X-ESR-S-00136
Rev. 1

Evaluation of Sludge Batch 8 Qualification with ISDP Salt Batch 6D Compliance to DWPF Waste Acceptance Criteria

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LIST OF ACRONYMS

ARP	Actinide Removal Process
CEDE	Committed Effective Dose Equivalent
CPC	Chemical Process Cell
CSS	Clarified Salt Solution
CSSX	Caustic Side Solvent Extraction
DCF	Dose Conversion Factor
DWPF	Defense Waste Processing Facility
EA	Environmental Assessment
ESP	Extended Sludge Processing
FSAR	Final Safety Analysis Report
HGR	Hydrogen Generation Rate
IDP	Inhalation Dose Potential
IS	Insoluble Solids
ISDP	Interim Salt Disposition Project
LFL	Lower Flammability Limit
LWPT	Late Wash Precipitate Tank
MCU	Modular CSSX Unit
MST	Monosodium Titanate
MW	Molecular Weight
NCSA	Nuclear Criticality Safety Assessment
NCSE	Nuclear Criticality Safety Evaluation
NO_x	Nitrous Oxide
PCCS	Production Composition Control System
PCT	Product Consistency Test
PRFT	Precipitate Reactor Feed Tank
RSD	Relative Standard Deviation
SAC	Specific Administrative Control
SE	Strip Effluent
SG	Specific Gravity
SME	Slurry Mix Evaporator
SRAT	Sludge Receipt and Adjustment Tank
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
TOC	Total Organic Carbon
TS	Total Solids
TSR	Technical Safety Requirements
WAC	Waste Acceptance Criteria
WAPS	Waste Acceptance Product Specifications
WCP	Waste Compliance Plan
Wt%	Weight percent

1.0 PURPOSE

Revision 1 of this document addresses the new 0.65 wt.% sulfate limit in glass for SB8. A Final Safety Analysis Report (FSAR) change was required prior to the implementation of the new sulfate limit, thus revision 0 of this document did not include the new sulfate limit. Based on the new sulfate limit and available analytical data for SB8 and Salt Batch 6D, the compositions were evaluated for acceptance against the Defense Waste Processing Facility (DWPF) Waste Acceptance Criteria (WAC) limits.

2.0 SUMMARY AND BACKGROUND

Prior to receipt of new material (e.g. salt or sludge) in the DWPF, the material must be evaluated for acceptability. Acceptability of material in the DWPF is based upon demonstrating that the material will meet requirements specified in the DWPF Waste Acceptance Criteria (WAC) [X-SD-G-00008]. The requirements include both processing limits as well as safety limits. This report was prepared to comply with the requirements listed in the DWPF WAC, and thus meets requirements as specified in the Technical Safety Requirement (TSR) Specific Administrative Control (SAC) 5.8.2.11, the Waste Acceptance Criteria (WAC) Program, which ensures that the composition of waste streams to be received into DWPF are within the Final Safety Analysis Report (FSAR) analyzed limits prior to transfer to the facility. In addition, this evaluation also serves to ensure that various processing limits specified in the DWPF WAC (typically as "targets") are satisfied. Note that this evaluation also serves to implement the Tank Farm compliance strategy [X-WCP-H-00019].

Sludge Batch 8 was originally qualified based on the qualification sample out of Tank 51 compared to the Sludge Batch 7b Waste Acceptance Product Specification (WAPS) sample and the projected blend of Tank 40 Sludge Batch 8 coupled with ISDP Macrobatch 6 (Tank 21 qualification sample) in the first issuance of this evaluation. This strategy for performing this evaluation is specified in Chapter 11 of the FSAR. Specifically, the strategy is described by the following:

"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]

In accordance with this description, the sludge contribution is evaluated using actual feed composition of Sludge Batch 8 feed as analyzed in WAPS sample. The salt contribution is evaluated by taking advantage of the most recent information on ISDP Macrobatch 6D and utilizing compositional data from the final salt batch blend [X-ESR-H-00501] and where applicable, analysis obtained directly from the facility (samples retrieved from the Precipitate Reactor Feed Tank (PRFT)). 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.

For this evaluation, the WAC requirement for glass quality and processability were more restrictive at higher waste loadings. The results of the calculations (for glass compositions greater than 36% WL) indicate that some of the glass compositions exceeded the ranges studied in the SB8 variability study [VSL-13R2580-1]. The durability model is reliant on the composition of the glass not a single component of the glass. To operate outside of the boundaries of the SB8 variability study, the glass composition must be within the compositional ranges used to develop and validate the durability model [MRS Symposium Volume 1107] and produce an acceptable release rate for B, Li, and Na as calculated via Product Composition Control System (PCCS). The glass compositions that exceeded the boundaries of the SB8 variability study met the durability model ranges and have acceptable release rates. Based on the results of the glass quality and processability, the PRFT volume is limited to 3000 gallons. However, there are compositional variations in each batch of PRFT material as seen in Attachment 13. This variation is dependent on the operations at 512-S. Therefore, it is recommended that each PRFT batch be sampled and a calculation performed to confirm the glass solubility and glass quality and processability WAC limits. If the glass composition is outside of the SB8 variability study, the projected glass composition shall be checked to ensure that it is within the model and validation range of the durability model and passes PCCS for B, Li, and Na release rates.

3.0 DISCUSSION OF RESULTS

3.1 Compliance with 512-S WAC

This section documents WAC compliance of the material to be transferred from the MST strike step of the Actinide Removal Process (ARP) (241-96H) to 512-S. X-ESR-H-00501 documents the blend calculation for Tank 49.

3.1.1 Gamma Shielding (DWPF WAC 5.3.1)

The 512-S WAC requires that in order to maintain a dose rate that does not exceed 0.5 mrem/hr for continuous occupancy in the 512-S facility, the Cs-137 concentration cannot exceed 1.11 Ci/gallon. Using the qualification value of the Salt Batch 6D material, the Cs-137 is 4.61E+07 pCi/mL or 0.221 Ci/gallon [X-ESR-H-00501]. The Cs-137 concentration is approximately 19.9 percent of the 512-S WAC of 1.11 Ci/gallon.

3.1.2 Inhalation Dose Potential (IDP) (DWPF WAC 5.3.2)

The inhalation dose potential for the MST/sludge to be transferred to 512-S shall have a total rem/gallon value less than or equal to 3.00E+06 rem/gallon, a Cs-137 concentration less than or equal to 1.11 Ci/gallon, and 512-S MST/sludge solids concentration less than or equal to 1.24E+08 Ci/gallon.

Two methods have been specified in the WAC for the inhalation dose calculation. The first method evaluates the dose by determining the total alpha and Sr-90 content of the ARP/MCU feed from Salt Batch 6D. The reported Ci/gallon values are multiplied by the dose conversion factors (DCFs) 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 512-S WAC limit.

The second method compares the eleven major inhalation dose radionuclides in the Salt Batch 6D 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 512-S WAC limit.

The first method resulted in the inhalation dose being approximately 6.48E+03 rem/gallon or 0.22 percent of the 512-S WAC limit of 3.00E+06 rem/gallon. The second method resulted in the inhalation dose being approximately 1.43E+04 rem/gallon or 0.47 percent of the 512-S WAC limit of 3.00E+06 rem/gallon. Results of the calculations can be found in Attachment 1.

The Cs-137 concentration of 0.221 Ci/gal meets the requirements of the 512-S WAC for inhalation dose potential. The Cs-137 value is approximately 19.9 percent of the limit specified in the 512-S WAC.

Similarly to the IDP limit for the 512-S feed, the two methods described above are used for the MST/sludge solids; however, the material is concentrated to 6 weight percent insoluble solids using a conservative concentration factor applied to all radionuclides except Cs-137, as Cs-137 is not adsorbed onto the MST. The methodology for determining the conservative concentration factor is described in N-ESR-S-00004.

The first method resulted in the inhalation dose being approximately 2.53E+06 rem/gallon or 2.04 percent of the 512-S MST/sludge solids WAC limit of 1.24E+08 rem/gallon. The second method resulted in the inhalation dose being approximately 3.96E+06 rem/gallon or 3.20 percent of the 512-S MST/sludge solids WAC limit of 1.24E+08 rem/gallon. Results of the calculations can be found in Attachment 1.

3.1.3 Nuclear Criticality Safety (DWPF WAC 5.3.3)

The waste to be transferred to 512-S shall have the following: a soluble uranium concentration less than or equal to 50 mg/L, a soluble plutonium concentration less than or equal to 0.3 mg/L, and U-235 (eq_sol) enrichment less than or equal to 3.0 wt.%.

An Engineering Type 1 Calculation X-CLC-G-00117 was performed that demonstrates that the Salt Batch 6 is compliant with the requirements from the ARP/Modular Caustic Side Solvent Extraction Unit (MCU) Nuclear Criticality Safety Evaluation (NCSE) [N-NCS-H-00192]. The calculation was performed by applying 2 standard deviations to the reported constituent values. This calculation demonstrates that the soluble uranium (U) and plutonium (Pu) concentrations and the U-235(eq_sol) enrichment are no more than the limits of 50 mg/L, 0.3 mg/L, and 3.0 wt%, respectively. The soluble U concentration was calculated to be 22.79 mg/L. This is 45.6% of the WAC limit. The soluble Pu concentration was calculated to be 0.0535 mg/L. This is 17.8% of the WAC limit. The U-235(eq_sol) enrichment was calculated to be 1.20 wt%. This is 40.0% of the WAC limit.

3.1.4 **Radiolytic Hydrogen Generation** (DWPF WAC 5.3.4)

The total radiolytic hydrogen generation rate (HGR) shall not exceed 1.64E-06 ft^3 H_2/hr/gal at 25°C. Compliance with this hydrogen generation rate for the 512-S feed material ensures that the flammability controls for the downstream process vessels are protected.

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 [N-CLC-S-00099]. Results are shown in Attachment 2.

The value of hydrogen generated for Salt Batch 6D material is 1.74E-07 ft^3 H_2/hr/gallon and the limit is 1.64E-06 ft^3 H_2 hr/gallon at 25°C. The value is 10.6 percent of the limit.

3.1.5 **Organic Concentration** (DWPF WAC 5.3.5)

The organic material present in the MST/sludge solids transferred to 512-S shall contribute less than 0.1% to the hydrogen Lower Flammability Limit (LFL).

The observation of the Salt Batch 6D values found no significant measurable organic constituents [X-ESR-H-00501]. These results indicate a negligibly small amount of organic material is present in the ARP/MCU feed. Previous analyses by Tank Farm Engineering concluded volatile organic content in the waste will not significantly contribute to flammability based on Tank Farm operational and processing history [X-ESR-G-00016]. In addition, both the current MCU solvent and NGS have been evaluated, and it has been determined that they will not significantly contribute to flammability [X-CLC-H-00581, X-ESR-H-00453]. Therefore, the organic material present in ISDP Salt Batch 6D will not exceed the 0.1% contribution limit to the hydrogen LFL [X-ESR-G-00016, X-CLC-H-00581, X-ESR-H-00453].

3.1.6 **Temperature** (DWPF WAC 5.3.6)

The waste to be transferred to 512-S shall be less than or equal to 45°C. The Waste Compliance Plan (WCP) compliance strategy is direct measurement prior to and during transfer [X-WCP-H-00019].

3.2 Compliance with DWPF WAC

MST/sludge solids will be sent from ARP to the DWPF. The strip effluent (SE) will be sent from MCU to the DWPF. These streams will be added to Sludge Batch 8 in the SRAT. Compliance with the DWPF WAC is being evaluated for Sludge Batch 8 with the

ARP/MCU material of ISDP Salt Batch 6D. This evaluation assumes any analyte that was reported in the WAPS at less than detection limit as real values. The average values are used for analytes that were reported as the actual measured value unless otherwise noted.

Sludge Batch 8 was qualified previously with Salt Batch 6 material and documented in X-ESR-S-00136, Rev. 0. Upon completion of Salt Batch 6D material at the DWPF, X-ESR-S-00136 will no longer be valid for WAC compliance which will result in this qualification report being used for WAC compliance. X-ESR-H-00551 qualification of ISDP Salt Batch 7 report will demonstrate compliance with Sludge Batch 8.

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 Sludge Batch 8 is 20.7 tons per year. This is approximately 20.0 percent of the DWPF WAC target of 103.52 tons per year. The algorithm assumes that at least 50% of the acid required will be added as nitric acid. DWPF is adding more than 50% of the acid requirement as formic acid for Sludge Batch 8. This percentage is significantly higher for Sludge Batch 8. Details of predicted NO_x emission calculations for Sludge Batch 8 can be found in Attachment 3.

For Salt Batch 6D, the NO_x emissions for the ARP contribution were calculated to be 14.8 tons/year which is approximately 14.3 percent of the DWPF WAC limit. This value is derived from PRFT sample results for the anions and the blend calculation results for the cations.

The estimated NO_x emission for Sludge Batch 8 with the ARP contribution is 35.5 tons per year. This is approximately 34.3 percent of the DWPF WAC target of no more than 103.52 tons per year.

3.2.2 Canister Heat Generation (DWPF WAC 5.4.2)

The heat generation per canister produced in the DWPF shall not exceed 437 watts/canister as calculated from the radionuclide content of the glass.

The projected canister heat generation was determined to be 159.2 watts per canister (104 W/canister for sludge, 16.0 W/canister for MST/sludge solids, and 38.8 W/canister for strip effluent at 3.31 Ci/gallon (see Section 3.2.3 for Cs-137). The calculated value is approximately 159.2 W/canister or 36.4 percent of the DWPF WAC limit of 437 W/canister. Calculations for canister heat generation can be found in Attachment 4.

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. Transfers from MCU are limited to 16.5 Ci/gallon 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 blended Sludge Batch 8 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. This is shown in Attachment 5. The calculated value for the sludge is 5.35E-01 mR/hr/g insoluble solids or 14.5 percent of the WAC limit of 3.7 mR/hr/g insoluble solids and 2.66E+02 mR/hr/gal or 6.53 percent of the WAC limit of 4070 mR/hr/gallon.

The MCU contribution to gamma shielding is limited to 16.5 Ci/gallon Cs-137. The contribution from Cs-137 is the value of the Salt Batch 6D material (0.221 Ci/gal) multiplied by a concentration factor of 15 in accordance with X-SD-G-00008. MCU contribution is thus nominally 3.31 Ci/gallon, which is 20.1 % of the WAC limit of 16.5 Ci/gallon Cs-137. Periodic sampling of the SE will monitor cesium concentration [X-WCP-H-00019].

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 value calculated from adding the individual alpha contributors from the Sludge Batch 8 in terms of insoluble solids was compared to the limit. Calculations are shown in Attachment 6. The total alpha concentration of 4.64E-04 Ci/g insoluble solids is approximately 30.9 percent of the DWPF WAC limit of 1.5E-03 Ci/gram insoluble solids.

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.

3.2.5 **Inhalation Dose Potential** (DWPF WAC 5.4.5)

The inhalation dose potential for the streams to be transferred to DWPF shall have a total rem/gallon value less than or equal to 2.47E+08 rem/gallon for the sludge stream, a Cs-137 concentration less than or equal to 1.34 Ci/gallon for the sludge stream, and a Cs-137 concentration less than or equal to 16.5 Ci/gallon for cesium strip effluent transfers.

Inhalation dose potential is calculated by the two methods described in 3.1.2. The first method resulted in the inhalation dose being approximately 3.98E+07 rem/gallon or 16.1 percent of the WAC limit using total alpha value calculated from adding the individual alpha contributors from the Sludge Batch 8. The second method resulted in the inhalation dose being approximately 3.62E+07 rem/gallon or 14.7 percent of the DWPF

WAC limit of 2.47E+08 rem/gallon for the sludge stream. Results of the calculations can be found in Attachment 7. Both methods show Sludge Batch 8 well below the DWPF WAC limit for total IDP.

The Cs-137 concentration in the sludge stream is 6.42E-01 Ci/gallon [X-SD-G-00008] which is 47.9 percent of the DWPF WAC limit of 1.34 Ci/gallon.

The MCU contribution is limited to 16.5 Ci/gallon of Cs-137. The concentration of 3.31 Ci/gallon (0.221 Ci/gal * 15 (X-SD-G-00008)) is approximately 20.1 percent of the WAC limit.

3.2.6 **Nuclear Criticality Safety** (DWPF WAC 5.4.6)

Compliance to the Nuclear Criticality Safety Criteria (NCSC) in Section 3.1.3 ensures that transfers from ARP and MCU will not challenge the NCSC for the DWPF facility as long as sludge transfers from the Tank Farm meet the four NCSC requirements listed below. Calculations are shown in Attachment 8.

1. The Pu-240 concentration shall exceed the Pu-241 concentration.
2. The overall Fe to equivalent Pu-239 weight ratio shall be greater than 160:1 and only Fe from the Tank Farm material shall be included in the calculation of the ratio.
3. The eq. Pu-239 concentration shall be $\leq$ 0.59 g/gallon if non-Tank Farm Pu is included in the sludge batch. Non-Tank Farm Pu was added to Sludge Batch 8; therefore, the limit is applicable.
4. The eq. U-235 enrichment shall be $\leq$ 0.93 wt% or $\leq$ 5 wt% with a Mn:U-235(eq_{SLU}) mass ratio of $\leq$ 70:1.

To ensure sufficient conservatism for 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 subtracted from the Pu-240 concentration while the average Pu-241 concentration was chosen as the denominator value.
2. Two standard deviations were subtracted from the Fe concentration and two standard deviations were added to each radionuclide that comprised the eq. Pu-239 concentration.
3. Two standard deviations were added to each radionuclide that comprised the eq. Pu-239 concentration.
4. Two standard deviations were added to each radionuclide that comprised the eq. U-235 concentration while the average weight percent value of each uranium isotope was chosen when calculating the total uranium concentration.

Choosing the average radionuclide weight percent values when determining the denominator for criteria 1 and 4 is consistent with the calculation method used to determine the percent soluble uranium concentration in the salt solution. It is considered sufficiently conservative to apply two standard deviations to the radionuclides that comprise the numerators of criteria 1 and 4 as appropriate, and, therefore, it is not necessary to account for the standard deviations of the radionuclides that comprise the denominators of criteria 1 and 4.

The results of the NCSC calculations are displayed in Table 1. All NCSC were met.

Table 1. Results of NCSC Calculations

	WAC Limit	Sludge Batch 8 WAPS Sample
Criteria #1	Pu-240 to Pu-241	20.4:1
Criteria #2	Fe/ Eq. Pu-239 ≥ 160:1	1.20E+03:1
Criteria #3	Pu-239 Equivalent ≤ 0.59 g/gal	1.04E-01 g/gal
Criteria #4	Eq. U-235 ≤ 0.93 wt%	7.11E-01%

3.2.7 **Glass Solubility** (DWPF WAC 5.4.7)

The concentration of the elements shown below shall not be exceeded. The results are shown below and the calculations are shown in Attachment 9.

Since these limits are applied on a glass basis, they are uniquely dependent upon the waste loading. As such, the waste loading utilized as the input to this calculation is a parameter which is procedurally limited to ensure each of these limits is satisfied.
As has been done in previous evaluations, DWPF Facility Engineering will target waste loading to attain an actual waste loading of 36%. Thus, qualifying the batch with 40% waste loading or higher is conservative. Table 2 summarizes the concentration of the oxides for the coupled operation of Sludge Batch 8 and Salt Batch 6D.

Table 2. Comparison of DWPF WAC Glass Solubility to Coupled Operation of Sludge Batch 8 and ISDP Salt Batch 6D

Species	Limit Wt. % in Glass	Value Wt.% in Glass	Percent Of Limit
TiO_2	2.00	0.486	24.28%
Cr_2O_3	0.30	0.050	16.74%
PO_4	3.00	0.060	1.99%
NaF	1.00	0.132	13.22%
NaCl	1.00	0.099	9.89%
Cu	0.50	0.033	6.60%
SO_4^{-2}	0.65	0.568	87.38%

3.2.8 **Corrosive Species** (DWPF WAC 5.4.8)

The concentration of SO_4^{2-} in washed sludge shall not exceed 0.058 M slurry and the concentration of Hg shall not exceed 21 g/L slurry. The sulfate concentration for the slurry is 0.0214 M for Sludge Batch 8, corresponding to a value of 36.9 % of the limit. The sulfate concentration for sludge coupled with Salt Batch 6D is 0.0250 M for a PRFT addition of 3,000 gallons, corresponding to 43.2 % of the limit. The mercury concentration for the slurry is 3.71 g/L for Sludge Batch 8, which is 17.7 % of the limit. The mercury concentration for sludge coupled with Salt Batch 6D is 9.47 g/L, corresponding to 45.1 % of the limit.

Detailed calculations for corrosive species can be found in Attachment 10.

3.2.9 **Sludge Solids Content** (DWPF WAC 5.4.9)

The sludge feed sent to DWPF has a target range of 12-19 weight percent dry total solids. The Sludge Batch 8 weight percent dry total solids was determined to be 17.21 weight percent [SRNL-STI-2013-00504]. The ARP process will transfer five weight percent total solids to the SRAT via the PRFT [X-CLC-S-00126]; however, DWPF Facility Engineering will modify the amount of sludge solids transferred to the SRAT to maintain the target of 12 to 19. DWPF Facility Engineering will perform calculations on each SRAT and SME batch to ensure the product is consistent with the design basis. Therefore, the target weight percent of 12-19 will be monitored per SRAT batch basis.

3.2.10 **Glass Quality and Processability** (DWPF WAC 5.4.10)

SRNL verified the quality and processability of Sludge Batch 8 material. The sample was processed at SRNL to match the planned processing in ESP for DWPF. A glass variability study was performed for SB8 prior to vitrifying the glass at SRNL by Vitreous State Laboratory (VSL) [VSL-13R2580-1]. The study demonstrated applicability of the current durability models to the SB8 composition region of interest as well as acceptability of the SB8 glasses with respect to the Environmental Assessment (EA) glass. A frit recommendation for SB8 was made from the glass variability study—Frit 803 [SRNL-L3100-2012-00195]. Frit 803 was used to make glass with the prepared sludge based on the SRNL recommendation for qualification [SRNL-STI-2013-00116]. The targeted waste loading was 36 weight percent sludge oxides [SRNL-STI-2013-00116].

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-91-116-6, WSRC-STI-2006-00014] and met the durability standards by a wide margin. 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 8 [VSL-13R2580-1]. There are minimal impacts (e.g., minimum compositional changes) on the DWPF flowsheet from these two streams compared to the sludge stream.

As the waste loading increases, there is the potential of being out of the variability study ranges. The glass model and validation ranges have been reviewed. Because of the coupling of Na_2O effects with Al_2O_3, Fe_2O_3, B_2O_3 and SiO_2 individual ranges (model and/or validation ranges), the glass composition must be within the range for all constituents of concern including but not limited to Na_2O, Al_2O_3, Fe_2O_3, B_2O_3, and SiO_2 [MRS Symposium Volume 1107]. The PCCS model will demonstrate the acceptability of the glass. A PRFT addition of 3,000 gallons is recommended initially. The WL range from 32 to 41 wt% was evaluated and determined to have acceptable glass quality; however, with increased waste loading the Na_2O is above the EA glass. Each PRFT may be sampled and a calculation performed to confirm an increase of the allowable amount meets the requirements of the glass quality and processability constraints.

Table 3. Comparison of DWPF Glass Quality and Processability for 32% WL

Attribute	Limit	Value	Evaluation
Boron Leach Rate	≤16.70 g/L	1.892	Passes
Lithium Leach Rate	≤ 9.57 g/L	1.655	Passes
Sodium Leach Rate	≤ 13.35 g/L	1.797	Passes
Liquidus Temp.	≤1050° Celsius	775.1	Passes
High Viscosity	≤110 poise	52.2	Passes
Low Viscosity	≥ 20 poise	52.2	Passes
Homogeneity Constraint	$Al_2O_3 \geq 4$ wt% **OR**	4.949	Passes
Homogeneity Constraint	$Al_2O \geq 3$ 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	$SiO_2 / (SiO_2 + Na_2O + Al_2O_3) > 0.62$	0.726	Passes

Table 4. Comparison of DWPF Glass Quality and Processability for 36% WL

Attribute	Limit	Value	Evaluation
Boron Leach Rate	≤16.70 g/L	2.357	Passes
Lithium Leach Rate	≤ 9.57 g/L	1.978	Passes
Sodium Leach Rate	≤ 13.35 g/L	2.211	Passes
Liquidus Temp.	≤1050° Celsius	812.6	Passes
High Viscosity	≤110 poise	39.5	Passes
Low Viscosity	≥ 20 poise	39.5	Passes
Homogeneity Constraint	$Al_2O_3 \geq 4$ wt% **OR**	5.576	Passes
Homogeneity Constraint	$Al_2O \geq 3$ 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	$SiO_2 / (SiO_2 + Na_2O + Al_2O_3) > 0.62$	0.699	Passes

Table 5. Comparison of DWPF Glass Quality and Processability for 40% WL

Attribute	Limit	Value	Evaluation
Boron Leach Rate	≤16.70 g/L	2.999	Passes
Lithium Leach Rate	≤ 9.57 g/L	2.404	Passes
Sodium Leach Rate	≤ 13.35 g/L	2.775	Passes
Liquidus Temperature -	≤1050° Celsius	874.6	Passes
High Viscosity	≤110 poise	28.7	Passes
Low Viscosity	≥ 20 poise	28.7	Passes
Homogeneity Constraint	$Al_2O_3 \geq 4$ wt% **OR**	6.206	Passes
Homogeneity Constraint	$Al_2O \geq 3$ 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	$SiO_2 / (SiO_2 + Na_2O + Al_2O_3) > 0.62$	0.671	Passes

3.2.11 H_2 Generation/N_2O Concentration (DWPF WAC 5.4.11)

The WAC criteria for hydrogen generation rate in the SRAT shall not exceed 0.65 lb/hr for 6,000 gallons of SRAT product and the Slurry Mix Evaporator (SME) shall not exceed 0.223 lb/hr for 6,000 gallons of SME product. The nitrous oxide concentration in the SRAT vapor space shall not exceed 15 volume percent.

The criteria were met during Shielded Cells testing at SRNL for Sludge Batch 8 [SRNL-STI-2013-00116]. The SRAT cycle during the Shielded Cells run yielded a hydrogen generation rate of 0.028 lb/hr and a nitrous oxide concentration of 3.5 volume percent [SRNL-STI-2013-00116]. The SME cycle during the Shielded Cell run yielded a hydrogen generation rate of 0.028 lb/hr [SRNL-STI-2013-00116].

SRNL has performed simulated Sludge Batch 8 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 8. Simulated DWPF sludge with the ARP/MCU additions did not negatively impact DWPF processing [SRNL-STI-2013-00243, SRNL-L3100-2013-00030].

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 1.22E-05 ft^3 H_2/hr-gallon for Sludge Batch 8. This calculated value is 13.6 percent of the DWPF WAC limit of 8.95E-05 ft^3 H_2/hr-gallon.

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 Strip Effluent Feed Tank (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, SRNL-L3100-2013-00030]. The organic material is negligible in Salt Batch 6D, as shown in X-ESR-H-00501 for ARP/MCU.

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 and shall be tracked and characterized by the sending facility prior to entering the DWPF CPC.
b) Strip effluent with the Next Generation Solvent (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

and shall be tracked and characterized by the sending facility prior to entering the DWPF CPC.

c) The boric acid concentration for the Strip Effluent with NGS or a blend of the two solvents shall be ≤ 0.0125M
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.

To account for analytical uncertainty, each SEHT transfer produced under the NGS Flowsheet will be verified that the equivalent volume nearest DWPF 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]. 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. Sludge Batch 8 coupled processing does not contain a non-sludge or non-salt stream.

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 gram per cubic meter of glass. DOE required that DWPF control waste loading such that the total concentration of the specified radionuclides is less than 897 grams per cubic meter [WDPD-10-20]. This limit was set to be consistent with the License Application for Yucca Mountain. 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. During initial processing of Sludge Batch 8 (i.e., prior to analysis of the

Sludge Batch 8 WAPS sample and obtaining the Sludge Batch 8 SME production data), DWPF Facility Engineering will monitor and calculate fissile loading as documented in X-ESR-S-00134.

The fissile content of the MST/sludge solids stream is insignificant compared to the sludge stream. Additionally, the only radionuclide of interest in the strip effluent stream is Cs-137 which is non-fissile.

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Attachment 1: Inhalation Dose Potential to Meet the 512-S Requirement (DWPF WAC 5.3.2)

Method 1

Radionuclide	512-S Feed Concentration (pCi/mL)	512-S Feed Concentration (Ci/gal)	Dose Potential CEDE DCF (rem/Ci)	512-S Feed IDP (rem/gal)
Sr-90	1.85E+05	7.00E-04	8.90E+04	6.23E+01
Total Alpha	9.97E+03	3.77E-05	1.70E+08	6.42E+03
512-S Feed Total Dose (rem/gal)				**6.48E+03**
512-S Feed WAC limit (rem/gal)				**3.00E+06**
% of WAC limit				**0.216%**

Method 2

Radionuclide	512-S Feed Concentration (pCi/mL)	512-S Feed Concentration (Ci/gal)	Dose Potential CEDE DCF (rem/Ci)	512-S Feed IDP (rem/gal)
Sr-90	1.85E+05	7.00E-04	8.90E+04	6.23E+01
Ru-106	1.30E+02	4.92E-07	2.40E+05	1.18E-01
Cs-137	5.83E+07	2.21E-01	1.90E+04	4.19E+03
Ce-144	1.22E+02	4.62E-07	2.00E+05	9.24E-02
Pm-147	1.16E+02	4.39E-07	1.90E+04	8.34E-03
Pu-238	1.27E+04	4.81E-05	1.70E+08	8.17E+03
Pu-239	1.25E+03	4.73E-06	1.90E+08	8.99E+02
Pu-240	1.25E+03	4.73E-06	1.90E+08	8.99E+02
Pu-241	4.39E+03	1.66E-05	3.30E+06	5.48E+01
Am-241	3.40E+01	1.29E-07	1.60E+08	2.06E+01
Cm-244	3.90E+01	1.48E-07	1.00E+08	1.48E+01
512-S Feed Total Dose (rem/gal)				**1.43E+04**
512-S Feed WAC limit (rem/gal)				**3.00E+06**
% of WAC limit				**0.47%**

Data from X-ESR-H-00501.
Dose Potential committed effective dose equivalent (CEDE) DCF references are defined in the DWPF WAC (X-SD-G-00008).

Attachment 1 (continued): Inhalation Dose Potential to Meet the 512-S Requirement (DWPF WAC 5.3.2)

Determination of bounding concentration of the ARP product stream using the methodology in N-ESR-S-00004.

Minimum possible sludge solids: 0 ppm sludge solids in the salt feed [N-ESR-S-00004]
Density of Salt Batch 6D: 1304 g/L [SRNL-STI-2013-00437]
ARP contribution: 0.2 g/L MST
Wt% solids of ARP product at concentration end point: 6 wt% [N-ESR-S-00004]
This is conservative as 512-S only concentrates to 5 wt% for field operations.

Amount in the LWPT for each batch

0.2 g/L MST + (0 ppm sludge solids * 1 g solids/1.0E+06 total slurry mass * 1340 g/L) = 0.2 g/L

Amount in the LWPT at concentration end point of 6 wt%

1304 g/L * (6 wt% / 100) = 78.24 g/L

Concentration Factor is the LWPT at concentration end divided by the LWPT for each batch

78.24 g/L / 0.2 g/L = 391.2

Method 1

Radionuclide	512-S Feed Concentration (pCi/mL)	512-S Feed Concentration (Ci/gal)	512-S MST/SS Concentration (Ci/gal)	Dose Potential CEDE DCF (rem/Ci)	512-S MSS/SS IDP (rem/gal)
Sr-90	1.85E+05	7.00E-04	2.74E-01	8.90E+04	2.44E+04
Total Alpha	9.97E+03	3.77E-05	1.48E-02	1.70E+08	2.51E+06
512-S MST/SS Total Dose (rem/gal)					**2.53E+06**
512-S MST/SS WAC Limit (rem/gal)					**1.24E+08**
% of WAC limit					**2.04%**

Attachment 1 (continued): Inhalation Dose Potential to Meet the 512-S Requirement (DWPF WAC 5.3.2)

Method 2

Radionuclide	512-S Feed Concentration (pCi/mL)	512-S Feed Concentration (Ci/gal)	512-S MST/SS Concentration (Ci/gal)	Dose Potential CEDE DCF (rem/Ci)	512-S MST/SS IDP (rem/gal)
Sr-90	1.85E+05	7.00E-04	2.74E-01	8.90E+04	2.44E+04
Ru-106	1.30E+02	4.92E-07	1.92E-04	2.40E+05	4.62E+01
Cs-137*	5.83E+07	2.21E-01	2.21E-01	1.90E+04	4.19E+03
Ce-144	1.22E+02	4.62E-07	1.81E-04	2.00E+05	3.61E+01
Pm-147	1.16E+02	4.39E-07	1.72E-04	1.90E+04	3.26E+00
Pu-238	1.27E+04	4.81E-05	1.88E-02	1.70E+08	3.20E+06
Pu-239	1.25E+03	4.73E-06	1.85E-03	1.90E+08	3.52E+05
Pu-240	1.25E+03	4.73E-06	1.85E-03	1.90E+08	3.52E+05
Pu-241	4.39E+03	1.66E-05	6.50E-03	3.30E+06	2.15E+04
Am-241	3.40E+01	1.29E-07	5.03E-05	1.60E+08	8.05E+03
Cm-244	3.90E+01	1.48E-07	5.77E-05	1.00E+08	5.77E+03
512-S MST/SS Total Dose (rem/gal)					**3.96E+06**
512-S MST/SS WAC Limit (rem/gal)					**1.24E+08**
% of WAC limit					**3.20%**

*Note: As Cs-137 is not concentrated at 512-S and processed at MCU for cesium extraction in the SE product stream to DWPF, the Cs-137 value is not concentrated for IDP limit for the MST/sludge solids stream.
Data from X-ESR-H-00501.
Dose Potential committed effective dose equivalent (CEDE) DCF references are defined in the DWPF WAC (X-SD-G-00008).

Attachment 2: Hydrogen Generation Rate from Salt Batch 6D Material for 512-S
(DWPF WAC 5.3.4)

Radionuclide	Results (pCi/mL)	Results (Ci/gal)	"Q" Value (W/Ci)	R (ft^3 $H_2/10^6$ BTU)	Heat Generation (W/gal)	Hydrogen Generation (ft^3 H_2/ hr/gal)
Co-60	4.89E+00	1.85E-08	1.54E-02	48.36	2.85E-10	4.71E-14
Y-90	1.85E+05	7.00E-04	5.54E-03	48.36	3.88E-06	6.40E-10
Sr-90	1.85E+05	7.00E-04	1.16E-03	48.36	8.12E-07	1.34E-10
Rh-106	1.30E+02	4.92E-07	1.89E-02	48.36	9.32E-09	1.54E-12
Sb-125	1.30E+02	3.90E-07	3.37E-03	48.36	1.31E-09	2.17E-13
Cs-134	1.03E+02	2.25E-05	1.02E-02	48.36	2.29E-07	3.79E-11
Cs-137	5.95E+03	2.21E-01	1.01E-03	48.36	2.23E-04	3.68E-08
Ba-137m	5.83E+07	2.09E-01	3.94E-03	48.36	8.23E-04	1.36E-07
Ce-144	5.52E+07	4.62E-07	6.58E-04	48.36	3.04E-10	5.01E-14
Pr-144	1.22E+02	4.62E-07	7.33E-03	48.36	3.39E-09	5.59E-13
Pm-147	1.22E+02	4.39E-07	3.67E-04	48.36	1.61E-10	2.66E-14
Eu-154	1.16E+02	5.53E-08	9.08E-03	48.36	5.02E-10	8.28E-14
Pu-238	1.46E+01	4.81E-05	3.26E-02	134.7	1.57E-06	7.20E-10
Pu-239	5.08E+01	4.73E-06	3.02E-02	134.7	1.43E-07	6.58E-11
Pu-240	1.44E+02	4.73E-06	3.06E-02	134.7	1.45E-07	6.65E-11
Am-241	2.62E-01	1.29E-07	3.28E-02	134.7	4.22E-09	1.94E-12
Cm-244	1.27E+04	1.48E-07	3.44E-02	134.7	5.07E-09	2.33E-12
Total (ft^3 H_2/hr/gal)						**1.74E-07**
512-S WAC limit (ft^3 H_2/hr/gal)						**1.64E-06**
% of WAC limit						**10.63%**

Data from X-ESR-H-00501.
R values are defined in the DWPF WAC (X-SD-G-00008).
Q values are defined in DOE/RW-0006.
1 BTU/hr = 2.93E-01 W

Attachment 3: 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 larger concentration between the supernate or slurry basis is used for conservatism.

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

	Result*	**Sludge Batch Result (M)**	**Factor**	**NO_x Contribution**
Hydroxide	0.194 mol/kg	2.25E-01	0.70	1.58E-01
Carbonate**	1180 mg/kg	2.28E-02	1.40	3.19E-02
Nitrite	0.312 M	3.12E-01	1.86	5.80E-01
Nitrate	0.140 M	1.40E-01	1.00	1.40E-01
Manganese ion*	5.29 wt%	1.92E-01	0.84	1.61E-01
Mercury ion*	1.86 wt%	1.85E-02	0.70	1.30E-02
NO_x emission				**1.08E+00**
NO_x Total (tons/yr) (NO_x total = 19.1 * NO_x emission)				**20.71**
DWPF WAC Limit (tons/yr)				**103.52**
% of Limit				**20.00%**

Data from SRNL-STI-2013-00504
* Manganese and mercury ion were determined using elemental data.
**Carbonate was determined from TIC values.

Data from SRNL-STI-2013-00504.
Mn = 5.29 wt% dry solids TS = 17.21 wt%
Hg = 1.86 wt% dry solids SG = 1.16 kg/L

Converting wt% dry solids to Molarity in slurry
M slurry = wt% dry solids/100*wt% total solids/100*SpG slurry*1000/MW
Mn = 5.29/100 * 17.21/100 * 1.16kg/L * 1000g/kg / 54.94 g/mol = 1.92E-01 M

Hydroxide = 0.194 mol/kg * 1.16 kg/L = 2.25E-01 M

Carbonate = 1180 mg/kg / 1000 mg/g / 60 g/mol * 1.16 kg/L = 2.28E-02 M

Sludge Only NO_x Emission

DWPF	**20.71 tons/year**
WAC LIMIT	**103.52 tons/year**
Percent of Limit	**20.0%**

Attachment 3 (continued): NO_x Emissions (DWPF WAC 5.4.1)

The same principle is used in determining the ARP contribution. The factor of 19.1 is not applicable. The ARP process is expected to feed DWPF at a rate of 0.151 gallon/min or 3.00E+05 L/yr [X-CLC-S-00113]. The NO_x emissions factor will lead to a total molarity of NO_x. Nitrogen dioxide's molecular weight (46 g/mol) is used to convert to g/L.

	Salt Batch Result	**Result (M)**	**Factor**	**NO_x Contribution (M)**
Hydroxide*	7.97E-01 M	7.97E-01	0.70	5.58E-01
Carbonate*	3.99E-01 M	3.99E-01	1.40	5.58E-01
Nitrite*	8.63E-02 M	8.63E-02	1.86	1.60E-01
Nitrate*	3.70E-01 M	3.70E-01	1.00	3.70E-01
Manganese ion**	1.63E+02 mg/L	2.97E-03	0.84	2.49E-03
Mercury ion**	1.92E+04 mg/L	9.58E-02	0.70	6.71E-02
Total NO_x contribution (M)				**1.72E+00**
Total NO_x contribution (g/L)				**7.89E+01**

*Data from Attachment 13.

** Data from X-ESR-H-00501. A conservative concentration factor of 373.2 (no sludge solids case) was determined in Attachment 2 using the methodology described in N-ESR-S-00004 for the 512-S MST/Sludge Solids [N-ESR-S-00004].

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 in gallons per minute can be found in Attachment 13.

NO_x = 7.89E+01 g/L * 0.0856 gal/min * 3.785 L/gal * 60 min/hr * 24 hrs/day * 365 days/ yr * lb/453.6 grams * tons/2000 lbs

The total NO_x contribution by ARP is 14.82 tons/year.

Total NO_x Emission

DWPF	**20.71 tons/year**
ARP	**14.82 tons/year**
TOTAL	**35.53 tons/year**
WAC LIMIT	**103.52 tons/year**
Percent of Limit	**34.32%**

Attachment 4: 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).

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])

Species	Ci/g Dried Sludge Slurry	Ci/lb Calcined Sludge Solids	Canister Heat Generation Factors (W/Ci)	Species Contribution to Canister Heat Generation (W/ lb Calcined solids)	Percent contribution to the total Canister Heat Generation
Sr-90*,$^{\alpha}$	9.85E-03	5.86E+00	6.70E-03	3.93E-02	82.398%
Ru-106*,$^{\beta}$	1.47E-07	8.75E-05	1.95E-02	1.71E-06	0.004%
Cs-137*,$^{\alpha}$	8.52E-04	5.07E-01	4.74E-03	2.40E-03	5.042%
Ce-144*,$^{\beta}$	6.44E-07	3.83E-04	8.00E-03	3.07E-06	0.006%
U-233$^{\gamma}$	6.52E-08	3.88E-05	2.86E-02	1.11E-06	0.002%
Pu-238$^{\beta}$	1.99E-04	1.18E-01	3.26E-02	3.86E-03	8.100%
Pu-239$^{\beta}$	7.78E-06	4.63E-03	3.02E-02	1.40E-04	0.293%
Pu-240$^{\beta}$	2.82E-06	1.68E-03	3.06E-02	5.14E-05	0.108%
Am-241$^{\alpha}$	2.74E-05	1.63E-02	3.28E-02	5.35E-04	1.122%
Cm-244$^{\delta}$	6.81E-05	4.05E-02	3.44E-02	1.39E-03	2.925%
Total Species Contribution (W/lb calcined solids)					**4.75E-02**
Canister Heat Generation (W/canister)					**1.04E+02**
WAC Limit (W/canister)					**437**
% of Limit					**23.9%**

Data from SRNL-L3100-2013-00200 (α), SRNL-L3100-2013-00209 (β), SRNL-L3100-2013-00213 (γ), SRNL-L3100-2013-00237 (δ).
* These radionuclides' Decay Heat Generation (W/Ci) contain daughter products in secular equilibrium.

Ci/lb calcined sludge solids
= Ci/g dried sludge slurry * (454 g/lb) * Dried to Calcine Factor
Dried to Calcine Factor = Total Solids wt% / Calcine wt% = 17.21 / 13.13 = 1.31 [SRNL-STI-2013-00504]

Total Canister Heat Generation (sludge only)	
DWPF	**104 W/canister**
WAC LIMIT	**437 W/canister**
Percent of Limit	**23.9%**

Attachment 4 (continued): Canister Heat Generation (DWPF WAC 5.4.2)

The ARP contribution to the watts per canister

Radionuclides	Coefficients	MST - Salt Ci/Gallon	Ci	Ci/lb of Calcine Mass	Coefficients*Ci/lb Calcine Mass
Sr-90	0.0067	2.74E-01	8.22E+02	5.50E-01	3.68E-03
Ru-106	0.0195	1.92E-04	5.77E-01	3.86E-04	7.53E-06
Cs-137	0.00474	2.21E-01	6.62E+02	4.43E-01	2.10E-03
Ce-144	0.008	1.81E-04	5.42E-01	3.63E-04	2.90E-06
U-233	0.0286	2.13E-04	6.40E-01	4.28E-04	1.22E-05
Pu-238	0.0326	1.88E-02	5.64E+01	3.77E-02	1.23E-03
Pu-239	0.0302	1.85E-03	5.55E+00	3.72E-03	1.12E-04
Pu-240	0.0306	1.85E-03	5.55E+00	3.72E-03	1.14E-04
Am-241	0.0328	5.03E-05	1.51E-01	1.01E-04	3.31E-06
Cm-244	0.0344	5.77E-05	1.73E-01	1.16E-04	3.99E-06
Total (Watts/ lb Calcine Mass)					**7.27E-03**
Canister Heat Generation (Watts/ Canister) (Total*2200)					**1.60E+01**

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

To perform the Salt Batch 6D evaluation for the ARP contribution, X-ESR-H-00501 was used. This data was converted to a Ci/gallon basis by multiplying concentrations provided in X-ESR-H-00501 by:

- A conversion factor for pCi or Ci (1.0E+12 pCi = 1.0 Ci)
- Multiplying by conversion factor for mL to gallons (3785 mL = 1 gallon), and
- A conservative concentration factor of 391.2 (no sludge solids case) was determined and documented in Attachment 1 of this report. This is calculated using the methodology described in N-ESR-S-00004 (NOTE: per N-ESR-S-00004, Cs-137 is not multiplied by this factor) for the IDP limit for 512-S MST/sludge solids.

An example using Sr-90 is provided below.
Per X-ESR-H-00501, Sr-90 = 1.85E+05 pCi/mL

Sr-90 Ci per gallon = 1.85E+05 pCi/mL * (1 Ci/1.0E+12 pCi) * 3785 mL/gal * 391.2 = 2.74E-01 Ci/gallon

To determine the total Curies, the volume of PRFT generated in one week must be determined. 3,000 gallons of PRFT per SRAT batch is recommended. An example of this conversion is shown below using Sr-90:

Sr-90 Ci = 2.74E-01 Ci/gal * 3,000 gallon = 8.22E+02 Ci

This volume is then converted to pounds of calcine mass by using Attachment 13. This calculation for conversion to pounds of calcine mass is shown below:
Lbs of Calcine Mass = 3,000 gallons * 3.785 L/gallon * 1.07 kg/L * 2.2046 lb/kg * 5.60 wt% calcine / 100 = 1,494 lb Calcine Mass

Attachment 4 (continued): Canister Heat Generation (DWPF WAC 5.4.2)

The total curies are divided by the calcine mass of PRFT to provide a Ci/Calcine mass basis. An example of this conversion is shown below for Sr-90.

Sr-90 Ci per lb Calcine Mass = 8.22E+02 Ci / 1,494 lbs Calcine Mass = 5.50E-01 Ci/lb Calcine Mass

Sr-90 W / lb Calcine Mass = 5.50E-01 Ci/lb Calcine Mass *0.0067 = 3.68E-03 W / lb Calcine Mass

<u>The MCU contribution to the watts per canister</u>

Radionuclides	**Coefficients**	**Strip Effluent Ci/Gallon**	**Ci**	**Ci/lb of Calcine Mass**	**Coeff*Ci/Lb = Watts/Lb Calcine Mass**
Cs-137	0.00474	3.31E+00	4.96E+04	3.72E+00	1.76E-02
Total					**1.76E-02**
Canister Heat Generation (Total*2200)					**3.88E+01**

*Note: Concentration Factor of 15 Applied.

To perform the MCU piece of the Salt Batch 6D evaluation, X-ESR-H-00501 was used. This data was converted to a Ci/Gallon basis by the methodology described above for Sr-90 (Note: Concentration Factor of 391.2 not applied). For MCU, the Cs-137 concentration factor is limited to 15 [X-SD-G-00008]. Thus, the Ci/Gallon for Cs-137 was multiplied by this factor. To obtain the total curies the Cs-137 Ci/gallon value was multiplied by 15,000 gallons [X-ESR-S-00105]. This is currently the maximum allowable amount of strip effluent that can be added to one SRAT batch. The calcined mass of 13,344 pounds for one SRAT batch was used. The calcined mass was derived from the following data:

Calcine Mass= 10,500 gallons * 3.785 L/gallon * 1.16 Kg/L * 17.21 Kg calcine/Kg slurry * 2.2045 Lbs/Kg = 13,344 Lbs

Where:
Volume of SRAT = 10,500 gallon [X-SD-G-00008, Section 5.4.6]
Density of SRAT = 1.16 Kg/L [SRNL-STI-2013-00504]
Calcine Wt.% Solids = 17.21 wt.% [SRNL-STI-2013-00504]

<u>Total Canister Heat Generation</u>

DWPF:	**104.4 W/canister**
ARP:	**16.0 W/canister**
MCU:	**38.8 W/canister**
Total:	**159.2 W/canister**
WAC LIMIT	**437 W/canister**
Percent of Limit	**36.4%**

Attachment 5: Gamma Shielding at DWPF (DWPF WAC 5.4.3)

Species	µCi/g dried sludge	Gamma Dose Constant (mR/hr/µCi)	Gamma Source Strength (mR/hr/g)	Gamma Source Strength (mR/hr/gal)
Co-60[α]	1.25E+00	1.37E-03	1.71E-03	1.29E+00
Ru-106[β]	1.47E-01	1.38E-04	2.03E-05	1.53E-02
Sb-125[α]	1.28E-01	3.80E-04	4.86E-05	3.68E-02
Cs-134[γ]	3.84E-01	9.99E-04	3.84E-04	2.90E-01
Cs-137[α]	8.52E+02	3.82E-04	3.25E-01	2.46E+02
Ce-144[β]	6.44E-01	2.33E-05	1.50E-05	1.13E-02
Eu-154[α]	1.11E+01	7.56E-04	8.39E-03	6.34E+00
Eu-155[δ]	1.59E+00	6.67E-05	1.06E-04	8.01E-02
Pu-238[β]	1.99E+02	7.90E-05	1.57E-02	1.19E+01
Gamma Source Strength (mR/hr/g)				**3.52E-01**
Gamma Source Strength (mR/hr/gal)				**2.66E+02**

Data from SRNL-L3100-2013-00200 (α), SRNL-L3100-2013-00209 (β), SRNL-L3100-2013-00213 (γ), SRNL-L3100-2013-00237 (δ).

Wt% Total Solids (TS) = 17.21 [SRNL-STI-2013-00504]
Wt% Insoluble Solids (IS) = 11.32 [SRNL-STI-2013-00504]
Specific Gravity of Slurry = 1.16 [SRNL-STI-2013-00504]

Gamma Source Strength (mR/hr/gal) = mR/hr/g*(Grams dried solids/gallon of slurry)
Grams dried solids/gallon of slurry = SpG slurry * 1000 * 3.785 * (wt% total solids/100)
= 1.16 * 1000 * 3.785 * (17.21 /100) = 755.6 g/gal

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 (17.21 / 11.32) [SRNL-STI-2013-00504].

Gamma Source Strength = 3.52E-01 * (1.52) = 5.35E-01 mR/hr/g insoluble solids

Gamma Source Strength	**2.66E+02 mR/hr/gallon**
WAC LIMIT	**4070 mR/hr/gallon**
Percent of Limit	**6.53%**

Gamma Source Strength	**5.35E-01 mR/hr/g insoluble solids**
WAC LIMIT	**3.7 mR/hr/g insoluble solids**
Percent of Limit	**14.5%**

Attachment 5 (continued): Gamma Shielding at DWPF (DWPF WAC 5.4.3)

To perform the Salt Batch 6D evaluation, the Cs-137 data from X-ESR-H-00501 was used.

Radioisotope	pCi/mL	Ci/gal
Cs-137	5.83E+07	2.21E-01

Gamma Source Strength **2.21E-01 Ci/Gallon**
WAC LIMIT **1.11 Ci/Gallon**
Percent of Limit **19.9%**

The MCU contribution is determined by multiplying the Cs-137 concentration by a concentration factor of 15 (X-SD-G-00008).

Maximum Cs-137 concentration
= Cs-137 concentration * concentration factor
= 2.21E-01 Ci/gal * 15 = 3.31E+00 Ci/gal

A Cs-137 concentration of 3.31 Ci/gal is 20.1 percent of the DWPF limit of 16.5 Ci/gal for Cs-137 in the SE.

Attachment 6: Neutron Shielding (DWPF WAC 5.4.4)

The total alpha concentration is determined by added the concentration of the individual alpha contributors.

Radionuclides	Ci/g TS	Ci/gal
U-233$^{\gamma}$	6.52E-08	4.91E-05
U-234$^{\gamma}$	5.25E-08	3.95E-05
U-235$^{\gamma}$	5.20E-10	3.92E-07
U-236$^{\gamma}$	1.06E-09	8.01E-07
U-238$^{\gamma}$	1.25E-08	9.41E-06
Pu-238$^{\beta}$	1.99E-04	1.50E-01
Pu-239$^{\beta}$	7.78E-06	5.86E-03
Pu-240$^{\beta}$	2.82E-06	2.13E-03
Am-241$^{\beta}$	2.74E-05	2.06E-02
Cm-244$^{\delta}$	6.81E-05	5.13E-02
Cm-245$^{\delta}$	1.08E-08	8.15E-06
Total Alpha	**3.05E-04**	**2.30E-01**

Data from SRNL-L3100-2013-00200 (α), SRNL-L3100-2013-00209 (β), SRNL-L3100-2013-00213 (γ), SRNL-L3100-2013-00237 (δ).

The contribution from the sludge is the following:
Total Alpha = 3.05E-04 Ci/g TS

Total Solids (TS) = 17.21 wt% [SRNL-STI-2013-00504]
Insoluble Solids (IS) = 11.32 wt% [SRNL-STI-2013-00504]

Ci/g insoluble solids

= 3.05E-04 Ci/g TS * (17.21 TS/ 11.32 IS)
= 4.64E-04 Ci/g insoluble solids

Neutron Shielding **4.64E-04 Ci/g insoluble solids**
WAC LIMIT **1.50E-03 Ci/g insoluble solids**
Percent of Limit **30.9%**

Attachment 7: Inhalation Dose Potential to Meet the DWPF Requirement (DWPF WAC 5.4.5)

The Sludge Batch 8 contribution to the IDP WAC limit.

Method 1

Radionuclide	Concentration (Ci/gal)	Dose Potential CEDE DCF (rem/Ci)	IDP (rem/gal)
Sr-90[α]	7.42E+00	8.90E+04	6.60E+05
Total Alpha*	2.30E-01	1.70E+08	3.91E+07
Total Dose (rem/gal)			**3.98E+07**
DWPF WAC limit (rem/gal)			**2.47E+08**
% of WAC limit			**16.1%**

* As seen in Attachment 6.

Method 2

Radionuclide	Concentration (Ci/gal)	Dose Potential CEDE DCF (rem/Ci)	IDP (rem/gal)
Sr-90[α]	7.42E+00	8.90E+04	6.60E+05
Ru-106[β]	1.11E-04	2.40E+05	2.66E+01
Cs-137[α]	6.42E-01	1.90E+04	1.22E+04
Ce-144[β]	4.85E-04	2.00E+05	9.70E+01
Pm-147[β]	9.43E-02	1.90E+04	1.79E+03
Pu-238[γ]	1.50E-01	1.70E+08	2.55E+07
Pu-239[γ]	5.86E-03	1.90E+08	1.11E+06
Pu-240[β]	2.13E-03	1.90E+08	4.05E+05
Pu-241[γ]	3.25E-05	3.30E+06	1.07E+05
Am-241[α]	2.06E-02	1.60E+08	3.30E+06
Cm-244[δ]	5.13E-02	1.00E+08	5.13E+06
Total Dose (rem/gal)			**3.62E+07**
DWPF WAC limit (rem/gal)			**2.47E+08**
% of WAC limit			**14.7%**

Data from SRNL-L3100-2013-00200 (α), SRNL-L3100-2013-00209 (β), SRNL-L3100-2013-00213 (γ), SRNL-L3100-2013-00237 (δ).
Dose Potential CEDE DCF references are defined in the DWPF WAC (X-SD-G-00008).

Attachment 8: Nuclear Criticality Safety (DWPF WAC 5.4.6)

Sludge Batch 8 WAPS sample was used for this calculation. The following qualification 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 qualification value by subtracting two standard deviations (X-SD-G-00008).

	Wt % TS	%RSD	Average plus 2 standard deviation	Average minus 2 standard deviation
Fe*	1.69E+01	1.2	1.73E+01	1.65E+01
U-233$^{\gamma}$	6.74E-04	13.6	8.57E-04	4.91E-04
U-234$^{\gamma}$	8.41E-04	15.4	1.10E-03	5.82E-04
U-235$^{\gamma}$	2.41E-02	2.8	2.54E-02	2.28E-02
U-236$^{\gamma}$	1.64E-03	6	1.84E-03	1.44E-03
U-238$^{\gamma}$	3.72E+00	0.6	3.76E+00	3.68E+00
Pu-239$^{\gamma}$	1.25E-02	3.4	1.34E-02	1.17E-02
Pu-240*$^{\beta}$	1.24E-03	15.6	1.63E-03	8.53E-04
Am-242m$^{\beta}$	1.47E-06	37	2.56E-06	3.82E-07
Cm-244$^{\delta}$	8.42E-05	15	1.09E-04	5.89E-05
Cm-245$^{\beta}$	6.30E-06	19	8.69E-06	3.91E-06
Pu-241**$^{\gamma}$	4.19E-05	0.5	4.23E-05	4.15E-05

*For Fe, it is conservative to calculate the qualification value by subtracting two standard deviations.
**As stated in Criteria #1 below, the average wt% sample result is used in the calculation.
Radionuclides are from SRNL-L3100-2013-00200 (α), SRNL-L3100-2013-00209 (β), SRNL-L3100-2013-00213 (γ), SRNL-L3100-2013-00237 (δ). Iron results are documented in SRNL-STI-2013-00504.

For U-233, the average plus 2 RSD and average minus 2 RSD can be determined as follows:
Average wt%TS ± (2 *(RSD/100)*Average wt% TS)
6.74E-04 wt%TS ± (2 *(13.6/100)* 6.74E-04 wt% TS) = 8.57E-04 wt%, 4.91E-04 wt% TS

Criteria #1

Pu-241 in the following calculation is taken from the average weight percent sample while the Pu-240 concentration is obtained by subtracting two standard deviations from the average Pu-240 weight percent value. The calculation below is conservative.

Pu-240 to Pu-241: 8.53E-04 / 4.19E-05
= 20.4:1

Attachment 8 (continued): Nuclear Criticality Safety (DWPF WAC 5.4.6)

Criteria #2

Eq. Pu-239 = Pu-239 + Pu-241 + Cm-244 + 15(Cm-245) + 35(Am-242m)
= (1.34E-02 + 4.23E-05 + 1.09E-04 + 15 *8.69E-06 +
35 *2.56E-06) wt% dried solids
= 1.37E-02 wt% dried solids

Fe/Eq. Pu-239 = 1.65E+01 /1.37E-02 wt% = 1.20E+03:1

For Iron, a conservative value using minus 2 standard deviations is used.

Criteria #3

H-Canyon plutonium was added to Sludge Batch 8; therefore, the Eq. Pu-239 concentration of ≤0.59 g/gallon requirement does apply.

Eq. Pu-239 (g/gallon) = (wt.% Eq. Pu-239 / 100) * SpG slurry * 1000* 3.785
* (wt% total solids / 100)
= (1.37E-02 / 100) * 1.16 * 1000 * 3.785 * (17.21 / 100)
= 1.04 E-01 g/gallon

Criteria #4

To calculate % Eq. U-235 Enrichment, divide Eq. U-235 by the U concentration to calculate Eq. U-235 Enrichment:

Eq. U-235 = U-235 + 1.4 * U-233

% U-235 Enrichment = (Eq. U-235/U) * 100

U = U-233 + U-234 + U-235 + U-236 + U-238

For U, the summation of U-233, U-234, U-235, U-236, and U-238, is taken from the average sample results. Assuming % Eq. U-235 with 2 standard deviations is conservative for this calculation. This methodology is consistent with Salt Batch Criticality evaluation at 512-S [N-NCS-H-00192 and X-CLC-G-00119].

Eq. U-235 = U-235 + 1.4 * U-233 = 2.54E-02 + 1.4 * 8.57E-04 = 2.66E-02

U = U-233 + U-234 + U-235 + U-236 + U-238
U = 6.74E-04 + 8.41E-04 + 2.41E-02 + 1.64E-03 + 3.72E+00
U = 3.75E+00

% U-235 Enrichment = (2.66E-02/3.75E+00) * 100 = 7.11E-01%

Attachment 9: Glass Solubility (DWPF WAC 5.4.7)

DWPF Facility Engineering will target waste loading to attain an actual waste loading of 36 percent, thus qualifying the batch with 40 percent waste loading or higher is conservative. While 36 percent is the target, some variance in the waste loading is anticipated. In order to calculate the oxide mass during coupled operations, the calcine masses of the ARP and sludge streams are needed. Since the ARP contribution is calculated on a weekly basis in Attachment 13, the oxide contribution from the sludge stream will be put on a weekly basis. The constituents of concern are limited to TiO_2, Cr_2O_3, PO_4, NaF, NaCl, Cu, and SO_4 both from a glass quality (TiO_2, Cr_2O_3, and Cu) and safety perspective (PO_4, NaF, NaCl, and SO_4).

Determine the mass of glass; assume a waste loading of 40 percent or greater.

In order to calculate the glass solubility of certain components for Sludge Batch 8, the amount of calcine mass in Tank 40 is calculated. In this evaluation, it is assumed DWPF produces 5 canisters a week at 100% attainment using a batch process (SRAT volume of 10,500 gallons [X-SD-G-00008]. The mass of each canister is assumed at 4,000 pounds. This produces 20,000 pounds of glass a week or 9.07E+06 g/week. This mass is used to calculate weight percent for some of the insoluble species.

Determine the mass of the elementals in Sludge Batch 8

The volume of Tank 40 has a specific gravity of 1.16 kg/L, total solids weight percent of 17.21 %, and calcine solids weight percent of 13.13 % [SRNL-STI-2013-00504].

The volume of Tank 40 is determined by using the fill factor of a Type IIIA Tank 3510 gallon/inch [S-CLC-G-00235] by the level in the tank. Tank 40 level was 194.4 inches on November 22, 2013. The volume of Tank 40, therefore, is 682,344 gallons.

The mass of the sludge slurry
= Volume * (3.785 L / 1 gal) * SpG * (wt% TS / 100)
= 682,344 gal * 3.785 L / 1 gal * 1.16 kg/L * (17.21 / 100) = 515,594 kg

The PRFT sample results and flow rates are provided in Attachment 13. Attachment 13 also discusses the adjustment of the analytical data for the PRFT. Presented in a table below is the calcine mass of each of the solubility elements/compounds of concern based on the maximum gallons of PRFT to meet the sulfate limit in the glass at a waste loading of 42%— 5,200 gallons. The calcine mass for the PRFT is calculated below along with example calculations for Ti and SO_4. The Ti is the average concentration since the ARP reduced the amount of MST to the process in October 2012—5.22 wt%. Attachment 13 shows the overall average of Ti for the PRFT. The SO_4 value for this calculation is the maximum SO_4 concentration since 2011 plus 2 standard deviations.

Calcine mass of the PRFT = 3.785 L/gal * 1.036 kg/L * 5.60 kg calcine / 100 kg slurry * 5,200 gallon = 1,175 kg calcine

Attachment 9 (continued): Glass Solubility (DWPF WAC 5.4.7)

Ti kg of calcine = wt% calcine * mass of calcine = [(5.22 kg Ti/100 kg dried slurry) * 7.57 kg dried slurry / 100 kg slurry / (5.60 kg calcine TS / 100) * 100] /100 * 1,175 kg calcine = 7.06E+00 wt% calcine / 100 * 1,175 kg calcine = 83.0 kg

SO4 = 1140 mg/kg * 100 kg slurry/ 5.71 kg calcine * 1 kg/1.0E06 mg * 1,175 kg calcine = 23.9 kg SO_4

PRFT Stream	Ti	Cr	PO4	F	Cl	Cu	SO4
Wt.%*	5.22E+00	-	-	-	-	-	
mg/Kg*	-	-	5.00E+02	5.00E+02	5.03E+02	-	1.14E+03
Calcined Wt.%	7.06E+00	-	8.93E-01	8.93E-01	8.97E-01	-	2.04E+00
Total Calcine Mass (Kg) Based on 5,200 Gallons of PRFT	8.30E+01	0.00E+00	1.05E+01	1.05E+01	1.05E+01		2.39E+01

*Data Taken from Attachment 13 except Ti which is the average of Ti since October 2012.

Provided in the tables below are the concentrations based on 10,500 gallons of sludge slurry. The volume is based on X-SD-G-00008, Section 5.4.6. An example calculation is provided for Tank 40 calcine mass and TiO_2 and SO_4 calculations.

Calcine mass for Tank 40 = 3.785 L/gal * 1.16 kg/L * 13.13 kg calcine / 100 kg slurry * 10,500 gallons = 6053.1 kg calcine

Tank 40 Ti kg = 1.40E-02 kg Ti/100 kg dried slurry * 17.21 kg dried slurry/100 kg slurry * 100 kg slurry / 13.13 kg calcine * 6053.1 kg calcine = 1.11 kg

Tank 40 PO_4 = 87.0 mg/ kg * 100 kg slurry/13.13 kg calcine * 1 kg/1.0E+06 mg * 6053.3 kg calcine = 4.01 kg

Tk 40 Sludge Stream	Ti	Cr	PO4	F	Cl	Cu	S
Wt.%*	1.40E-02	7.29E-02	-	-	-	7.00E-02	3.44E-01
mg/Kg*	-	-	8.70E+01	8.70E+01	8.70E+01	-	-
Total Calcine wt%	1.84E-02	9.56E-02	6.63E-02	6.63E-02	6.63E-02	9.17E-02	4.51E-01
Total Calcine Mass (Kg) Based on 10,500 Gallons of Sludge Slurry	1.11E+00	5.78E+00	4.01E+00	4.01E+00	4.01E+00	5.55E+00	2.73E+01

*Data from SRNL-STI-2013-00504

To convert elemental masses to an oxide basis, the following conversion factors can be used:

Conversion	Ratio of Molecular Weights to Multiply
Ti to TiO_2*	=79.878/47.88=1.668
Cr to Cr_2O_3**	=151.99/52/2=1.461
F to NaF*	=41.99/19 = 2.210
Cl to NaCl*	= 58.44/35.45=1.649
S to SO_4*	=96.06/32.06=2.996

Attachment 9 (continued): Glass Solubility (DWPF WAC 5.4.7)

Based on this information and the elemental information (presented above), the total kilograms of each analyte can be calculated for the sludge with PRFT material. These calculations are found below:

Total TiO_2 (PRFT + Tank 40) Kg = 83 Kg * 1.668 + 1.11 Kg * 1.668= 138 Kg + 1.85 Kg = 140 Kg

Total TiO_2 (Sludge Only) Kg = 1.11 Kg * 1.668 = 1.85 Kg

Total Cr_2O_3 (PRFT + Tk 40 Sludge) = 0 Kg* 1.461 + 5.78 Kg * 1.461 = 0 Kg + 8.45 Kg = 8.45 Kg

Total Cr_2O_3 (Sludge Only) = 5.78 Kg * 1.461 = 8.45 Kg

Total PO_4 (PRFT + Tk 40 Sludge) = 4.01 Kg + 10.5 Kg = 14.5 Kg

Total PO_4 (Sludge Only) = 4.01 Kg

Total NaF (PRFT + Tk 40 Sludge) Kg = 10.5 Kg * 2.210 + 4.01 Kg * 2.210 = 8.86 Kg + 8.86 Kg = 32.1 Kg

Total NaF (Sludge Only) Kg = 4.01 Kg* 2.210 = 8.86 Kg

Total NaCl (PRFT + Tk 40 Sludge) Kg = 10.5 * 1.649 + 4.01 Kg *1.649 = 17.4 Kg + 6.61 Kg = 24.0 Kg

Total NaCl (Sludge Only) Kg = 4.01 * 1.649 = 6.61 Kg

Total Cu (PRFT + Tk 40 Sludge) = 0 Kg + 5.55 Kg = 5.55 Kg

Total Cu (Sludge Only) = 5.55 Kg

Total SO_4 (PRFT + Tk 40 Sludge) = 23.9 Kg + 27.3 Kg * 2.996 = 23.9 Kg + 81.8 Kg = 106 Kg

Total SO_4 (Sludge Only) = 27.3*2.996 Kg = 81.8 Kg

Attachment 9 (continued): Glass Solubility (DWPF WAC 5.4.7)

In order to calculate the solubility of the components listed above

Calcine mass for the Blend and PRFT = 6,053 kg calcine Tank 40 + 1,175 kg calcine PRFT = 7,228 kg calcine

To calculate a glass mass for a given waste loading, the calcine sludge mass with or without PRFT material is divided by the waste loading (WL). An example calculation is provided below along with an example for calculating the concentration of TiO_2 in glass at a given WL. This methodology was used to determine the values provided in the Sludge Only and Coupled Operation tables.

Glass Mass for Coupled Glass @ WL of 32% = 7,228kg calcine / (32 kg slurry / 100)
= 22,588 kg calcine

Coupled Operation TiO_2 @ WL of 32% = 140 kg TiO_2 / 22,588 kg calcine * 100
= 0.62 wt%

As can be seen the table below for Sludge Only Coupled Operation, a 40% WL can be achieved without exceeding the solubility limit for sulfate in the glass.

Attachment 9 (continued): Glass Solubility (DWPF WAC 5.4.7)

		Sludge Only						
WL	**Mass of Glass (kg)**	**TiO_2 (Wt.%)**	**Cr_2O_3 (Wt.%)**	**PO_4 (Wt.%)**	**NaF (Wt.%)**	**NaCl (Wt.%)**	**Cu (Wt.%)**	**SO_4 (Wt.%)**
32	22588	6.21E-01	3.74E-02	6.42E-02	1.42E-01	3.50E-02	2.94E-02	4.32E-01
33	21903	6.40E-01	3.86E-02	6.62E-02	1.46E-01	3.60E-02	3.03E-02	4.46E-01
34	21259	6.60E-01	3.98E-02	6.82E-02	1.51E-01	3.71E-02	3.12E-02	4.59E-01
35	20652	6.79E-01	4.09E-02	7.02E-02	1.55E-01	3.82E-02	3.21E-02	4.73E-01
36	20078	6.99E-01	4.21E-02	7.22E-02	1.60E-01	3.93E-02	3.30E-02	4.86E-01
37	19536	7.18E-01	4.33E-02	7.42E-02	1.64E-01	4.04E-02	3.39E-02	5.00E-01
38	19021	7.38E-01	4.44E-02	7.63E-02	1.69E-01	4.15E-02	3.49E-02	5.13E-01
39	18534	7.57E-01	4.56E-02	7.83E-02	1.73E-01	4.26E-02	3.58E-02	5.27E-01
40	18070	7.76E-01	4.68E-02	8.03E-02	1.77E-01	4.37E-02	3.67E-02	5.40E-01
41	17630	7.96E-01	4.79E-02	8.23E-02	1.82E-01	4.48E-02	3.76E-02	5.54E-01
42	17210	8.15E-01	4.91E-02	8.43E-02	1.86E-01	4.59E-02	3.85E-02	5.67E-01
43	16810	8.35E-01	5.03E-02	8.63E-02	1.91E-01	4.70E-02	3.94E-02	5.81E-01
44	16428	8.54E-01	5.15E-02	8.83E-02	1.95E-01	4.81E-02	4.04E-02	5.94E-01

Attachment 9 (continued): Glass Solubility (DWPF WAC 5.4.7)

Coupled Operations								
WL	**Mass of Glass (kg)**	**TiO_2 (Wt.%)**	**Cr_2O_3 (Wt.%)**	**PO_4 (Wt.%)**	**NaF (Wt.%)**	**NaCl (Wt.%)**	**Cu (Wt.%)**	**SO_4 (Wt.%)**
32	22588	6.21E-01	3.74E-02	6.42E-02	1.42E-01	1.06E-01	2.46E-02	4.68E-01
33	21903	6.40E-01	3.86E-02	6.62E-02	1.46E-01	1.10E-01	2.54E-02	4.83E-01
34	21259	6.60E-01	3.98E-02	6.82E-02	1.51E-01	1.13E-01	2.61E-02	4.97E-01
35	20652	6.79E-01	4.09E-02	7.02E-02	1.55E-01	1.16E-01	2.69E-02	5.12E-01
36	20078	6.99E-01	4.21E-02	7.22E-02	1.60E-01	1.19E-01	2.77E-02	5.26E-01
37	19535	7.18E-01	4.33E-02	7.42E-02	1.64E-01	1.23E-01	2.84E-02	5.41E-01
38	19021	7.38E-01	4.44E-02	7.63E-02	1.69E-01	1.26E-01	2.92E-02	5.56E-01
39	18534	7.57E-01	4.56E-02	7.83E-02	1.73E-01	1.29E-01	3.00E-02	5.70E-01
40	18070	7.76E-01	4.68E-02	8.03E-02	1.77E-01	1.33E-01	3.07E-02	5.85E-01
41	17630	7.96E-01	4.79E-02	8.23E-02	1.82E-01	1.36E-01	3.15E-02	6.00E-01
42	17210	8.15E-01	4.91E-02	8.43E-02	1.86E-01	1.39E-01	3.23E-02	6.14E-01
43	16810	8.35E-01	5.03E-02	8.63E-02	1.91E-01	1.43E-01	3.30E-02	6.29E-01
44	16428	8.54E-01	5.15E-02	8.83E-02	1.95E-01	1.46E-01	3.38E-02	6.43E-01

Attachment 9 (continued): Glass Solubility (DWPF WAC 5.4.7)

Presented below are the glass solubility limits for sludge only and coupled operations at a 40% waste loading limit. As can be seen below, sludge only and coupled glasses are below the solubility limits for specified elements.

Comparison of DWPF WAC Glass Solubility to Coupled Operation of Sludge Batch 8 and 5,200 gallons of ISDP Salt Batch 6D

	Sludge Only	Coupled Operation	WAC Limits	% of Limit	% of Limit
Element	Wt.% at 40 WL	Wt.% at 40 WL	Wt%	Sludge Only	Coupled Operation
TiO_2	0.0122	0.776	2.00	0.61%	38.82%
Cr_2O_3	0.0559	0.047	0.30	18.62%	15.59%
PO_4	0.0265	0.080	3.00	0.88%	2.68%
NaF	0.0586	0.177	1.00	5.86%	17.74%
NaCl	0.0437	0.133	1.00	4.37%	13.28%
Cu	0.0367	0.031	0.50	7.34%	6.15%
SO_4	0.5404	0.585	0.65	83.14%	89.99%

In the past, the sulfate solubility WAC is the limiting factor for processing. With the increased WAC limit for sulfate to 0.65 wt% in glass, glass quality and processability is now the limiting constraint. Therefore, while 5,200 gallons of PRFT material can be processed at a 44% WL and still be within compliance, only 3,000 gallons can be added to stay within the glass quality and processability constraint. The same methodology is used to determine the glass solubility limits for sludge only and coupled operations at a 40% waste loading limit with 3,000 gallon addition of PRFT material.

Comparison of DWPF WAC Glass Solubility to Coupled Operation of Sludge Batch 8 and 3,000 gallons of ISDP Salt Batch 6D

	Sludge Only	Coupled Operation	WAC Limits	% of Limit	% of Limit
Element	Wt.% at 40 WL	Wt.% at 40 WL	Wt%	Sludge Only	Coupled Operation
TiO_2	0.0122	0.486	2.00	0.61%	24.28%
Cr_2O_3	0.0559	0.050	0.30	18.62%	16.74%
PO_4	0.0265	0.060	3.00	0.88%	1.99%
NaF	0.0586	0.132	1.00	5.86%	13.22%
NaCl	0.0437	0.099	1.00	4.37%	9.89%
Cu	0.0367	0.033	0.50	7.34%	6.60%
SO_4	0.5404	0.568	0.65	83.14%	87.38%

Attachment 9 (continued): Glass Solubility (DWPF WAC 5.4.7)

	Sludge Only							
WL	**Mass of Glass (kg)**	**TiO_2 (Wt.%)**	**Cr_2O_3 (Wt.%)**	**PO_4 (Wt.%)**	**NaF (Wt.%)**	**NaCl (Wt.%)**	**Cu (Wt.%)**	**SO_4 (Wt.%)**
32	18916	9.80E-03	4.47E-02	2.12E-02	4.69E-02	3.50E-02	2.94E-02	4.32E-01
33	18343	1.01E-02	4.61E-02	2.19E-02	4.83E-02	3.60E-02	3.03E-02	4.46E-01
34	17803	1.04E-02	4.75E-02	2.25E-02	4.98E-02	3.71E-02	3.12E-02	4.59E-01
35	17295	1.07E-02	4.89E-02	2.32E-02	5.13E-02	3.82E-02	3.21E-02	4.73E-01
36	16814	1.10E-02	5.03E-02	2.39E-02	5.27E-02	3.93E-02	3.30E-02	4.86E-01
37	16360	1.13E-02	5.17E-02	2.45E-02	5.42E-02	4.04E-02	3.39E-02	5.00E-01
38	15929	1.16E-02	5.31E-02	2.52E-02	5.56E-02	4.15E-02	3.49E-02	5.13E-01
39	15521	1.19E-02	5.45E-02	2.58E-02	5.71E-02	4.26E-02	3.58E-02	5.27E-01
40	15133	1.22E-02	5.59E-02	2.65E-02	5.86E-02	4.37E-02	3.67E-02	5.40E-01
41	14764	1.26E-02	5.73E-02	2.72E-02	6.00E-02	4.48E-02	3.76E-02	5.54E-01
42	14412	1.29E-02	5.87E-02	2.78E-02	6.15E-02	4.59E-02	3.85E-02	5.67E-01
43	14077	1.32E-02	6.00E-02	2.85E-02	6.30E-02	4.70E-02	3.94E-02	5.81E-01
44	13757	1.35E-02	6.14E-02	2.92E-02	6.44E-02	4.81E-02	4.04E-02	5.94E-01

Attachment 9 (continued): Glass Solubility (DWPF WAC 5.4.7)

Coupled Operations								
WL	**Mass of Glass (kg)**	**TiO_2 (Wt.%)**	**Cr_2O_3 (Wt.%)**	**PO_4 (Wt.%)**	**NaF (Wt.%)**	**NaCl (Wt.%)**	**Cu (Wt.%)**	**SO_4 (Wt.%)**
32	21034	3.88E-01	4.02E-02	4.78E-02	1.06E-01	7.91E-02	2.64E-02	4.54E-01
33	20397	4.01E-01	4.14E-02	4.93E-02	1.09E-01	8.16E-02	2.72E-02	4.69E-01
34	19797	4.13E-01	4.27E-02	5.08E-02	1.12E-01	8.41E-02	2.80E-02	4.83E-01
35	19231	4.25E-01	4.40E-02	5.23E-02	1.16E-01	8.65E-02	2.89E-02	4.97E-01
36	18697	4.37E-01	4.52E-02	5.38E-02	1.19E-01	8.90E-02	2.97E-02	5.11E-01
37	18192	4.49E-01	4.65E-02	5.53E-02	1.22E-01	9.15E-02	3.05E-02	5.25E-01
38	17713	4.61E-01	4.77E-02	5.68E-02	1.26E-01	9.39E-02	3.13E-02	5.40E-01
39	17259	4.73E-01	4.90E-02	5.83E-02	1.29E-01	9.64E-02	3.22E-02	5.54E-01
40	16828	4.86E-01	5.02E-02	5.98E-02	1.32E-01	9.89E-02	3.30E-02	5.68E-01
41	16417	4.98E-01	5.15E-02	6.13E-02	1.35E-01	1.01E-01	3.38E-02	5.82E-01
42	16026	5.10E-01	5.27E-02	6.28E-02	1.39E-01	1.04E-01	3.46E-02	5.96E-01
43	15654	5.22E-01	5.40E-02	6.43E-02	1.42E-01	1.06E-01	3.55E-02	6.11E-01
44	15298	5.34E-01	5.53E-02	6.58E-02	1.45E-01	1.09E-01	3.63E-02	6.25E-01

Attachment 10: Corrosive Species (DWPF WAC 5.4.8)

The concentration of SO_4^{2-} in washed sludge shall not exceed 0.058 M slurry. The concentration of Hg shall not exceed 21 g/L slurry.

From Attachment 9 the sulfate mass can be calculated for the Tank 40. The sulfate mass contained in 10,500 gallons of Tank 40 sludge only is 81.1 kg and for Tank 40 coupled operation 106 kg, respectively per a volume of 10,500 gallons on a bounding basis adding 5,200 gallons of PRFT material to each SRAT batch and meeting the 0.65 wt% in glass for sulfate. Note: the PRFT amount is limited by the quality and thus only 3,000 gallons will be added. Based on this information the sulfate concentration can be calculated as follows:

Molarity for SO_4 for Tank 40 = 1000 g/ kg * 1gal/3.785L * mol / 96.06 g SO4 * 81.8 kg / 10,500 gallons = 2.14E-02 M

Molarity for SO_4 for Coupled Operation = 1000 g/ kg * 1gal/3.785L * mol/ 96.06 g SO4 * 106 kg /10,500 gallons = 2.77E-02 M

Using the same methodology in Attachment 9 with 3,000 gallons of PRFT, the Tank 40 only coupled is 2.50E-02 M or 43.2% of corrosive species limit for sulfate.

SO_4 M for Blend Sludge Only:	**2.14E-02 M**
WAC LIMIT:	**0.058 M**
Percent of Limit:	**36.9%**

SO_4 M for Blend with PRFT:	**2.77E-02 M**
WAC LIMIT:	**0.058 M**
Percent of Limit:	**47.7%**

Attachment 10 (continued): Corrosive Species (DWPF WAC 5.4.8)

Mercury Concentration

For the PRFT contribution, the results for Hg reported in X-ESR-H-00501 will be used. The Hg concentration will be multiplied by a volume 3,000 gallons (Attachment 13) and a concentration factor of 391.2 (Attachment 1). This mass will be added to the mass of Hg determined from the sludge only stream to determine what the Hg concentration will be for coupled operations. The concentration of Hg from the Tank 40 sludge only stream can be found in SRNL-STI-2013-00504 and assuming a volume of 10,500 gallons in a SRAT batch (X-SD-G-00008, Section 5.4.6). The calculations can be found below.

Kg Hg for PRFT = 5.15E+01 mg Hg/L * 391.2 * 3,000 gallon * 3.785 L/gal * g/1000 mg * kg/1000 g = 228.8 kg

Kg Hg for Tank 40 = 1.86 kg Hg/100 Kg dried * 17.21 kg Dried/100 kg * 1.16 kg/ L * 10,500 gallons * 3.785 L/gallons = 147.57 kg

Total Hg (PRFT + Tk 40 Sludge) = 228.8 Kg + 147.57 Kg= 376.4 Kg

g/L for sludge only = 147.574 kg Hg/10500 gallon * gal/3.785 L * 1000 g/kg = 3.71 g/L

g/L for Coupled Operation = 376.4 kg Hg/10500 gallon * gal/3.785L * 1000 g/kg = 9.47 g/L

Hg for Sludge Only:	**3.71 g/L**
WAC LIMIT:	**21 g/L**
Percent of Limit:	**17.7%**

Hg for Coupled Operation:	**9.47 g/L**
WAC LIMIT:	**21 g/L**
Percent of Limit:	**45.1%**

Attachment 11: Glass Quality and Processability (DWPF WAC 5.4.11)

Assume DWPF produces 5 canisters a week at 100% attainment. The mass of each canister is assumed at 4,000 pounds. This produces 20,000 pounds of glass a week or 9.07E+06 g/week. This mass is used to calculate weight percent for some of the insoluble species.

Determine the mass of the elementals in Sludge Batch 8

The volume of Tank 40 has a specific gravity of 1.13 kg/L, total solids weight percent of 17.21 %, and calcine solids weight percent of 13.13 % [SRNL-STI-2013-00504].

The volume of Tank 40 is determined by using the fill factor of a Type IIIA Tank 3510 gallon/inch [S-CLC-G-00235] by the level in the tank. Tank 40 level was 194.4 inches on November 22, 2013. The volume of Tank 40, therefore, is 682,344 gallons.

The mass of the sludge slurry
= Volume * (3.785 L / 1 gal) * SpG * (wt% TS / 100)
= 682,344 gal * 3.785 L / 1 gal * 1.16 kg/L * (17.21 / 100) = 515,594 kg

Calcine mass for SRAT
= Volume * (3.785 L / 1 gal) * SpG * (wt% CS / 100)
where the volume of the SRAT is assumed a nominal 6,300 gallons. Reducing the volume of sludge is conservative for quality as the NaO_2 constraint in glass is now the limiting factor.

= 6,300 gallons * 3.785 L/gal * 1.16 kg/L * 13.13 kg calcine / 100 kg slurry
= 3631.9 kg calcine

Calcine mass of the PRFT
= Volume * (3.785 L / 1 gal) * SpG * (wt% CS / 100)
= 3,000 gallons * 3.785 L/gal * 1.036 kg/L * 4.08 kg calcine / 100 kg slurry
= 479.7 kg calcine

The total calcine mass = 3631.9 kg + 479.7 kg = 4,111.6 kg

The Mass of glass for sludge only, with PRFT addition, and mass of frit are listed in the table below. An example is shown for a waste loading (WL) of 32 wt%.

Sludge only = calcine mass sludge only (based on volume of SRAT) / (WL /100)
= 3631.9 kg / (32/100) = 11350 kg

Coupled = total calcine mass with ARP addition / (WL /100)
= 4,111.6 kg / (32/100) = 12849 kg

Amount of Frit added = Mass of Glass (coupled at WL) – Calcine mass with ARP addition
= 12849 kg - 4,111.6 kg = 8737.15 kg

Attachment 11: Glass Quality and Processability (DWPF WAC 5.4.11)

Waste Loading wt%	Sludge Only kg calcined	Coupled kg calcined	Mass of Frit kg
32	11350	12849	8737
33	11006	12459	8348
34	10682	12093	7981
35	10377	11747	7636
36	10089	11421	7310
37	9816	11112	7001
38	9558	10820	6708
39	9312	10543	6431
40	9080	10279	6167
41	8858	10028	5917

The sodium value will be used as the example calculation as sodium is contained in sludge, MST sludge solids (ARP contribution), and frit.

The mass of the elemental oxide
= Calcine mass * wt. % elemental/100 * Gravimetric Factor / (wt% CS / wt% TS)

Sodium = 3631.9 kg * 1.45E+01/100 * 1.348 / (13.13 / 17.21) = 930.5 kg

Mass of Oxide with ARP contribution.
Only sodium and or titanium are added in MST/sludge solids. Sample results are provided in Attachment 13. Average values are used for sodium and titanium.
= mass of the elemental oxide + mass of sodium oxide or titanium dioxide

Mass of sodium oxide
= (wt % Na in PRFT/100) * calcine mass of PRFT /* Gravimetric Factor / (wt% CS / wt% TS for PRFT)
= 33.9/100 * 479.7 kg * 1.348 / (4.08 / 5.98) = 321.6 kg

Mass of Oxide with ARP contribution of sodium oxide
= 930.5 kg + 321.6 kg = 1252.1 kg

Mass of oxide with Frit addition
Frit is comprised of B_2O_3, Li_2O, MgO, Na_2O and SiO_2 with a weight percent of 8, 6, 0, 8, and 78, respectively for Frit 803 [X-SPP-S-00018]. The total mass of frit added was determined in the table above.
= Mass of Oxide with ARP contribution + Mass from Frit

Mass of sodium oxide
= (wt % Na_2O in Frit /100) * mass of Frit added at 32 wt% WL
= 8/100 * 8,737 = 698.97 kg

Attachment 11: Glass Quality and Processability (DWPF WAC 5.4.11)

A summary of the Frit 803 additions is show below

Waste Loading (wt%)	**mass Frit (kg)**	**B_2O_3 (kg)**	**Li_2O (kg)**	**MgO (kg)**	**Na_2O (kg)**	**SiO_2 (kg)**
32	8737	698.97	524.23	0.00	698.97	6814.97
33	8348	667.82	500.87	0.00	667.82	6511.28
34	7981	638.51	478.88	0.00	638.51	6225.44
35	7636	610.87	458.15	0.00	610.87	5955.94
36	7310	584.76	438.57	0.00	584.76	5701.42
37	7001	560.07	420.05	0.00	560.07	5460.65
38	6708	536.67	402.50	0.00	536.67	5232.55
39	6431	514.48	385.86	0.00	514.48	5016.15
40	6167	493.39	370.04	0.00	493.39	4810.57
41	5917	473.34	355.00	0.00	473.34	4615.02

Mass of oxide with Frit addition for sodium oxide at 32 wt% WL
= (930.5 kg + 321.6 kg) + 698.97 kg = 1252.1 kg + 698.97 kg = 1951.1 kg

Mass of Oxide Elemental
= Mass of oxide with Frit addition / Gravimetric Factor

Mass of Oxide Elemental for sodium oxide
= 1951.1 kg / 1.348 = 1447.4 kg

Weight Percent of Oxide Elemental
= Mass of Oxide Elemental / Total Mass of Oxide w/ Frit addition * 100
where Total Mass of Oxide w/ Frit addition is the summation of all mass oxide with frit addition (shown in table below)

Weight Percent of Oxide Elemental for sodium oxide
= 1447.4 kg / 12686.3 kg * 100 = 11.409 wt%

The elemental weight percent in glass are then statistically analyzed to determine the quality and processability of the glass using Production Composition Control System (PCCS) using target weight percent solids, weight percent calcine solids, and a density of approximately 40 weight percent, 33 weight percent, and 1.30 specific gravity, respectively. The elemental weight percent in glass shown below has significant figures required for PCCS.

Attachment 11: Glass Quality and Processability (DWPF WAC 5.4.11)

Waste Loading of 32 wt%

	wt % Elemental	Factor	Mass of Oxide (kg)	Mass of Oxide w/ ARP addition	Mass of Oxide w/ Frit addition (kg)	Mass of Oxide Elemental (kg)	wt. % Elemental (kg)
Al	6.98E+00	1.8895	627.838	627.8380	627.8380	332.2773	2.619174%
B	0	3.2199	0.0000	0.0000	698.9717	217.0802	1.711133%
Ba	3.80E-04	1.1165	0.0202	0.0202	0.0202	0.0181	0.000143%
Ca	9.68E-01	1.3992	64.4764	64.4764	64.4764	46.0809	0.363232%
Ce	2.12E-01	1.1713	11.8209	11.8209	11.8209	10.0921	0.079551%
Cr	7.29E-02	1.4616	5.0723	5.0723	5.0723	3.4703	0.027355%
Cu	7.00E-02	1.2518	4.1708	4.1708	4.1708	3.3318	0.026263%
Fe	1.69E+01	1.4297	1150.210	1150.210	1150.210	804.5110	6.341553%
K	1.06E-01	1.2046	6.0785	6.0785	6.0785	5.0460	0.039775%
La	5.18E-02	1.1728	2.8920	2.8920	2.8920	2.4659	0.019437%
Li	0	2.15253	0.0000	0.0000	524.2288	243.5409	1.919710%
Mg	2.29E-01	1.6583	18.0777	18.0777	18.0777	10.9014	0.085930%
Mn	5.29E+00	1.2912	325.1580	325.1580	325.1580	251.8262	1.985019%
Na	1.45E+01	1.348	930.4717	1252.117	1951.089	1447.3954	11.409086%
Ni	1.64E+00	1.2726	99.3530	99.3530	99.3530	78.0709	0.615393%
Pb	3.39E-02	1.0772	1.7384	1.7384	1.7384	1.6138	0.012721%
Si	1.10E+00	2.1393	35.0328	35.0328	6850.007	3201.9854	25.239631%
Ti	1.40E-02	1.6685	1.1120	85.1780	85.1780	51.0506	0.402406%
Th	8.16E-01	1.1379	44.2018	44.2018	44.2018	38.8450	0.306196%
U	3.74E+00	1.1792	209.9444	209.9444	209.9444	178.0397	1.403397%
Zn	2.67E-02	1.2447	1.5821	1.5821	1.5821	1.2710	0.010019%
Zr	6.58E-02	1.3508	4.2312	4.2312	4.2312	3.1324	0.024691%
Total Mass of Oxide w/ Frit addition (kg)					12686.3		

B Leaching:	1.892 g/L
Li Leaching:	1.655 g/L
Na Leaching:	1.797 g/L
Liquidus:	777.100 °C
Viscosity:	52.207 poise
Homogeneity:	208.808 wt% oxide
Al_2O_3:	4.949 wt% oxide
Conserv:	99.924 wt% oxide
Frit:	79.065 wt% oxide
R_2O:	19.560 wt% oxide
Nepheline:	0.726 ratio

Attachment 11: Glass Quality and Processability (DWPF WAC 5.4.11)

Waste Loading of 34 wt%

B Leaching:	1.076 g/L
Li Leaching:	1.048 g/L
Na Leaching:	1.055 g/L
Liquidus:	950.860 °C
Viscosity:	36.607 poise
Homogeneity:	226.182 wt% oxide
Al_2O_3:	8.984 wt% oxide
Conserv:	99.776 wt% oxide
Frit:	71.373 wt% oxide
R_2O:	19.716 wt% oxide
Nepheline:	0.663 ratio

Waste Loading of 35 wt%

B Leaching:	2.225 g/L
Li Leaching:	1.888 g/L
Na Leaching:	2.094 g/L
Liquidus:	805.697 °C
Viscosity:	42.449 poise
Homogeneity:	213.412 wt% oxide
Al_2O_3:	5.419 wt% oxide
Conserv:	99.961 wt% oxide
Frit:	77.075 wt% oxide
R_2O:	20.089 wt% oxide
Nepheline:	0.706 ratio

Attachment 11: Glass Quality and Processability (DWPF WAC 5.4.11)

Waste Loading of 36 wt%

B Leaching:	2.357 g/L
Li Leaching:	1.978 g/L
Na Leaching:	2.211 g/L
Liquidus:	812.575 °C
Viscosity:	39.451 poise
Homogeneity:	214.952 wt% oxide
Al_2O_3:	5.576 wt% oxide
Conserv:	99.926 wt% oxide
Frit:	76.410 wt% oxide
R_2O:	20.265 wt% oxide
Nepheline:	0.699 ratio

Waste Loading of 37 wt%

B Leaching:	2.497 g/L
Li Leaching:	2.073 g/L
Na Leaching:	2.335 g/L
Liquidus:	832.581 °C
Viscosity:	36.581 poise
Homogeneity:	216.491 wt% oxide
Al_2O_3:	5.734 wt% oxide
Conserv:	99.952 wt% oxide
Frit:	75.745 wt% oxide
R_2O:	20.442 wt% oxide
Nepheline:	0.693 ratio

Waste Loading of 38 wt%

B Leaching:	2.670 g/L
Li Leaching:	2.188 g/L
Na Leaching:	2.487 g/L
Liquidus:	832.178 °C
Viscosity:	33.840 poise
Homogeneity:	218.032 wt% oxide
Al_2O_3:	5.891 wt% oxide
Conserv:	100.282 wt% oxide
Frit:	75.080 wt% oxide
R_2O:	20.619 wt% oxide
Nepheline:	0.686 ratio

Attachment 11: Glass Quality and Processability (DWPF WAC 5.4.11)

Waste Loading of 39 wt%

B Leaching:	2.803 g/L
Li Leaching:	2.276 g/L
Na Leaching:	2.604 g/L
Liquidus:	840.561 °C
Viscosity:	31.225 poise
Homogeneity:	219.573 wt% oxide
Al_2O_3:	6.048 wt% oxide
Conserv:	99.943 wt% oxide
Frit:	74.414 wt% oxide
R_2O:	20.795 wt% oxide
Nepheline:	0.678 ratio

Waste Loading of 40 wt%

B Leaching:	2.999 g/L
Li Leaching:	2.404 g/L
Na Leaching:	2.775 g/L
Liquidus:	874.591 °C
Viscosity:	28.737 poise
Homogeneity:	221.116 wt% oxide
Al_2O_3:	6.206 wt% oxide
Conserv:	99.970 wt% oxide
Frit:	73.747 wt% oxide
R_2O:	20.972 wt% oxide
Nepheline:	0.671 ratio

Waste Loading of 41 wt%

B Leaching:	3.179 g/L
Li Leaching:	2.520 g/L
Na Leaching:	2.932 g/L
Liquidus:	882.985 °C
Viscosity:	26.374 poise
Homogeneity:	222.660 wt% oxide
Al_2O_3:	6.364 wt% oxide
Conserv:	99.966 wt% oxide
Frit:	73.080 wt% oxide
R_2O:	21.150 wt% oxide
Nepheline:	0.664 ratio

Attachment 12: Hydrogen Generation Rate for DWPF (DWPF WAC 5.4.12)

Radionuclide	Results (Ci/gal)	Heat Generation Factors (W/Ci)	Heat Generation (W/gal)	R (ft^3 $H_2/10^6$ BTU)	Hydrogen Generation (ft^3 H_2/hr/gal)
Co-60[α]	1.54E-02	9.40E-04	1.45E-05	48.36	2.39E-09
Y-90[α]	5.54E-03	7.42E+00	4.11E-02	48.36	6.78E-06
Sr-90[α]	1.16E-03	7.42E+00	8.61E-03	48.36	1.42E-06
Rh-106[γ]	1.89E-02	1.11E-04	2.10E-06	48.36	3.47E-10
Ru-106[γ]	1.89E-02	1.11E-04	2.10E-06	48.36	3.47E-10
Sb-125[α]	3.37E-03	9.63E-05	3.25E-07	48.36	5.36E-11
Cs-134[γ]	1.02E-02	2.89E-04	2.94E-06	48.36	4.86E-10
Cs-137[α]	1.01E-03	6.42E-01	6.48E-04	48.36	1.07E-07
Ba-137m[α]	3.94E-03	6.07E-01	2.39E-03	48.36	3.95E-07
Ce-144[γ]	6.58E-04	4.85E-04	3.19E-07	48.36	5.27E-11
Pr-144[γ]	7.34E-03	4.85E-04	3.56E-06	48.36	5.87E-10
Pm-147[γ]	3.67E-04	9.43E-02	3.46E-05	48.36	5.71E-09
Eu-154[α]	9.08E-03	8.34E-03	7.57E-05	48.36	1.25E-08
Pu-238[γ]	3.26E-02	1.50E-01	4.89E-03	134.7	2.25E-06
Pu-239[γ]	3.02E-02	5.86E-03	1.77E-04	134.7	8.14E-08
Pu-240[β]	3.06E-02	2.13E-03	6.51E-05	134.7	2.99E-08
Am-241[γ]	3.28E-02	2.06E-02	6.76E-04	134.7	3.11E-07
Cm-244[γ]	3.44E-02	5.13E-02	1.76E-03	134.7	8.10E-07
Total (ft^3 H_2/hr/gal)					**1.22E-05**
DWPF WAC limit (ft^3 H_2/hr/gal)					**8.95E-05**
% of WAC limit					**13.6%**

Data from SRNL-L3100-2013-00200 (α), SRNL-L3100-2013-00209 (β), SRNL-L3100-2013-00213 (γ), SRNL-L3100-2013-00237 (δ).
R values are defined in the DWPF WAC (X-SD-G-00008).
Q values are defined in DOE/RW-0006.
1 BTU/hr = 2.93E-01 W

DWPF	**1.22E-05 ft^3 H_2/hr/gal**
WAC LIMIT	**8.95E-05 ft^3 H_2/hr/gal**
Percent of Limit	**13.6%**

Attachment 13: Summary of DWPF Precipitate Reactor Feed Tank (PRFT) Lab Data from February 2011 to September 2013

PRFT	2/3/2011	5/21/2011	6/22/2011	7/5/2011	9/1/2011	11/24/2011	12/16/2011	1/10/2012	5/2/2012	8/16/2012
Sample ID	200005267	2E+08	200007464	200007768	2E+08	200010093	2E+08	2E+08	2E+08	2E+08
Density	-	1.048	1.028	1.037	1.008	1.048	1.063	1.034	1.045	1.025
Weight Percent Solids	6.1	7.4	7.1	7.2	6	6.1	6.2	6.5	6.88	-
Wt. % High Temperature Calcine	4.5	5.3	4.8	4.8	4.5	4.3	4.7	4.5	4.59	-
Flouride(mg/Kg)	508	498	508	498	537	529	521	535	502	466
Chloride(mg/Kg)	508	498	508	498	537	529	521	535	502	518
Nitrate (mg/Kg)	9708	3668	15573	12681	3497	10460	11043	11002	11548	7088
Nitrite (mg/Kg)	1740	1963	2674	2159	1991	2433	2618	2621	2733	1685
Sulfate (mg/Kg)	508	501	544	434	537	529	521	535	507	468
Phosphate (mg/Kg)	508	498	508	498	537	529	521	535	502	468
Formate (mg/Kg)	508	498	-	498	537	529	521	535	502	468
Oxalate (mg/Kg)	4138	-	5576	5071	4825	5048	4871	4739	5106	4676
Base Equivalents (OH and CO3)	0.54	0.63	0.55	0.47	0.51	0.5	0.46	0.47	0.49	-
Na (wt.%)	31.7	30.2	28.9	27.2	31.4	32.9	32.1	29.0	29.7	-
Ti (wt.%)	10.4	11.2	8.2	12.7	14.4	14.0	14.3	13.1	10.8	-

PRFT	10/18/2012	2/14/2013	3/20/2013	4/4/2013	4/26/2013	6/3/2013	6/27/2013	7/17/2013	8/1/2013	8/27/2013	9/5/2013	Average of All Samples	Stdev	%RSD
Sample ID	2E+08	2E+08	2E+08	2E+08	2E+08	2E+08	2E+08	2E+08	2E+08	2E+08	2E+08			
Density	1.036	1.052	1.009	1.033	1.043	1.04875	1.039	1.043	1.023	1.028	1.023	1.036	1.47E-02	1.42E+00
Weight Percent Solids	5.74	5.73	5.88	4.95	4.12	5.54	5.4	6.39	5.62	6.38	5.43	5.98	7.96E-01	1.33E+01
Wt. % High Temperature Calcine	4.29	4.36	4.23	2.72	2.295	3.72	3.49	3.3	3.67	3.84	2.35	4.08	7.63E-01	1.87E+01
Flouride(mg/Kg)	505	473	484	504	510	475	473	471	500	494	515	500	2.08E+01	4.15E+00
Chloride(mg/Kg)	505	473	484	504	510	475	473	471	500	494	515	503	1.97E+01	3.92E+00
Nitrate (mg/Kg)	8473	11481	14304	14322	15604	14014	11764	13189	13322	17356	17213	12350	2.79E+03	2.26E+01
Nitrite (mg/Kg)	1746	2194	2661	2582	2715	2423	2127	2267	2564	3164	2878	2379	4.02E+02	1.69E+01
Sulfate (mg/Kg)	505	517	570	702	754	733	641	682	878	863	810	614	1.31E+02	2.14E+01
Phosphate (mg/Kg)	505	473	484	504	510	475	473	471	500	494	515	500	2.08E+01	4.16E+00
Formate (mg/Kg)	505	473	484	504	510	475	473	471	500	494	515	500	2.12E+01	4.24E+00
Oxalate (mg/Kg)	4416	4600	5221	4630	4653	4485	4363	4805	4106	4340	4470	4741	3.67E+02	7.75E+00
Base Equivalents (OH and CO3)	0.66	0.53	0.52	0.47	0.46	0.41	0.37	0.41	0.46	0.49	0.46	0.493	6.86E-02	1.39E+01
Na (wt.%)	39.2	37.3	34.3	44.4	48.3	33.1	32.5	30.3	35.0	35.5	34.2	33.899	5.23E+00	1.54E+01
Ti (wt.%)	6.6	7.0	6.1	7.2	6.9	5.8	6.2	4.8	3.3	3.0	0.8	8.325	4.06E+00	4.88E+01

Less Than Detection
"-" (Indicates No Data)
Number of Replicates Adjusted

Assumptions used in Calculations using PRFT Data:

- 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 200015280) reported for the PRFT Base Equivalents has been adjusted by multiplying the standard deviation by two to produce a value of 0.797 M (0.66 + 2 * 6.86E-02). This value bounds the base equivalent data reported above.
  - Carbonate is present in the salt solution at ~0.3 M 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. A value of 0.5 was applied to the adjusted value for base equivalents to produce a value of 0.399 M (0.797 M * 0.5) for carbonate. This is conservative since the carbonate is approximately 1.345 times higher than the salt solution.
  - 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 22,937 ppm (17,356 ppm + 2*2,790) and 3968 ppm (3,164 ppm + 2*402). 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 1.07 g/mL (1.036 g/mL + 2*1.47E-02), 7.57 wt.% solids (5.98 wt.% +2*7.96E-01), and 5.60 wt. % high temperature calcine solids (4.08 wt.% +2*0.763), 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. Ti concentration has dropped in accordance with this reduction in MST (see sample data reported from October 2012 to September 2013). Above the average Ti for October 2012 to September 2013 is 5.22E+00 wt.%.
- 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 13 (continued): PRFT Flow Rate in Gallons Based on Salt Processing Volume

Calculation to Determine Flow Rate to PRFT based on Salt Processing Rate:

To calculate the total volume sent to the PRFT that correlates to a salt processing volume, Appendix K of X-CLC-S-00113 is used. The flow rates for Case K support a salt processing mass of 3.7308E07 pounds (lb) per year (two strike tanks, 1.8654E07 pounds per year per tank) and 1.332E06 pounds per year of PRFT material. The density of the salt solution is 10.81 lb/gallon and the density of the PRFT material is 8.6 Lb/gallon. Using this information the following calculations can be made to determine a ratio of gallons of PRFT to Salt Solution:

$$Gallons\ of\ Salt\ Solution\ per\ Year\ from\ Tank\ 49 = \frac{1.8654E07\ lbs}{year} * 2 * \frac{gallon}{10.81\ lbs}$$

$$= 3.4513E06\ \frac{gal\ of\ Salt\ Solution}{year}$$

$$Gallons\ of\ Salt\ Solution\ Received\ in\ PRFT\ per\ year = \frac{1.332E06\ lbs}{year} * \frac{gallon}{8.6\ lbs}$$

$$= 1.549E05\ \frac{gal\ of\ PRFT}{year}$$

$$Ratio\ of\ Gallons\ of\ PRFT\ to\ Salt\ Solution\ from\ Tank\ 49$$

$$= \frac{1.549E05\ \frac{gal\ of\ PRFT}{year}}{3.4513E06\ \frac{gal\ of\ Salt\ Solution}{year}} = \frac{0.04488\ gallons\ of\ PRFT}{Gallon\ of\ salt\ solution}$$

Assumption:

- Revision 17 of SRR-LWP-2009-00001, Appendix H contains a table of salt solution that is to be processed via ARP/MCU. Fiscal Year (FY 13) includes a goal of 1.111 K gallons and FY 14 indicates a goal of 1,060 K gallons. Revision 18 of SRR-LWP-2009-00001 increases the amount of salt solution processed in each FY. For FY 13, FY 14, and FY 15 the salt solution volumes are assumed to be 1,401 K gallons, 2,581 K gallons, and 2,451 K gallons, respectively. However, FY14 milestone is to process 800 K gallons; therefore, 1,000 K will be used to bound the volume of PRFT.

Attachment 13 (continued): PRFT Flow Rate in Gallons Based on Salt Processing Volume

Based on the PRFT to Salt Solution ratio calculated above, an annual volume can be calculated for the PRFT based on 1,000 K gallons of salt solution. From the annual amount, a weekly volume amount can then be determined. This calculation is shown below:

$$Annual\ Volume\ PRFT = \frac{0.04488\ gallons\ of\ PRFT}{Gallon\ of\ salt\ solution} * \frac{1.00E06\ gallon}{year} = \frac{4.49E04\ \ gal\ of\ PRFT}{year}$$

$$Weekly\ Volume\ PRFT = \frac{4.49E04\ \ gal\ of\ PRFT}{year} * \frac{1\ year}{52\ weeks} = \frac{863.03\ \ gal\ of\ PRFT}{week}$$

$$Gallon\ per\ Minute\ Amount\ for\ PRFT = \frac{4.49E04\ \ gal\ of\ PRFT}{year} * \frac{1\ year}{52\ weeks} * \frac{1\ week}{7\ days} * \frac{1\ day}{24\ hours} * \frac{1\ hour}{60\ minutes} = 0.0856 \frac{gal\ of\ PRFT}{minute}$$