solids}} * \frac{19.6 \text{ g Dried Solids}}{100 \text{ g slurry}} * 1.15\frac{\text{g slurry}}{\text{mL}} * \frac{1 \text{ mol Mn}}{54.94 \text{ g Mn}} * \frac{1000\text{mL}}{1\text{L}}$$

= 2.47E-01 M

NO_x total

=19.1(0.70 [1.32] + 1.40 [.0932] + 1.86[0.280] + [0.130] + 0.84[0.247] + 0.70[0.035])

= 36.97 tons/yr

The same approach, in principle, is used in determining the ARP NO_x concentration for each analyte. The total concentration of NO_x is derived by summing the contributing analytes shown. Nitrogen dioxide's molecular weight (46 g/mol) is used to convert the molarity to g/L.

NOx Contributor	Salt Batch 8 Result	Salt Batch 9 Result	Result (M)	Factor	NO_x Contribution (M)
Hydroxide*	---		9.08E-01	0.70	6.36E-01
Carbonate*	---		4.54E-01	1.40	6.36E-01
Nitrite*	---		8.77E-02	1.86	1.63E-01
Nitrate*	---		3.66E-01	1.00	3.66E-01
Manganese ion** (mg/L)	---	4.19E-01	2.86E-03	0.84	2.40E-03
Mercury ion** (mg/L)	---	6.28E+01	1.17E-01	0.70	8.22E-02
Manganese ion*** (mg/L)	8.00E-01	---	5.49E-03	0.84	4.61E-03
Mercury ion*** (mg/L)	1.29E+02	---	2.43E-01	0.70	1.70E-01
				Salt Batch 9 Total NO_x (M)	1.88
				Salt Batch 8 Total NO_x (M)	1.97
				Salt Batch 9 Total NO_x (g/L)	86.71
				Salt Batch 8 Total NO_x (g/L)	90.84

*Calculated using PRFT sample data in Attachment 11.

** Data from SRNL-STI-2015-00622. For Salt Batch 9, a conservative concentration factor of 375 (no sludge solids case) was determined using the methodology described in N-ESR-S-00004 for the 512-S MST/Sludge Solids in Attachment 1 of X-ESR-H-00807. This concentration factor is applied to the species that are concentrated during filtration in 512-S.

*** Data from SRNL-STI-2014-00561. For Salt Batch 8, a concentration factor of 377.1 was calculated in Attachment 1 of X-ESR-H-00739. This concentration factor is applied to the species that are concentrated during filtration in 512-S.

The results given in mg/L are converted to mole/L by dividing by 1000 mg/g and dividing by the molecular weight (g/mole).

The ARP contribution is determined by using total NO_x contribution multiplied by the feed from ARP to DWPF. The flowrate calculation of 0.0856 gal/min is found in Attachment 9 of X-ESR-H-00807.

Salt Batch 9 Mn [M]

$$= 0.419 \frac{\text{mg}}{\text{L}} * 375 * \frac{1 \text{ mol}}{54.94 \text{ g Mn}} * \frac{1\text{g}}{1000 \text{ mg}}$$

= 2.86E-03 M

Mn NO_x Contribution

= 2.86E-03M * 0.84

= 2.40E-03 M

Total NO_x Contribution (tons/year) = 86.71 g/L *3.785 L/gal * 0.0856 gal/min * 60 min/hr * 24 hrs/day * 365 days/ yr * lb/453.6 grams * ton/2000 lbs
= 16.24 tons/year

The Tank 51 material NO_x contribution is 36.97 tons/year.

The Total Salt Batch 9 NO_x contribution by ARP is 16.24 tons/year.
The Total Salt Batch 8 NO_x contribution by ARP is 17.01 tons/year.

Total Salt Batch 9 ARP + Tank 51 material NO_x contribution = 53.21 tons/year
Total Salt Batch 8 ARP + Tank 51 material NO_x contribution = 53.98 tons/year

DWPF WAC Limit = 103.52 tons/yr
Salt Batch 9 % of WAC Limit = 51.40 %
Salt Batch 8 % of WAC Limit = 52.15 %

Attachment 2: Canister Heat Generation (DWPF WAC 5.4.2)

The computational technique for sludge processing for canister heat generation is described in the WAC [X-SD-G-00008]. The concentrations are calculated on a Ci/lb, calcined solids basis.

Canister Heat Generation (W/canister) = 2200 (0.00670[Sr-90] + 0.0195[Ru-106] + 0.00474[Cs-137] + 0.00800[Ce-144] + 0.0286[U-233] + 0.0326[Pu-238] + 0.0302[Pu-239] + 0.0306[Pu-240] + 0.0328[Am-241] + 0.0344[Cm-244])

Tank 51 Material Canister Heat Generation						
Species	Activity (µCi/g)	Activity (Ci/g)	Activity on Total Solids Basis (Ci/lb)	Activity on Calcined Solids Basis (Ci/lb)	Canister Heat Generation Factors Coefficients (W/Ci)	Canister Heat Generation (W/lb)
Sr-90	4.56E+03	4.56E-03	2.07E+00	2.65E+00	0.0067	1.78E-02
Ru-106	1.20E-01	1.20E-07	5.44E-05	6.97E-05	0.0195	1.36E-06
Cs-137	1.13E+03	1.13E-03	5.13E-01	6.57E-01	0.00474	3.11E-03
Ce-144	3.70E-01	3.70E-07	1.68E-04	2.15E-04	0.008	1.72E-06
U-233	7.43E-02	7.43E-08	3.37E-05	4.32E-05	0.0286	1.23E-06
Pu-238	1.36E+02	1.36E-04	6.17E-02	7.90E-02	0.0326	2.58E-03
Pu-239	4.21E+00	4.21E-06	1.91E-03	2.45E-03	0.0302	7.39E-05
Pu-240	1.60E+00	1.60E-06	7.26E-04	9.30E-04	0.0306	2.84E-05
Am-241	1.16E+01	1.16E-05	5.26E-03	6.74E-03	0.0328	2.21E-04
Cm-244	4.06E+00	4.06E-06	1.84E-03	2.36E-03	0.0344	8.12E-05
Total Canister Heat Generation (W/lb)						2.39E-02
Tank 51 (W/Canister)						**52.47**
WAC Limit (W/Canister)						**792**
% of WAC Limit Sludge Only (%)						**6.63**

Data from SRNL-STI-2016-00026.

An example using Sr-90 is provided below.

Sr-90 Total Solids Wt %

$$4.56E3\frac{\mu Ci}{g} * \frac{1Ci}{1E6\mu Ci} * \frac{453.592\ g}{1\ lb} = 2.07\frac{Ci}{lb}$$

Total Solids to Calcine Solids Conversion Factor

$$\frac{19.59\text{ Wt \% Total Solids}}{15.3\text{ Wt \% Calcined Solids}} = 1.28$$

Sr-90 Canister Heat Generation Contribution (W/lb)

$$2.07\frac{\text{Ci}}{\text{lb}} * 1.28 * 0.0067\frac{\text{W}}{\text{Ci}} = 0.0178\frac{\text{W}}{\text{lb}}$$

Salt Batch 9 Canister Heat Generation ARP Contribution				
Species	Rad Concentration (pCi/mL)	Concentration (Ci/gal)	Canister Heat Generation Factors Coefficients (W/Ci)	Canister Heat Generation on Calcined Solids Basis (W/lb)
Sr-90	4.31E+05	1.63E-03	0.0067	9.53E-03
Ru-106	9.27E+01	3.51E-07	0.0195	5.96E-06
Cs-137**	2.44E+08	9.24E-01	0.00474	1.02E-02
Ce-144	1.56E+02	5.90E-07	0.008	4.12E-06
U-233	1.71E+01	6.47E-08	0.0286	1.61E-06
Pu-238	4.16E+04	1.57E-04	0.0326	4.48E-03
Pu-239	8.71E+02	3.30E-06	0.0302	8.68E-05
Pu-240	1.14E+03	4.31E-06	0.0306	1.15E-04
Am-241	3.46E+00	1.31E-08	0.0328	3.74E-07
Cm-244	1.94E+00	7.34E-09	0.0344	2.20E-07
Total Canister Heat Generation (W/lb)				**2.44E-02**
Canister Heat Generation (W/canister)				**53.67**

Data for calculations from SRNL-STI-2015-00622

**No concentration factor applied to Cs-137 per N-ESR-S-00004.

A conservative concentration factor of 375 (no sludge solids case) was determined and documented in Attachment 1 of X-ESR-H-00807. This is calculated using the methodology described in N-ESR-S-00004 for 512-S MST/sludge solids. This concentration factor is applied to the species that are concentrated during filtration in 512-S.

An example using Sr-90 concentration is provided below.

Salt Batch 9 Sr-90 Concentration (Ci/gal)

$$4.31\text{E+05}\frac{\text{pCi}}{\text{mL}} * \frac{1\text{Ci}}{1\text{E12 pCi}} * \frac{3{,}785\text{mL}}{1\text{ gal}} = 1.63\text{E-03}\frac{\text{Ci}}{\text{gal}}$$

To determine the total canister heat generation, the maximum volume of PRFT that can be added to each SRAT batch must be determined. The glass quality constraints are tested at various MST/SS additions to the SRAT. 5,300 gallons of PRFT was shown to meet the WAC Limits with Sludge Batch 9. An example of this conversion is shown below using this maximum PRFT to SRAT volume of 5,300 gallons with Sr-90:

ARP Calcine Mass Contribution (lbs)

$$5{,}300 \text{ gallons PRFT} * 1.055 \frac{\text{g}}{\text{mL}} * 3{,}785 \frac{\text{ml}}{\text{gal}} * \frac{4.89 \text{ g PRFT Calcined Solids}}{100 \text{ g PRFT}} * \frac{1 \text{ lb}}{453.592 \text{ g}}$$
$$= 2{,}280 \text{ lbs Calcine Mass}$$

-PRFT density and Wt% data are found in Attachment 11.

Salt Batch 9 Sr-90 Canister Heat Generation Contribution (W/lb)

$$1.63\text{E-}03 \frac{\text{Ci}}{\text{gal}} * 5{,}300 \text{ gal PRFT} * 375 \text{ Conc. Factor} * 0.0067 \frac{\text{W}}{\text{Ci}} * \frac{1}{2{,}280 \text{lbs Calcine Mass}}$$
$$= 9.53\text{E-}03 \frac{\text{W}}{\text{lb}}$$

Salt Batch 8 Canister Heat Generation ARP Contribution				
Species	Rad Concentration (pCi/mL)	Concentration (Ci/gal)	Canister Heat Generation Factors Coefficients (W/Ci)	Canister Heat Generation on Calcined Solids Basis (W/lb)
Sr-90	4.91E+05	1.86E-03	0.0067	1.09E-02
Ru-106	6.35E+01	2.40E-07	0.0195	4.11E-06
Cs-137*	2.13E+08	8.06E-01	0.00474	8.88E-03
Ce-144	1.36E+02	5.15E-07	0.008	3.61E-06
U-233	2.83E+01	1.07E-07	0.0286	2.69E-06
Pu-238	5.63E+04	2.13E-04	0.0326	6.09E-03
Pu-239	1.35E+03	5.11E-06	0.0302	1.35E-04
Pu-240	2.28E+03	8.63E-06	0.0306	2.32E-04
Am-241	5.85E+00	2.21E-08	0.0328	6.37E-07
Cm-244	1.99E+00	7.53E-09	0.0344	2.27E-07
Total Canister Heat Generation (W/lb)				**2.63E-02**
Canister Heat Generation (W/canister)				**57.79**

Data from SRNL-STI-2014-00561. For Salt Batch 8, a concentration factor of 377.1 was calculated in X-ESR-H-00739. *It was not applied to Cs-137 per N-ESR-S-00004.

Salt Batch 9 Canister Heat Generation MCU Contribution					
Species	Canister Heat Generation Coefficients (W/Ci)	Rad Concentration (pCi/mL)	Concentration (Ci/gal)	Maximum Rad Contribution per 15,000 gallons Strip Effluent (SE) (Ci)	Canister Heat Generation (W/lb)
Cs-137	0.00474	2.44E+08	9.24E-01	1.39E+04	6.39E-02
Canister Heat Generation (W/canister)					**140.56**

Salt Batch 8 Canister Heat Generation MCU Contribution					
Species	Canister Heat Generation Coefficients (W/Ci)	Rad Concentration (pCi/mL)	Concentration (Ci/gal)	Maximum Rad Contribution per 15,000 gallons Strip Effluent (SE) (Ci)	Canister Heat Generation (W/lb)
Cs-137	0.00474	2.13E+08	8.06E-01	1.21E+04	5.58E-02
Canister Heat Generation (W/canister)					**122.70**

- For the Salt Batch 9, to perform the MCU contribution of the Canister Heat generation evaluation, SRNL-STI-2015-00622 was used.
- Salt Batch 8 data is from SRNL-STI-2014-00561.
- For MCU, the Cs-137 concentration factor is limited to 15 [X-SD-G-00008].
- To obtain the maximum Curie contribution, the Cs-137 Ci/gallon value was multiplied by 15,000 gallons [S-CLC-S-00070]. This is currently the maximum allowable amount of strip effluent (SE) that can be added to one SRAT batch.

SRAT Calcine Solids (lb)

$$10{,}500 \text{ gallons SRAT} * 1.15 \frac{\text{g slurry}}{\text{mL}} * \frac{3{,}785 \text{ mL}}{1 \text{ gal}} * \frac{15.3 \text{ g Calcine Solids}}{100 \text{ g slurry}} * \frac{1 \text{ lb}}{453.592 \text{ g}}$$
$$= 15{,}416 \text{ lbs Calcine mass}$$

SRNL-STI-2015-00693 used for slurry density and Calcine solid Wt%.

Salt Batch 9 Cs-137 MCU Canister Heat Generation Contribution (W/lb)

$$0.924 \frac{\text{Ci}}{\text{gal}} * 15{,}000 \text{ gal SE} * 15 \text{ MCU Conc Factor} * 0.00474 \frac{\text{W}}{\text{Ci}} * \frac{1}{15{,}416 \text{ lbs SRAT Calcine Mass}}$$

$$= 0.0639 \text{ W/lb}$$

Salt Batch 9 Cs-137 Watts/canister

$$0.0639\frac{W}{lb} * 2200 \text{ Heat Generation Factor} = 140.56 \text{ Watts/canister}$$

Total Canister Heat Generation (sludge only)

Tank 51 Material	**52.47 W/canister**
WAC Limit	**792 W/canister**
Percent of Limit	**6.63%**

Total Canister Heat Generation with Salt Batch 9 components

Tank 51 Material	**52.47W/canister**
ARP	**53.67 W/canister**
MCU	**140.56 W/canister**
TOTAL	**246.70 W/canister**
WAC Limit	**792 W/canister**
Percent of Limit	**31.15%**

Total Canister Heat Generation with Salt Batch 8 components

Tank 51 Material	**52.47 W/canister**
ARP	**57.79 W/canister**
MCU	**122.70 W/canister**
TOTAL	**232.96W/canister**
WAC Limit	**792 W/canister**
Percent of Limit	**29.41%**

Attachment 3: Gamma Shielding (DWPF WAC 5.4.3)

Species	Radionuclide Concentration (µCi/g)	Radionuclide Concentration (µCi/gal)	Dose Constant (mR/hr/µCi)	Gamma Source Strength (mR/hr/gal)	Gamma Source Strength (mR/hr/g)
Co-60	3.23E-01	2.75E+02	1.37E-03	3.77E-01	4.43E-04
Ru-106	1.20E-01	1.10E+02	1.38E-04	1.52E-02	1.66E-05
Sb-125	5.10E-02	4.30E+01	3.80E-04	1.63E-02	1.94E-05
Cs-134	3.10E-01	2.60E+02	9.99E-04	2.60E-01	3.10E-04
Cs-137	1.13E+03	9.64E+05	3.82E-04	3.68E+02	4.32E-01
Ce-144	3.70E-01	3.10E+02	2.33E-05	7.22E-03	8.62E-06
Eu-154	4.84E+00	4.13E+03	7.56E-04	3.12E+00	3.66E-03
Eu-155	6.74E-01	5.75E+02	6.67E-05	3.84E-02	4.50E-05
Pu-238	1.36E+02	1.16E+05	7.90E-05	9.16E+00	1.07E-02
Total Gamma Source Strength (mR/hr/gal)				**3.81E+02**	
Total Gamma Source Strength (mR/hr/g)				**4.47E-01**	
WAC Limit (mR/hr/gal)				**4070**	
% of WAC Limit (%)				**9.37**	

Data from SRNL-STI-2016-00026

Wt % Insoluble (IS)	14.61
Wt% Total Solids (TS)	19.59
Ratio	1.34
Gamma Source Strength (IS) (mR/hr/g)	5.99E-01
WAC Limit (mR/hr/g)	**3.7**
% of WAC Limit	**16.20**

Data from SRNL-STI-2016-00026

Gamma Source Strength (mR/hr/g)

$$= (\text{mR/hr/g}) * \frac{\text{Wt\% TS}}{\text{Wt\% IS}}$$

The total Gamma Source Strength for insoluble solids is determined by the addition of Gamma Source Strength in Ci/g dried sludge multiplied by the ratio of total solids to insoluble solids.

= (19.59 / 14.61).
= 1.34

Gamma Source Strength

= 4.47E-01 mR/hr/g *1.34
= 5.99E-01 mR/hr/g insoluble solids

Salt Batch 8			
Species	Concentration (pCi/mL)	Concentration (Ci/gal)	Concentration with Concentration Factor (15) Applied (Ci/gal)
Cs-137	2.13E+08	8.06E-01	12.09
Salt Batch 9			
Cs-137	2.44E+08	9.24E-01	13.85

Salt Batch 8 Data from SRNL-2014-00561/Salt Batch 9 from SRNL-STI-2015-00622

Salt Batch 8 Cs-137 SE transfer Concentration (Ci/gallon)

= 15 * 8.06E-01 Ci/gal
= 12.09 Ci/gallon

Salt Batch 9 Cs-137 SE transfer Concentration (Ci/gallon)

= 15* 9.24E-01 Ci/gal
= 13.85 Ci/gallon

WAC Limit (Ci/gallon) = 16.5
Salt Batch 8 % of WAC Limit = 73.29%
Salt Batch 9 % of WAC Limit = 83.96%

Attachment 4: Neutron Shielding (DWPF WAC 5.4.4)

The total alpha concentration is reported by SRNL in SRNL-STI-2016-00026.

Wt% TS (Total Solids)	19.59
Wt% IS (Insoluble Solids)	14.61
Ratio	1.34
Total Alpha (TS) (Ci/g)	1.97E-04
Total Alpha (IS) (Ci/g)	**2.64E-04**
WAC Limit (Ci/g)	**1.50E-03**
% of WAC	**17.61**

SRNL-STI-2016-00026

The contribution from the sludge is the following:

Total Alpha

= 1.97E-04 Ci/g TS

Ratio of Total Solids (TS)/Insoluble Solids (IS)

$$\frac{19.59 \text{ Wt \% TS}}{14.61 \text{ Wt \% IS}} = 1.34$$

Ci/g insoluble solids

$$1.97\text{E-}04 \frac{\text{Ci}}{\text{g}} \text{TS} * 1.34 = 2.64\text{E-}04 \frac{\text{Ci}}{\text{g}} \text{IS}$$

Neutron Shielding = **2.64E-04 Ci/g insoluble solids**
WAC LIMIT = **1.50E-03 Ci/g insoluble solids**
Percent of Limit = **17.61%**

Attachment 5: Inhalation Dose Potential (DWPF WAC 5.4.5)

A) The Sludge Batch 9 contribution to the IDP WAC limit.

Method 1						
Species	Results (Ci/gal)	RSD (%)	Standard Dev (Ci/gal)	Results + 2 Standard Dev (Ci/gal)	Dose Conversion Factor (rem/Ci)	IDP (rem/gal)
Sr-90	3.89E+00	8	3.11E-01	4.51E+00	8.90E+04	4.02E+05
Total Alpha	1.68E-01	1.4	2.35E-03	1.73E-01	1.70E+08	2.94E+07
					Total IDP (rem/gal)	**2.98E+07**
					WAC (rem/gal)	**8.00E+07**
					% of WAC (%)	**37.20**

Data from SRNL-STI-2016-00026

Method 2						
Species	Results (Ci/gal)	RSD (%)	Standard Dev (Ci/gal)	Results + 2 Standard Dev (Ci/gal)	Dose Conversion Factor** (rem/Ci)	IDP (rem/gal)
Sr-90	3.89E+00	8	3.11E-01	4.51E+00	8.90E+04	4.02E+05
Ru-106	1.10E-04	---	---	1.10E-04	2.40E+05	2.64E+01
Cs-137	9.64E-01	2.9	2.80E-02	1.02E+00	1.90E+04	1.94E+04
Ce-144	3.10E-04	---	---	3.10E-04	2.00E+05	6.20E+01
Pm-147	5.10E-02	---	---	5.10E-02	1.90E+04	9.69E+02
Pu-238	1.16E-01	17	1.97E-02	1.55E-01	1.70E+08	2.64E+07
Pu-239	3.59E-03	1.4	5.03E-05	3.69E-03	1.90E+08	7.01E+05
Pu-240	1.37E-03	1.2	1.64E-05	1.40E-03	1.90E+08	2.67E+05
Pu-241	2.65E-02	18	4.77E-03	3.60E-02	3.30E+06	1.19E+05
Am-241	9.92E-03	4.2	4.17E-04	1.08E-02	1.60E+08	1.72E+06
Cm-244	3.46E-03	10	3.46E-04	4.15E-03	1.00E+08	4.15E+05
					Total IDP (rem/gal)	**3.01+07**
					WAC (rem/gal)	**8.00E+07**
					% of WAC (%)	**37.59**

Data from SRNL-STI-2016-00026

**Dose conversion factors were obtained from X-SD-G-00008.

Attachment 5 (Continued): Inhalation Dose Potential (DWPF WAC 5.4.5)

B.) Sludge Stream Cs-137 Concentration Accounting for Analytical Uncertainty

= 1.02E+00 Ci/gal

WAC Limit **= 1.34 Ci/gallon**
% of WAC Limit **= 76.12%**

C.)

Analyte	Concentration (Ci/gal)	RSD (%)	Standard Deviation (Ci/gal)	Concentration + 2 Standard Deviations (Ci/gal)
Cs-137 Salt Batch 9	9.24E-01	0.26	2.40E-03	9.28E-01
Cs-137 Salt Batch 8	8.06E-01	2.2	1.80E-02	8.42E-01

Salt Batch 9 Cs-137 strip effluent transfer Concentration (Ci/gallon)

= 15 * 0.928 Ci/gal
= 13.93 Ci/gallon

Salt Batch 8 Cs-137 strip effluent transfer Concentration (Ci/gallon)

=15 * 0.842 Ci/gal
=12.63 Ci/gallon

WAC (Ci/gallon) **= 16.5 Ci/gallon**
Salt Batch 9 % of WAC **= 84.42 %**
Salt Batch 8 % of WAC **= 76.55 %**

Attachment 6: Nuclear Criticality Safety (DWPF WAC 5.4.6)

The following values were calculated applying two standard deviations where applicable. As iron (Fe) is the most abundant and effective neutron absorber, it is conservative to calculate the value by subtracting two standard deviations [X-SD-G-00008].

Species	Wt %	RSD (%)	Standard Deviation	Wt% + 2 Standard Deviation	Wt% - 2 Standard Deviations
Mn	6.03E+00	3	1.81E-01	6.39E+00	5.67E+00
Fe	1.80E+01	3	5.40E-01	1.91E+01	1.69E+01
U-233	7.67E-04	2.6	1.99E-05	8.07E-04	7.27E-04
U-234	8.57E-04	3.7	3.17E-05	9.20E-04	7.94E-04
U-235	4.45E-02	1.3	5.79E-04	4.57E-02	4.33E-02
U-236	2.35E-03	0.67	1.57E-05	2.38E-03	2.32E-03
U-238	3.05E+00	1.2	3.66E-02	3.12E+00	2.98E+00
Pu-239	6.78E-03	1.4	9.49E-05	6.97E-03	6.59E-03
Pu-241	3.02E-05	18	5.44E-06	4.11E-05	1.93E-05
Am-242m	1.97E-05	---	---	1.97E-05	1.97E-05
Cm-244	5.02E-06	10	5.02E-07	6.02E-06	4.02E-06
Cm-245	3.00E-07	---	---	3.00E-07	3.00E-07
				$U_{(total)}$ (Wt%)	3.17E+00
				U-235$_{(eq(slu))}$ (Wt%)	4.68E-02
				U-235$_{(eq(slu))}$ (Wt%) Enrichment	1.47E+00
				Pu-239$_{(eq)}$ excluding U-235$_{(eq(slu))}$ (Wt%)	7.71E-03
				Pu-239$_{(eq)}$ (Wt%)	3.81E-02

Data from SRNL-STI-2016-00026 and SRNL-STI-2015-00693

Criteria #1

Species	Wt% (TS)	RSD (%)	Standard Deviation	Wt% + 2 Standard Deviations	Wt% - 2 Standard Deviations
Pu 240	7.03E-04	1.2	8.44E-06	7.20E-04	6.86E-04
Pu 241	3.02E-05	18	5.44E-06	4.11E-05	1.93E-05
				WAC	**Pu 240 conc. > Pu 241 conc.**
				[Pu-240]>[Pu-241]	**Criteria met**

For the most conservative representation, the Wt% (TS) - 2 Standard Deviations of Pu-240 was used while the Wt% (TS) +2 Standard Deviations of Pu-241 was used.

[Pu-240] to [Pu-241] = 6.86E-04 > 4.11E-05

Criteria #2

U-235$_{(eqSLU)}$

= U-235 Wt% + 1.4*(U-233 Wt %)
= 4.57E-02 + (1.4 * 8.07E-04)
= 4.68E-02 Wt%

Eq. Pu-239

= Pu-239 + Pu-241 + Cm-244 + 15(Cm-245) + 35(Am-242m) + 0.65(U-235(eq$_{SLU}$))

= (6.97E-03) + (4.11E-05) + (6.02E-06) + (15 * 3.00E-07) + (35 * 1.97E-05) + (0.65*4.68E-02) Wt%
= 3.81E-02 Wt%

Fe/Eq. Pu-239 $= \frac{1.69E+01}{3.81E-02}$ Wt%

= 4.44E+02

For Iron, a value of minus 2 standard deviations is used for conservatism. Analytical uncertainty was applied to the equivalent Pu-239 Wt% in equation above as directed by the DWPF WAC [X-SD-G-00008].

WAC criteria is met - Fe: Eq. Pu-239 = 444:1 ≥ 160:1

Criteria #3

H-Canyon plutonium was added to Sludge Batch 9; therefore, the Eq. Pu-239 concentration of ≤0.59 g/gallon requirement does apply.

Eq. Pu-239 (g/gallon) excluding* U-235$_{(eq(slu))}$ *[X-SD-G-00008]

3.81E-02 Wt% - (0.65*4.68E-02 U-235$_{eq}$Wt%)

= 7.71E-03 Pu-239 Wt% excluding U-235$_{(eq(slu))}$

$$= \frac{7.71\text{E-03 g (Eq. Pu} - 239)}{100 \text{ g Total Solids}} * 1.15\frac{\text{g}}{\text{mL}} * 3{,}785\frac{\text{mL}}{\text{gal}} * \frac{19.6 \text{ g Total Solids}}{100 \text{ g Slurry}}$$

= 6.58E-02 g/gal

WAC criteria is met - 0.0658 g/gal ≤ 0.59 g/gal

Criteria #4

U$_{(total)}$ (Wt%)	3.17E+00
U-235$_{(eqSLU)}$ enrichment (Wt%)	1.47E+00
Mn mass ratio (g)	5.07E+05
U-235$_{(eqSLU)}$ (g)	4.19E+03
Mn:U-235$_{(eqSLU)}$	**121**
WAC Limit- Mn:U-235$_{(eqSLU)}$	**≥ 70:1**

Mn Mass Ratio

*For conservatism, the calculations below utilize Mn Wt% - 2 Standard deviations.

= Mn (Wt%) / 100 * Slurry Density * 3,785 mL/gal * 10,500 gallons sludge * Wt% (TS)

= 5.67 g Mn /100 g solids * 1.15 g slurry/mL sludge * 3,785 mL/gal * 10,500 gallons sludge * 19.6 g solids / 100 g slurry

=5.07E+05 g Mn

U-235$_{(eqSLU)}$

= U-235$_{(eqSLU)}$ (Wt%) * Slurry Density * 3,785 mL/gal * 10,500 gallons sludge * Wt% (TS)

= 4.68E-02g/100 g * 1.15 g/mL * 3,785 mL/gal * 10,500 gallons sludge * 19.6 g solids / 100 g slurry

= 4.19E+03 g U-235$_{(eqSLU)}$

Mass Ratio of Mn: U-235$_{(eqSLU)}$

$$= \frac{5.07E+05 \text{ g Mn}}{4.19E+03 \text{ g U-235(eqSLU))}}$$

$$= 1.21E+02$$

WAC criteria is met - Mn: U-235$_{(eqSLU)}$ = 1.21E+02:1 ≥ 70:1

Attachment 7: Glass Solubility (DWPF WAC 5.4.7)

Sludge Stream Only			
Species	**Wt % Total Solids (%)**	**Calcine Mass Tank 51 (kg)**	**Oxide Conversion (kg)**
Ti/TiO$_2$	3.26E-02	**2.92**	4.87
Cr/Cr$_2$O$_3$	1.20E-01	**10.75**	15.71
P/PO$_4$*	2.40E-01	**65.79****	65.79
F/NaF	1.00E-01	**8.96**	19.80
Cl/NaCl	1.00E-01	**8.96**	14.77
Cu	4.12E-02	**3.69**	3.69
S/SO$_4$	1.76E-01	**15.77**	47.23

*Phosphate Analytical Uncertainty Calculation Shown below.
** SRNL-STI-2015-00693 reports Phosphorous. Needed to be converted to phosphate for analysis. Shown below.

Species	Wt % Total Dried Solids (%)	RSD (%)	Standard Deviation (%)	Wt. % + 2 Standard Deviations (%)
P/PO$_4$	2.03E-01	9	1.83E-02	2.40E-01

SRAT Volume (gal)	10,500*	PRFT Volume (gal)	5,300**
Wt% TS (%)	19.6	PRFT Wt% TS (%)	6.523
Calcined Wt% (%)	15.3	PRFT Calcine Wt% (%)	4.887
Slurry Density (kg/L)	1.15	PRFT Density (kg/L)	1.055
Calcine Mass Tank 51 (kg)	6,993	Calcine Mass PRFT (kg)	1,034
Coupled Calcine Mass (kg)			8027

*SRAT Batch Volume is nominal per X-SD-G-00008
**PRFT volume per SRAT batch based on PCCS modeling.

Calcined Mass of Tank 51

$$10{,}500 \text{ gallons SRAT} * 3.785 \frac{\text{L}}{\text{gallon}} * \frac{15.3 \text{ kg Calcined Solids}}{100 \text{ kg Total Solids}} * \left(1.15 \frac{\text{kg}}{\text{L}}\right)$$

$$= 6992.7 \text{ kg Tank 51 Calcine Mass}$$

Phosphate Calcine Mass Tank 51

$$= \frac{0.240 \text{ kg P}}{100 \text{ kg solids}} * \frac{19.6 \text{ kg Total Solids}}{100 \text{ kg Slurry}} * \frac{100 \text{ kg Slurry}}{15.3 \text{ kg Calcined Solids}} * 6{,}992.7 \text{ kg Calcined solids} * 3.07 \text{ P: PO4 conversion factor}$$

= 65.79 Calcined Mass PO_4 (kg)

Ti Calcine Mass in Tank 51

$$= \frac{0.0326 \text{ kg Titanium}}{100 \text{ kg Total Solids}} * \frac{19.6 \text{ kg Total Solids}}{100 \text{ kg Slurry}} * \frac{100 \text{ kg Slurry}}{15.3 \text{ kg Calcined Solids}} * 6992.7 \text{ kg Calcined solids}$$

$$= 2.92 \text{ Calcine Mass Titanium (kg)}$$

Oxide Conversion

Molecular Weight Conversion	Ratio
Ti:TiO_2	1.67
Cr:Cr_2O_3	1.461
F:NaF	2.21
Cl:NaCl	1.65
S:SO_4	2.996
P:PO_4	3.07

Ti:TiO_2 Oxide Conversion

$$= 2.92 \text{ Calcine Mass Titanium (kg)} * 1.67 \text{ Mass ratio Ti: TiO2}$$

= 4.87 kg TiO_2

Sludge Only								
Waste Load (%)	Glass Mass (kg)	Wt % TiO2 (%)	Wt % Cr2O3 (%)	Wt % PO4 (%)	Wt % NaF (%)	Wt % NaCl (%)	Wt % Cu (%)	Wt % SO4 (%)
26	2.69E+04	1.81E-02	5.84E-02	2.45E-01	7.36E-02	5.49E-02	1.37E-02	1.76E-01
28	2.50E+04	1.95E-02	6.29E-02	2.63E-01	7.93E-02	5.91E-02	1.48E-02	1.89E-01
32	2.19E+04	2.23E-02	7.19E-02	3.01E-01	9.06E-02	6.76E-02	1.69E-02	2.16E-01
33	2.12E+04	2.30E-02	7.41E-02	3.10E-01	9.34E-02	6.97E-02	1.74E-02	2.23E-01
34	2.06E+04	2.37E-02	7.64E-02	3.20E-01	9.63E-02	7.18E-02	1.79E-02	2.30E-01
35	2.00E+04	2.44E-02	7.86E-02	3.29E-01	9.91E-02	7.39E-02	1.85E-02	2.36E-01
36	1.94E+04	2.51E-02	8.09E-02	3.39E-01	1.02E-01	7.60E-02	1.90E-02	2.43E-01
37	1.89E+04	2.58E-02	8.31E-02	3.48E-01	1.05E-01	7.81E-02	1.95E-02	2.50E-01
38	1.84E+04	2.65E-02	8.54E-02	3.58E-01	1.08E-01	8.02E-02	2.01E-02	2.57E-01
39	1.79E+04	2.72E-02	8.76E-02	3.67E-01	1.10E-01	8.24E-02	2.06E-02	2.63E-01
40	1.75E+04	2.79E-02	8.99E-02	3.76E-01	1.13E-01	8.45E-02	2.11E-02	2.70E-01
41	1.71E+04	2.86E-02	9.21E-02	3.86E-01	1.16E-01	8.66E-02	2.16E-02	2.77E-01
42	1.66E+04	2.93E-02	9.44E-02	3.95E-01	1.19E-01	8.87E-02	2.22E-02	2.84E-01
43	1.63E+04	3.00E-02	9.66E-02	4.05E-01	1.22E-01	9.08E-02	2.27E-02	2.90E-01
44	1.59E+04	3.07E-02	9.89E-02	4.14E-01	1.25E-01	9.29E-02	2.32E-02	2.97E-01
45	1.55E+04	3.14E-02	1.01E-01	4.23E-01	1.27E-01	9.50E-02	2.38E-02	3.04E-01
46	1.52E+04	3.21E-02	1.03E-01	4.33E-01	1.30E-01	9.71E-02	2.43E-02	3.11E-01

Glass Mass @ 32% Glass Waste Loading

$$\frac{6992.7\ \text{Tank 51 Calcine Mass (kg)}}{\frac{32}{100}} = 21,852\ \text{kg Glass}$$

Wt% TiO_2 @ 32 % Waste Loading

$$\frac{4.87\ \text{kg TiO2}}{21{,}852\text{kg}} * 100 = 0.022\ \text{Wt \% TiO2}$$

Wt% Cr_2O_3 @ 32 % Waste Loading

$$\frac{15.71\ \text{kg Cr2O3}}{21{,}852\ \text{kg Glass}} * 100 = 0.072\ \text{Wt \% Cr2O3}$$

Wt% PO_4 @ 32 % Waste Loading

$$\frac{65.79\ \text{kg PO4}}{21{,}852\ \text{kg}} * 100 = 0.301\ \text{Wt \% PO4}$$

Wt% NaF @ 32% Waste Loading

$$\frac{19.80\ \text{kg NaF}}{21{,}852\ \text{kg}} * 100 = 0.091\ \text{Wt \% NaF}$$

Wt% NaCl @ 32% Waste Loading

$$\frac{14.77\ \text{kg NaCl}}{21{,}852\ \text{kg}} * 100 = 0.068\ \text{Wt \% NaCl}$$

Wt% Cu @ 32% Waste Loading

$$\frac{3.69\ \text{kg Cu}}{21{,}852\ \text{kg}} * 100 = 0.017\ \text{Wt \% Cu}$$

Wt% SO_4 @ 32% Waste Loading

$$\frac{47.23\ \text{kg SO4}}{21{,}852\ \text{kg}} * 100 = 0.216\ \text{Wt \% SO4}$$

PRFT Stream					
Species	Wt% (%)	Concentration (mg/kg)	Calcined Wt% (%)	Mass (kg)	Oxide Conversion (kg)
Ti	5.78	---	0.0771	79.75	133.06
Cr	---	---	---	---	---
PO_4	---	571.19	0.0117	12.09	12.09
F	---	500.14	0.0102	10.58	23.39
Cl	---	499.85	0.0102	10.58	17.43
Cu	---	---	---	---	---
SO_4	---	1114.70	0.0228	23.59	23.59

Sludge+PRFT Stream								
Waste Load (%)	Glass Mass (kg)	Wt% TiO2 (%)	Wt % Cr2O3 (%)	Wt % PO4 (%)	Wt % NaF (%)	Wt % NaCl (%)	Wt % Cu (%)	Wt % SO4 (%)
26	3.09E+04	4.47E-01	5.09E-02	2.52E-01	1.40E-01	1.04E-01	1.20E-02	2.29E-01
28	2.87E+04	4.81E-01	5.48E-02	2.72E-01	1.51E-01	1.12E-01	1.29E-02	2.47E-01
30	2.68E+04	5.16E-01	5.87E-02	2.91E-01	1.61E-01	1.20E-01	1.38E-02	2.65E-01
32	2.51E+04	5.50E-01	6.26E-02	3.10E-01	1.72E-01	1.28E-01	1.47E-02	2.82E-01
33	2.43E+04	5.67E-01	6.46E-02	3.20E-01	1.78E-01	1.32E-01	1.52E-02	2.91E-01
34	2.36E+04	5.84E-01	6.65E-02	3.30E-01	1.83E-01	1.36E-01	1.56E-02	3.00E-01
35	2.29E+04	6.01E-01	6.85E-02	3.40E-01	1.88E-01	1.40E-01	1.61E-02	3.09E-01
36	2.23E+04	6.19E-01	7.05E-02	3.49E-01	1.94E-01	1.44E-01	1.66E-02	3.18E-01
37	2.17E+04	6.36E-01	7.24E-02	3.59E-01	1.99E-01	1.48E-01	1.70E-02	3.26E-01
38	2.11E+04	6.53E-01	7.44E-02	3.69E-01	2.04E-01	1.52E-01	1.75E-02	3.35E-01
39	2.06E+04	6.70E-01	7.63E-02	3.78E-01	2.10E-01	1.56E-01	1.79E-02	3.44E-01
40	2.01E+04	6.87E-01	7.83E-02	3.88E-01	2.15E-01	1.60E-01	1.84E-02	3.53E-01
41	1.96E+04	7.05E-01	8.03E-02	3.98E-01	2.21E-01	1.64E-01	1.89E-02	3.62E-01
42	1.91E+04	7.22E-01	8.22E-02	4.08E-01	2.26E-01	1.68E-01	1.93E-02	3.71E-01
43	1.87E+04	7.39E-01	8.42E-02	4.17E-01	2.31E-01	1.73E-01	1.98E-02	3.79E-01
44	1.82E+04	7.56E-01	8.61E-02	4.27E-01	2.37E-01	1.77E-01	2.02E-02	3.88E-01
45	1.78E+04	7.73E-01	8.81E-02	4.37E-01	2.42E-01	1.81E-01	2.07E-02	3.97E-01
46	1.74E+04	7.90E-01	9.00E-02	4.46E-01	2.47E-01	1.85E-01	2.12E-02	4.06E-01

PRFT Calcine Mass

$$5{,}300 \text{ gallons PRFT} * 3.785 \left(\frac{\text{L}}{\text{gallon}}\right) * 1.055 \, \frac{\text{kg PRFT}}{\text{L}} * \left(\frac{4.887 \text{ kg Calcine PRFT}}{100 \text{ kg PRFT}}\right)$$

$$= 1{,}034 \text{ kg PRFT Calcine Mass}$$

Titanium PRFT Calcine Mass

$$\left(\frac{5.78 \text{ kg Ti}}{100 \text{ kg Total Solids}}\right) * \frac{6.523 \text{ kg Total Solids}}{100 \text{ kg PRFT}} * \frac{100 \text{ kg PRFT}}{4.887 \text{ kg Calcine PRFT}} * 1{,}034 \text{ kg PRFT Calcine Mass}$$

$$= 79.75 \text{ kg } TiO_2$$

Titanium PRFT Oxide Conversion

$$= 79.75 \text{ kg TiO2} * 1.668 \text{ (Ti: TiO2)}$$

$$= 133.060 \text{ kg } TiO_2$$

Chloride PRFT Mass: Oxide Conversion

$$499.85\frac{mg}{kg}Cl * \frac{100\ kg\ PRFT}{4.887\ kg\ Calcine\ PRFT} * \frac{1kg}{1E+06\ mg} * 1{,}034\ kg\ Calcine\ PRFT * 1.65(Cl: NaCl)$$

$$= 17.434\ kg\ NaCl$$

Sulfate PRFT Mass Conversion

$$\left(1114.7\frac{mg}{kg}\ SO4\right) * \frac{100kg\ PRFT}{4.887\ kg\ Calcine\ PRFT} * \frac{1\ kg}{1E+06\ mg} * 1{,}034\ kg\ Calcine\ PRFT$$

$$= 23.59\ kg\ SO4$$

*No oxide conversion is needed for sulfate data; reported as SO_4 concentration.

Coupled Glass Mass @ 32% Waste Loading

$$= \frac{6992.7\ kg\ Tank\ 51\ Calcine\ Mass + 1{,}034\ kg\ PRFT\ Calcine\ Mass}{(\frac{32}{100})} = 25{,}084\ kg\ glass$$

Species @ 40% Waste Loading	Wt %WAC Limit (%)	Sludge Only Wt % (%)	Coupled Wt % (%)	Sludge Only % of WAC Limit (%)	Coupled % of WAC Limit (%)
TiO_2	2	0.028	**0.687**	1.39	34.37
Cr_2O_3	0.3	0.090	**0.078**	29.96	26.10
PO_4	3	0.376	**0.388**	12.55	12.94
NaF	1	0.113	**0.215**	11.32	21.52
NaCl	1	0.084	**0.160**	8.45	16.05
Cu	0.5	0.021	**0.018**	4.22	3.68
SO_4	0.65	0.270	**0.353**	41.57	54.29

Attachment 8: Corrosive Species (DWPF WAC 5.4.8)

Waste Stream	Calcine Mass SO_4 (kg)	Mols SO_4	M
Sludge Only	47.23	491.69	0.012
Coupled	70.82	737.21	0.019
DWPF WAC Limit (M)			0.058
Sludge Only % of WAC			**21.33**
Coupled PRFT/Sludge % of WAC			**31.98**

Using Calcined mass (kg) calculated from Attachment 7.

Sulfate Concentration in Washed Sludge Only

The SRAT sludge volume is assumed to be the maximum allowable volume of 10,500 gallons.

$$= \frac{47.23\ \text{kg SO4} * \frac{(1\ \text{mol SO4})}{0.096\ \text{kg SO4}}}{\left(10{,}500\ \text{gallons SRAT} * \frac{(3.785\ \text{L})}{1\ \text{gallon}}\right)}$$

= 0.012 M

Tank 51 Coupled with Salt Batch 9			
Waste Stream	Wt% TS (%)	Concentration (g/L)	Hg Mass (g)
Hg Sludge Only	3.12E+00	7.03E+00	2.79E+05
Salt Batch 9 Hg Contribution	---	6.28E-02	4.72E+05
Coupled Hg (g)			7.52E+05
Sludge only Concentration Hg (g/L)			**7.03**
Coupled Concentration Hg (g/L)			**18.9**
Hg WAC Limit (g/L)			**21**
Sludge Only % of WAC (%)			**33.48**
Coupled Hg % of WAC (%)			**90.08**

Sludge Data from SRNL-STI-2015-00693. Salt Batch 9 Data from SRNL-STI-2015-00622

Mercury Concentration in Washed Sludge

$$= \frac{3.12 \text{ g Hg}}{100 \text{ g Total Solids}} * \frac{19.59 \text{ g Total Solids}}{100 \text{ g Slurry}} * 1.15 \frac{\text{g slurry}}{\text{mL}} * 1000 \frac{\text{mL}}{\text{L}}$$

= 7.03 g/L Mercury

Washed Sludge Mass Contribution

$$= 7.03 \frac{\text{g}}{\text{L}} * 10{,}500 \text{ gallons SRAT} * \frac{3.785\text{L}}{1 \text{ gal}}$$

= 2.79E+05 g Hg

Salt Batch 9 ARP Hg Mass Contribution

$$= 0.0628 \frac{\text{g Hg}}{\text{L}} * 5300 \text{ gallons PRFT} * \frac{3.785 \text{ L}}{1 \text{ gallon}} * 375 \text{ ARP Concentration Factor}$$

= 4.72E+05 g Hg

Coupled Sludge/ARP Hg Concentration

$$= \frac{(2.79\text{E}{+}05 \text{ g Hg} + 4.72\text{E}{+}05 \text{ g Hg})}{(10{,}500 \text{ gallons SRAT} * \frac{3.785 \text{ L}}{1 \text{ gal}})}$$

= 18.9 g/L Coupled Hg Concentration

Tank 51 Coupled with Salt Batch 8			
Waste Stream	Wt% TS (%)	Concentration (g/L)	Hg Mass Contribution (g)
Hg Sludge Only	3.12E+00	7.03E+00	2.79E+05
Salt Batch 8 Hg Contribution	---	1.29E-01	5.52E+05
		Total Hg (g)	831,720
		Sludge only Concentration Hg (g/L)	**7.03**
		Coupled Concentration Hg (g/L)	**20.93**
		Hg WAC Limit (g/L)	**21**
		Sludge Only % of WAC (%)	**33.48**
		Coupled Hg % of WAC (%)	**99.66**

Salt Batch 8 Mercury Mass Contribution

$$= 0.129\ \mathrm{Hg}\frac{\mathrm{g}}{\mathrm{L}} * \frac{3.785\ \mathrm{L}}{1\ \mathrm{gal}} * 3{,}000\ \text{gallons PRFT} * 377.1\ \text{ARP concentration factor}$$

$$= 5.52\mathrm{E}{+}05\ \mathrm{g\ Hg}$$

- Due to the lack of Hg data for the salt streams coming to DWPF, a conservative approach was taken to estimate the concentration of Hg. The concentration factor utilized to establish FSAR IDP limits was used along with the assumption that all of the Hg would be accumulated in the Late Wash Precipitate Tank (LWPT) and subsequently sent to DWPF. Mercury in the salt stream is mainly soluble [X-CLC-S-00113]. A review of the Tank 50 quarterly Saltstone WAC samples demonstrates the total mercury concentration to be similar to the total mercury in the salt batch qualification samples (Tank 21 analysis) following ARP/MCU processing. Hence, assuming that all of the mercury goes into the DWPF process stream is conservative.
- Very few samples have been collected from the PRFT and Strip Effluent Hold Tank (SEHT) located at MCU and characterized for total Hg. These samples indicate the Hg concentration of the salt streams to be less than 83 mg/L for Salt Batch 7A, 7B, and 8 versus the assumed value in this ESR of 28,500 mg/L [X-ESR-S-00279, Rev.1]. The data reported for the PRFT and SEHT supports the Tank 50 data in that a small fraction of Hg is sent to DWPF and the majority of mercury is in the Decontaminated Salt Solution sent to Tank 50.
- Filtration only ARP operations of Tank 21 material is not expected to impact the behavior of mercury. Furthermore, based on X-ESR-S-00279 Rev.1, the mercury contribution of the PRFT to DWPF coupled operations is not expected to influence the SRAT mercury concentration as considerably as this calculation suggests.
- The use of the concentration factor and the Tank 21 concentration build a substantial amount of conservatism into this calculation. Future efforts will be taken to develop a conservative Hg basis for incoming salt streams to DWPF using process knowledge and available analytical data.
- The Corrosive Species mercury calculation coupled with Salt Batch 8 concentration bounds the PRFT volume at 3,000 gallons with all of the built-in conservatism applied.

Attachment 9: Radiolytic Hydrogen Generation (DWPF WAC 5.4.12)

Species	Concentration (Ci/gal)	Q value* (W/Ci)	Concentration (BTU/hr/gal)	R - value (ft^3/10^6 BTU)	HGR (ft^3/hr/gal)
Co-60	2.75E-04	1.541E-02	1.446E-05	48.36	6.99E-10
Y-90	3.89E+00	5.540E-03	7.355E-02	48.36	3.56E-06
Sr-90	3.89E+00	1.160E-03	1.540E-02	48.36	7.45E-07
Ru-106	1.10E-04	5.951E-04	2.234E-07	48.36	1.08E-11
Rh-106	1.10E-04	1.894E-02	7.111E-06	48.36	3.44E-10
Sb-125	4.30E-05	3.370E-03	4.946E-07	48.36	2.39E-11
Cs-134	2.60E-04	1.019E-02	9.042E-06	48.36	4.37E-10
Cs-137	9.64E-01	1.010E-03	3.323E-03	48.36	1.61E-07
Ba-137	9.12E-01	3.940E-03	1.226E-02	48.36	5.93E-07
Ce-144	3.10E-04	6.580E-04	6.962E-07	48.36	3.37E-11
Pr-144	3.10E-04	7.338E-03	7.764E-06	48.36	3.75E-10
Pm-147	5.10E-02	3.670E-04	6.388E-05	48.36	3.09E-09
Eu-154	4.13E-03	9.081E-03	1.280E-04	48.36	6.19E-09
Pu-238	1.16E-01	3.259E-02	1.290E-02	134.7	1.74E-06
Pu-239	3.59E-03	3.024E-02	3.705E-04	134.7	4.99E-08
Pu-240	1.37E-03	3.056E-02	1.429E-04	134.7	1.92E-08
Am-241	9.92E-03	3.283E-02	1.112E-03	134.7	1.50E-07
Cm-244	3.46E-03	3.437E-02	4.059E-04	134.7	5.47E-08
				1 BTU/hr	2.93E-01 W
				Total Radiolytic Hydrogen generation (f^3/hr/gal)	**7.08E-06**
				WAC Limit (ft^3/hr/gal)	**8.95E-05**
				% of WAC Limit (%)	**7.91**

*Q Values from DOW-RW-0006/Data from SRNL-STI-2016-00026

Co-60 HGR (ft^3/hr/gal)

$$2.75\text{E-}04\,\frac{\text{Ci}}{\text{gal}} * 1.541\text{E-}02\,\frac{\text{W}}{\text{Ci}} * \frac{1\,\frac{\text{BTU}}{\text{hr}}}{0.293\ \text{W}} * 48.36\,\frac{\text{ft}^3}{10^6\,\text{BTU}}$$

$$= 6.99\text{E-}10\ \text{ft}^3/\text{hr/gal}$$

Total Tank 51 Material HGR	**= 7.08E-06 ft^3/hr/gal**
Salt Batch 8 512-S HGR[X-ESR-H-00739]	**= 6.35E-07 ft^3/hr/gal**
Salt Batch 9 512-S HGR [X-ESR-H-00807]	**= 7.27E-07 ft^3/hr/gal**
Salt Batch 8 Coupled HGR	**= 7.71 E-06 ft^3/hr/gal**
Salt Batch 9 Coupled HGR	**= 7.81E-06 ft^3/hr/gal**
DWPF WAC Limit	**= 8.95 E-05 ft^3/hr/gal**
Sludge Only % of WAC Limit	**= 7.91%**
Salt Batch 8 Coupled % of WAC Limit	**= 8.62%**
Salt Batch 9 Coupled % of WAC Limit	**= 8.72%**

Attachment 10: Criticality for 2H – Evaporator Evaluation (Tank Farm WAC 11.6.1)

To ensure sufficient conservatism in the evaluation, the standard deviation associated with each applicable measured radionuclide weight percent value was applied within the NCSC calculations in the following manner:

1. Two standard deviations were added to each U and Pu radionuclide concentration that comprised the eq. U-235 concentration in the numerator while the average concentration of each U and Pu radionuclide was chosen when calculating the eq. U concentration in the denominator.
2. Two standard deviations were added to each Pu radionuclide concentration that comprised the Pu concentration in the numerator while the average concentration of each U and Pu was chosen when calculating the total fissionable concentration in the denominator.

Sludge Batch 9

Radionuclide	Wt %	RSD%	Standard Deviation (Wt %)	Concentration + 2 Standard Deviations (Wt %)
U-233	7.67E-04	2.6	1.99E-05	8.07E-04
U-234	8.57E-04	3.7	3.17E-05	9.20E-04
U-235	4.45E-02	1.3	5.79E-04	4.57E-02
U-236	2.35E-03	0.67	1.57E-05	2.38E-03
U-238	3.05E+00	1.2	3.66E-02	3.12E+00
Total U	3.10E+00			
Pu-239	6.78E-03	1.4	9.49E-05	6.97E-03
Pu-241	3.02E-05	18	5.44E-06	4.11E-05

*Data from SRNL-STI-2016-000026

U-235 (eq) = U-235 + (1.4* U-233) + 2.25*(Pu-239 + Pu-241)

= 4.57E-02 Wt% + (1.4 * 8.07E-04 Wt%) + 2.25 *(6.97E-03 Wt% +4.11E-05 Wt%)

= 6.26E-02 Wt%

% U-235 (eq) enrichment = (U-235 (eq) / Total U)*100

= 6.26E-02 Wt% / 3.10E+00 Wt%) * 100

=2.02%

U-235 (Eq) **2.02 Wt%**
U-235 Enrichment WAC Limit **5.5 Wt%**
% of Enrichment Limit **36.71%**

Sludge Batch 9 ratio of Pu to fissionable isotopes

Ratio = (Pu-239 + Pu-241)/ (U-235 + U-238 + Pu-239 + Pu-241) *100

= (6.97E-03 Wt% + 4.11E-05 Wt%) /(4.45E-02 Wt% + 3.05E+00 Wt% + 6.78E-03 Wt% + 3.02E-05 Wt%) * 100

= 0.226%

Other fissionable radionuclides are not included for conservatism.

Pu (Eq.) **0.226 Wt%**
Ratio Fissile Pu WAC Limit **2 Wt%**
% of Ratio Limit **11.3%**

Salt Batch 9						
Species	Specific Activity (Ci/g)	Concentration (pCi/mL)	Concentration (mg/L)	RSD (%)	Standard Deviation	Concentration + 2 Standard Deviations (mg/L)
U-233	9.68E-03	1.71E+01	1.77E-03	1.5	2.65E-05	1.82E-03
U-234	6.25E-03	9.25E+01	1.48E-02	1	1.48E-04	1.51E-02
U-235	2.16E-06	2.32E-01	1.07E-01	3.3	3.54E-03	1.14E-01
U-236	6.47E-05	1.41E+00	2.18E-02	1.3	2.83E-04	2.24E-02
U-238	3.36E-07	3.55E+00	1.06E+01	0.67	7.07E-02	1.07E+01
Pu-239	6.22E-02	8.71E+02	1.40E-02	7.7	1.08E-03	1.62E-02
Pu-241	1.03E+02	1.70E+04	1.65E-04	---	---	1.65E-04
Total U			1.07E+01	---	---	1.09E+01

*Data for calculations from SRNL-STI-2015-00622

Salt Batch 8						
Species	Specific Activity (Ci/g)	Concentration (pCi/mL)	Concentration (mg/L)	RSD (%)	Standard Deviation	Concentration + 2 Standard Deviations (mg/L)
U-233	9.68E-03	2.83E+01	2.92E-03	---	---	2.92E-03
U-234	6.25E-03	1.18E+02	1.89E-02	4.8	9.07E-04	2.07E-02
U-235	2.16E-06	4.18E-01	1.93E-01	0.5	9.67E-04	1.95E-01
U-236	6.47E-05	1.57E+00	2.43E-02	6.1	1.48E-03	2.72E-02
U-238	3.36E-07	8.42E+00	2.50E+01	0.3	7.51E-02	2.52E+01
Pu-239	6.22E-02	1.35E+03	2.17E-02	12	2.61E-03	2.69E-02
Pu-241	1.03E+02	2.23E+04	2.17E-04	8.9	1.93E-05	2.55E-04
Total U			2.53E+01	---	---	2.54E+01

*Data from SRNL-STI-2014-00561

Salt Batch Uranium Enrichment

Salt Batch 9 U-235 (Eq.)	**1.44 Wt%**
Salt Batch 8 U-235 (Eq.)	**1.02 Wt%**
U-235 Enrichment WAC Limit	**5.5 Wt%**
Salt Batch 9 % of WAC	**26.1%**
Salt Batch 8 % of WAC	**18.63%**

Salt Batch ratio of Pu to fissionable isotopes

Salt Batch 9 Pu (Eq.)	**0.153 Wt%**
Salt Batch 8 Pu (Eq.)	**0.11 Wt%**
Ratio Fissile Pu WAC Limit	**2 Wt%**
Salt Batch 9 % of WAC	**7.65%**
Salt Batch 8 % of WAC	**5.38%**

Attachment 11: DWPF Analytical Lab PRFT Data through 1/2016

DWPF Analytical Lab PRFT Data through 1/18/2016
Assumptions used in Calculations using PRFT Data:

- It is valid to use historical analytical PRFT data for this evaluation because there has been insignificant variation in the data reported regarding transitions from Salt Batch to Salt Batch. Salt Batch 9 composition does not vary significantly in comparison to Salt Batch 8.
- Since free hydroxide and carbonate are not individually reported, the base equivalents can be used in lieu of actual measurements of these species.
- Conservative assumptions were made for the NO_x Emissions calculation in regards to the salt contribution. These are found below:
    - Since NaOH is added at 512-S during processing evolutions and is present in the salt solution, it is assumed that the average base equivalents for the PRFT results is equal to the hydroxide concentration. This is conservative due to the fact that there are other species present in the PRFT sample that will consume acid during the titration of the PRFT sample such as Na_2CO_3 and $NaNO_2$.
    - The highest value (Sample ID 200018208) reported for the PRFT Base Equivalents has been adjusted by multiplying the standard deviation by two to produce a value of 0.908 M (0.7 + 2 * .104). This value bounds the base equivalent data reported above.
    - Carbonate is present in the salt solution at <0.1 M for both Salt Batch 8 and 9 and is expected to remain soluble and partition to the Clarified Salt Solution during Salt Processing. Since a small amount could be present (as Na_2CO_3) from trapped interstitial supernate in the MST solids, and CO_2 absorption is possible in the PRFT, the carbonate cannot be removed from consideration in the NO_x Emissions calculation. Even though current operation has no MST strike, minimal amounts of solids are present and accounted for on a conservative basis. A factor of 0.5 was applied to the adjusted value for base equivalents to produce a conservative carbonate concentration of 0.454 M (0.908 M * 0.5).
    - The highest values for nitrate and nitrite (Sample ID 200017699) have been adjusted by multiplying the standard deviation of each by two to produce values of 22,668 ppm (17,356 ppm + 2*2,656) and 4,036 ppm (3,164 ppm + 2*436). These values bound the data reported above.

- The average density, weight percent solids, and weight percent high temperature calcined solids have been adjusted by multiplying the standard deviation of each by two to produce values of 1.055 g/mL (1.030 g/mL + 2*0.012), 6.522 wt.% solids (5.445 wt.% +2*0.54), and 4.89 wt. % high temperature calcine solids (3.64 wt.% +2*.626),

Attachment 11 (Continued): DWPF Analytical Lab PRFT Data through 1/2016

respectively. This was done to bound the majority of the individual sample results reported for these measurements.

- Average values were used for the Ti, fluoride, chloride, and phosphate. This is conservative because fluoride, chloride, and phosphate are at or below the detection limit of the instrument. Using average Ti concentration is conservative due to the reduction (0.2 g/MST/L) of MST at 241-96H operations or ARP operation with no MST. Ti concentration has dropped in accordance with this reduction in MST (see sample data reported from October 2012 to February 2014). The average Ti for October 2012 to January 2016 is 5.78 Wt%.
- A drop in Ti Wt% is expected in the upcoming samples due to not striking with MST.
- The most recent PRFT sample data reported was not included in the calculations. Weight percent results indicate flushing of the PRFT lines and are not a representative sample.
- The highest value for sulfate (Sample ID 200017466) has been adjusted by multiplying the standard deviation by two to produce a value of 1140 ppm (878 ppm + 2*131) for sulfate. This value bounds the sulfate data reported above.

Attachment 11 (Continued): DWPF Analytical Lab PRFT Data through 1/2016

PRFT	8/15/2012	10/18/2012	2/14/2013	2/20/2013	4/4/2013	4/26/2013	6/3/2013	6/27/2013	7/17/2013	8/1/2013	8/27/2013	9/5/2013	1/1/2014	2/6/2014
Sample ID	200014781	200015280	200016056	200016103	200016487	200016692	200016993	200017197	200017349	200017466	200017699	200017776	200018208	200018396
Density	1.025	1.036	1.052	1.009	1.033	1.043	1.04975	1.039	1.043	1.023	1.028	1.023	1.032	1.01
Weight Percent Solids	6.05	5.74	5.73	5.88	4.95	4.12	5.54	5.4	5.39	5.62	6.38	5.43	6.28	5.76
Wt. % High Temperature Calcine	4.86	4.29	4.36	4.23	2.72	2.295	3.72	3.49	3.9	3.67	3.84	2.95	4.62	3.47
Fluoride (mg/Kg)	506	505	473	484	504	510	475	473	471	500	494	515	526	528
Chloride (mg/Kg)	-	505	473	484	504	510	475	473	471	500	494	515	526	528
Nitrate (mg/Kg)	7809	8473	11481	14304	14322	15604	14014	11784	13189	13322	17356	17213	12826	11218
Nitrite (mg/Kg)	1843	1746	2194	2661	2582	2715	2423	2127	2287	2564	3164	2878	2111	1977
Sulfate (mg/Kg)	506	505	517	670	702	754	733	641	682	878	863	810	606	579
Phosphate (mg/Kg)	336	505	473	484	504	510	475	473	471	500	494	515	526	528
Formate (mg/Kg)	506	505	473	484	504	510	475	473	471	500	494	515	528	528
Oxalate (mg/Kg)	5063	4416	4600	5221	4630	4659	4485	4969	4805	4106	4340	4470	3785	4480
Base Equivalents (OH and CO_3)	0.68	0.66	0.53	0.52	0.47	0.46	0.41	0.37	0.41	0.46	0.49	0.46	0.7	0.62
Na (Wt%)	39.0	39.2	37.3	34.9	44.4	48.3	33.1	32.5	30.3	35.0	35.5	34.2	36.2	34.2
Ti (Wt%)	8.3	6.6	7.0	6.1	7.2	6.9	5.8	6.2	4.8	3.3	3.0	0.8	1.3	1.3

8/10/2014	10/7/2014	12/21/2014	2/23/2015	8/26/2015	1/5/2016	1/11/2016	1/18/2016					
200019205	200019477	200019771	200020044	200020707	200021289	200021308	200021337	Average of All Samples	Stdev	%RSD	Max	Average + 2 Stdev
1.017	1.043	1.019	1.033	1.032	1.014	1.022	1.016	1.02979	0.01247	1.21076	1.05200	1.05472
5.21	4.65	5.14	5.15	5.61	5.55	4.77	2.69	5.44515	0.53885	9.89597	6.38000	6.52285
3.5	3.11	3.16	3.48	3.73	3.78	3.18	2.12	3.63557	0.62583	17.21413	4.86000	4.88724
508	511	502	507	488	506	517	508	500.14286	17.00672	3.40037	528.00000	534.15630
508	511	502	507	488	506	517	508	499.85000	17.39412	3.47987	528.00000	534.63823
8919	9271	10683	10655	12053	11785	10228	6940	12214.70238	2656.00050	21.74429	17356.00000	17526.70338
1547	1836	2353	2329	2462	3109	2721	1858	2363.29810	436.11755	18.45377	3164.00000	3235.53319
508	511	502	641	672	733	652	508	650.70238	118.34900	18.18788	878.00000	887.40038
508	511	502	507	488	506	517	508	492.04762	39.57079	8.04207	528.00000	571.18920
508	511	502	507	488	506	517	508	500.23810	17.16364	3.43109	528.00000	534.56537
4274	3822	4008	3793	4273	4107	3760	2627	4384.05952	425.87247	9.71411	5221.00000	5235.80447
0.44	0.4	0.39	0.37	0.378	0.47	0.38	0.27	0.47943	0.10404	21.70137	0.70000	0.68751
31.9	34.8	32.7	32.8	29.6	31.47	32.81	33.10	35.25544	4.49915	12.76157	48.32300	44.25373
5.5	8.2	6.7	9.780	8.3	7.28	7.27	6.21	5.77837	2.50200	43.29940	9.78000	10.78238

Attachment 12: Technical Reviews

SectionReviewers

1.0 C. I. Aponte, A. Samadi-Dezfouli
2.0 C. I. Aponte, A. Samadi-Dezfouli
3.0 C. I. Aponte, A. Samadi-Dezfouli
3.1 A. Samadi-Dezfouli
3.2 C. I. Aponte (Excluding 3.2.7, 3.2.8, 3.2.10) A. Samadi-Dezfouli
3.3 C. I. Aponte, A.Samadi-Dezfouli
4.0 C. I. Aponte, A. Samadi-Dezfouli

The reviewers also reviewed the corresponding attachments to the sections.

The following pages attached to the end of this evaluation are the Technical Report Checklists completed by the document reviewers.