This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-09SR22505 with the U.S. Department of Energy.

X-ESR-H-00158, Rev. 0

Evaluation of ISDP Batch 2 Qualification Compliance to 512-S, DWPF, Tank Farm, and Saltstone Waste Acceptance Criteria

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X-ESR-H-00158
Revision 0

Keywords:
ARP/MCU, DWPF, Tank 49H, WAC Compliance

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LIST OF ACRONYMS

ARP	Actinide Removal Process
CSS	Clarified Salt Solution
CSSX	Caustic Side Solvent Extraction
DBP	Dibutylphosphate
D_{cs}	Distribution Factor
DF	Decontamination Factor
DSA	Documented Safety Analysis
DSS	Decontaminated Salt Solution
DWPF	Defense Waste Processing Facility
EDTA	Ethylenediaminetetraacetic acid
ESS	Extract Strip Scrub
FME	Foreign Material Exclusion
HEU	Highly Enriched Uranium
HGR	Hydrogen Generation Rate
IDP	Inhalation Dose Potential
ISDP	Interim Salt Disposition Project
LFL	Lower Flammability Limit
LPPP	Low Point Pump Pit
LWE	Liquid Waste Engineering
LWO	Liquid Waste Organization
LWHT	Late Wash Hold Tank
LWPT	Late Wash Precipitate Tank
MCU	Modular CSSX Unit
MST	Monosodium Titanate
NAS	Sodium aluminosilicate
NCSA	Nuclear Criticality Safety Assessment
NCSE	Nuclear Criticality Safety Evaluation
NO_x	Nitrate/Nitrite
NTU	Nephelometric Turbidity Units
PIC	Potential Impact Category
PRFT	Precipitate Reactor Feed Tank
SAC	Specific Administrative Control
SCDHEC	South Carolina Department of Health and Environmental Control
SE	Strip Effluent
SED	Strip Effluent Decanter
SEFT	Strip Effluent Feed Tank
SEHT	Strip Effluent Hold Tank
SME	Slurry Mix Evaporator
SRAT	Sludge Receipt and Adjustment Tank
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
SVOA	Semi-Volatile Organic Analysis
TBP	Tributyl phosphate
TF	Tank Farm
TMA	Trimethylamine
TOC	Total Organic Carbon
TPB	Tetraphenyl borate
TSR	Technical Safety Requirement
TTQAP	Task Technical and Quality Assurance Plan
VOA	Volatile Organic Analysis
WAC	Waste Acceptance Criteria
WAPS	Waste Acceptance Product Specifications (for Vitrified High-Level Waste Forms)
WCP	Waste Compliance Plan

1.0 PURPOSE

The purpose of this report is to document the acceptability of the second macrobatch (Salt Batch 2) of Tank 49H waste to H Tank Farm, DWPF, and Saltstone for operation of the Interim Salt Disposition Project (ISDP).

2.0 SUMMARY AND BACKGROUND

2.1 Summary

Tank 49 feed meets the Waste Acceptance Criteria (WAC) requirements specified by References 11, 12, and 13. Salt Batch 2 material is qualified and ready to be processed through ARP/MCU to the final disposal facilities.

The following key attributes of the Tank 49 feed to ARP/MCU are noted:

- The sum of the fractions for determining Hazard Category for MCU is calculated to be < 0.3.
- Actinide removal is not required to meet waste acceptance criteria and it is not required to maintain MCU as a Hazard Category 3 Facility.
- Cs-137 requires a Decontamination Factor (DF) to meet the Saltstone WAC.
- NCSE criterion for U-235 (eq) is met: 685.20g maximum potential fissile mass within the ARP/MCU boundary versus a limit of 1,980 g.
- Extraction, Scrub and Strip tests for Cesium removal criteria are met.
- MST testing demonstrates expected DFs for Pu and Sr.
- Solids formation testing indicates a low potential for NAS.
- The Tank 49 contents are also lower than the 0.4 Ci/gal criteria for additional shielding over the SEHT and SED cells.

2.2 Background

The Interim Salt Disposition Project (ISDP) consists of two flowsheets that have been developed based on two technologies: the Actinide Removal Process and the Modular Caustic Side Solvent Extraction Unit (MCU). The ARP flowsheet involves two strike tanks where Monosodium Titanate (MST) is added to the salt solution in the 241-96H Tank Farm facility. The MST is added to remove the majority of the soluble strontium and actinides from the salt solution. The MST/salt solution is then transferred to the Late Wash Precipitate Tank (LWPT) in the 512-S facility for filtration. Three streams are generated as a result of this filtration, an MST/sludge solids solution and a clarified salt solution (CSS). The MST/sludge solid solution is transferred via the Low Point Pump Pit (LPPP) to the Precipitate Reactor Feed Tank (PRFT) in 221-S for eventual incorporation into the final glass product. The solids wash water is used to wash the MST/sludge solid solution after reaching five weight percent before transferring to DWPF. The solids wash water is then transferred directly to Tank 50H. The CSS is stored in the Late Wash Hold Tank (LWHT) until it is transferred to MCU where it is processed through a solvent extraction process. The products of this process are a nitric acid solution containing concentrated cesium called strip effluent (SE) and a decontaminated salt solution (DSS). The DSS is sent to Saltstone via Tank 50H for final disposition. The SE is transferred to the Strip Effluent Feed Tank (SEFT) in 221-S.

Transfers to prepare for Tank 49 feed included the following:

- Tank 25 supernate was transferred to Tank 41
- Tank 41 supernate was then transferred to Tank 49
- Tank 22 supernate was transferred to Tank 49
- 50-weight percent sodium hydroxide was transferred to Tank 49 to support a hydroxide concentration of 2.0 M.

The first macrobatch was qualified using samples from Tank 49 after transfers had been completed (Ref. 1). An effort to streamline the qualification process was made for this macrobatch. This second macrobatch was qualified using a combination of existing and, where needed, new analyses from the source tanks feeding Tank 49, as well as minimal confirmation sampling from Tank 49 after all final transfers took place.

The salt solution for Salt Batch 2 consists of the heel of Tank 49H (Salt Batch 1), Tank 41H supernate (dissolved saltcake supernate from Tank 25F), Tank 22H supernate, and 19 M sodium hydroxide solution for sodium and hydroxide adjustment. The qualification and sampling strategy is located in X-ESR-H-00141 (Ref. 2). Using the existing data, as well as recent analyses, a blend evaluation was performed to determine the concentrations of all chemicals and radionuclides needed to qualify the salt batch prior to processing through ARP/MCU (Ref. 3).

Confirmation sampling from Tank 49 included the following after final transfer:

- organic constituents, based on leak scenario into Tank 41 from HEU transfer;
- process performance parameters that included a final sodium concentration, potassium concentration which is detrimental to CSSX solvent third phase formation, filtered radionuclides including actinides U (mass), Pu-238, Sr-90, and cesium (137 and 134);
- and Pu and U isotopes for the Nuclear Criticality Safety Evaluation (NCSE).

In addition, some other nuclides and chemicals were analyzed using the confirmatory sample. All of these analyses are found in Reference 4.

Settled insoluble solids in Tank 49 will be disturbed during slurry pump operation. Tank 49 was settled for a shift after transfer, then sampled. The blend calculation has been validated using confirmatory analysis with some exceptions. Also, post-transfer analysis/calculations have been performed/validated.

As part of the qualification sample strategy (Ref. 2), the confirmation sample results were to be compared with the blend evaluation (Ref. 3). Upon this comparison, Pu-238 through 240 and U-233 showed a high percent standard deviation between the confirmation sample analyses and the blend evaluation. In these cases, the most confirmatory values were at least an order of magnitude higher than the blend evaluation values. Further study showed that Salt Batch 1 in Tank 49 had settled for 43 days prior to taking a confirmatory sample for plutonium, but Salt Batch 2 settled no longer than 24 hours prior to confirmatory sampling. This then prompted a second confirmatory sample of Salt Batch 2 to be taken 35 days after the first confirmatory sample, allowing for a longer settling time.

In addition, some other nuclides and chemicals were analyzed using the second confirmatory sample. All of these analyses are found in Reference 10.

The Tank 49 heel level prior to startup of Salt Batch 2 formation was 180.2 inches (Ref. 5), resulting in a volume of approximately 632,502 gallons (Ref. 6). Final transfer volumes into Tank 49 were the following (Ref. 5):

- 123,201 gallons from Tank 41
- 197,465 gallons from Tank 22
- 83,325 gallons of sodium hydroxide

The variable depth samples from Tanks 22 and 41 were shipped to SRNL for qualification on July 22, 2008, and August 28, 2008, respectively (Ref. 4). Tasks were performed by SRNL to demonstrate the processability of the feed through the ARP and MCU flowsheets. Using an initial blend calculation (Ref. 7) for volumes, SRNL made up an ISDP composite to perform processability tests. Actual volumes transferred into Tank 49 varied slightly from the predicted volumes. The greatest discrepancy was the volume transferred from Tank 41, which contained the higher concentrations of nuclides and chemicals. This volume was approximately 87 percent of the predicted volume. Therefore, the ISDP composite used by SRNL for processability testing contains higher nuclide concentrations that those actually in Tank 49, making the testing results bounding for Salt Batch 2. Analyses were performed in accordance with a Task Technical Quality and Assurance Plan (TTQAP) (Ref. 8). The results of the analyses were documented in report SRNL-STI-2008-00446 (Ref. 4). These analyses, along with existing data, were used to perform the blend evaluation to determine the concentrations of chemicals and radionuclides in Tank 49 post-transfer.

N-NCS-H-00192 requires isolation of Tank 49H after taking the criticality samples, to ensure no additional fissile mass is added to Tank 49H and to measure the equivalent U-235 in the Tank 49H feed to assure an equivalent U-235 fissile mass is not accumulated within the ARP/MCU boundary (Ref. 9). Variable depth samples were taken from Tank 49 on December 2, 2008, and were analyzed to comply with NCSE requirements. Prior to pulling the Tank 49 Salt Batch 2 qualification samples, several barriers required per N-NCS-H-00192, “Nuclear Criticality Safety Evaluation (NCSE): Actinide Removal Process (ARP) and Modular CSSX Unit (MCU),” were not performed. A position paper was written that evaluated the criticality safety impacts of the omitted barriers on the ARP/MCU, 512-S, and 96H facilities (Ref. 47). Based on this evaluation, there is sufficient evidence to conclude that no waste transfers in or out of Tank 49 took place after samples were taken, and therefore the samples were representative of Tank 49 contents. Furthermore, based on this evaluation, no uncharacterized supernate from Tank 49 has entered 96H or 512-S facility.

The second set of variable depth samples taken from Tank 49 on January 6, 2009, were analyzed for plutonium and uranium isotopes to determine the effect of tank settling as discussed above.

Both radiological and chemical contributions were considered in this analysis. Where possible, data from confirmatory sampling (Ref. 4 and Ref. 10) were evaluated against criteria in References 11, 12, and 13. For other constituents, Tank 49 blend concentrations (Ref. 3) were evaluated. These references are the WAC for Sludge, ARP, and MCU Process Transfers to 512-S and DWPF (Ref. 11), the WAC for Liquid Waste Transfers to the 241-F/H Tank Farms (Ref. 12), and the Saltstone WAC (Ref. 13). In addition, calculations based on initial feed predictions were reviewed to ensure they were still bounded.

3.0 DISCUSSION OF RESULTS

Analytical results of Tanks 49, 41, and 22 samples, as well as constituents concentrations calculated in the blend evaluation (Ref. 3) and confirmation results (Ref. 4 and 10) were used to compare against waste acceptance criteria to determine compliance with the WACs.

The Tank Farm pulled samples from both Tank 22H and 41H on July 22, 2008, and August 28, 2008, respectively. The Tank 22H material arrived at SRNL in two dip bottles (HTF-22-08-108 and -110) and one 4L carboy (HTF-22-08-107). The Tank 41H material arrived at SRNL in two dip bottles (HTF-41-08-129 and -130) and one 4L carboy (HTF-41-08-128). Variable depth samples (duplicate samples taken at three depths) were taken from Tank 49H on December 2, 2008 (HTF-49-08-166 through 168) for confirmatory purposes. A second set of variable depth samples were taken from Tank 49 on January 6, 2009 (HTF-49-08-176 through 178), and were analyzed for plutonium and uranium isotopes to determine the effect of tank settling as discussed above.

The following activities were performed using the Tanks 22 and 41 Samples:

1. Each variable depth sample was visually inspected for solids and density measurements were completed. The uniformity of these measurements was used to demonstrate that the variable depth samples were representative of the tank contents.
2. Variable depth samples were then composited and chemical and radionuclide characterization was performed for each tank. Using mixing ratios derived from Reference 7, the Tank 22 and 41 samples were combined with a Tank 49 sample from a previous study. Furthermore, 50 wt % caustic was added to the composite to reach a free hydroxide of 2.0 M (to inhibit aluminum compound precipitation). The following activities were performed using this composite:

- Laboratory protocols developed by personnel at the Savannah River National Laboratory (SRNL) were used to test the ARP and MCU flowsheets. The composite sample was contacted with monosodium titanate (MST) for 24 hours. This contact and filtration was used to demonstrate the strontium and actinide removal from the liquid which is part of the ARP. Filtration then provided liquid for further testing as well as solids to be analyzed. The filtrate was contacted with qualified MCU solvent so that cesium decontamination could be assessed.

- Salt solution was analyzed to meet the DWPF/512-S, Tank Farm/MCU and Saltstone WACs.
- MST/sludge solids slurry containing insoluble solids was analyzed.
- Tank 49H feed was analyzed in order to provide data to determine if Tank Farm TSRs and MCU Hazard Characterization are met.
- A solvent extraction protocol consisting of an extraction, two scrubs, and three strips were performed on material from the ARP (MST strike) test. Analyses of the SE and DSS streams were performed.

The following activities were performed using the Tank 49H Sample taken on December 2, 2008:

1. Each variable depth sample was visually inspected for solids and density measurements were completed. The uniformity of these measurements was used to demonstrate that the variable depth samples were representative of the tank contents.
2. Variable depth samples were composited and chemical and radionuclide characterization was performed in accordance with the TTQAP (Ref. 8) for confirmatory purposes and for NCSA evaluation.

The WAC compliances were calculated using the blend evaluation (Ref. 3) and the confirmatory analyses (Ref. 4 and 10). The Tank 49H material was used for qualification without crediting the ARP/MCU process except for cesium limits for the Saltstone evaluation. Process knowledge is credited for specific analytes not analyzed. However, bounding actinide and cesium concentrations were used where appropriate. The average was used in calculations and comparisons except where noted. When SRNL data reported an analyte below detection limit, the highest detection limit was used as an actual value for calculations and comparison. When SRNL reported results for an analyte at detection limits and an actual value, an average value was calculated from the detection limit(s) and the actual read value(s) (see tritium results in Table 12 of Ref. 4 for example).

Constituent concentrations calculated in the blend evaluation (Ref. 3) were compared to Tank 49 confirmation analyses (Ref. 4). Analytical values for plutonium-238 through -240 and uranium-233 were considerably higher than those predicted in the blend evaluation. In these cases, the most recent confirmatory values were at least an order of magnitude higher than the blend evaluation values. Further study showed that Salt Batch 1 in Tank 49 had settled for 43 days prior to taking a confirmatory sample for plutonium, but Salt Batch 2 settled no longer than 24 hours prior to confirmatory sampling. This then prompted a second confirmatory sample of Salt Batch 2 to be taken 35 days after the first confirmatory sample, allowing for a longer settling time. The results of the second confirmatory sampling were within the expected range.

3.1 Compliance with 512-S WAC (Ref. 11)

This section documents WAC compliance of the material to be transferred from 241-96H to 512-S.

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 analytical results of the Salt Batch 2 material, the average of Cs-137 content of the composite samples is 5.34E+07 pCi/mL or 0.202 Ci/gallon (Ref. 4). The Cs-137 concentration is approximately 18 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 soluble Pu-238 concentration less than or equal to 3.0E-03 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 Tank 49H. The reported Ci/gallon values are multiplied by the dose conversion factors to obtain a final rem per gallon value. For total alpha, the dose conversion factor is the conversion factor for Pu-238. The rem per gallon values for total alpha and Sr-90 are then summed and compared to the 512-S WAC limit.

The second method compares the eleven major inhalation dose radionuclides in the Salt Batch 2 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 1.90E+04 rem/gallon or 0.6 percent of the 512-S WAC limit of 3.00E+06 rem/gallon. The second method resulted in the inhalation dose being approximately 2.43E+04 rem/gallon or 0.8 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 0.202 Ci/gal meets the requirements of the 512-S WAC for inhalation dose potential. The Cs-137 value is approximately 18 percent of the limit specified in the 512-S WAC.

The soluble Pu-238 was found to be 2.78E+04 pCi/mL or 1.05E-04 Ci/gal (Ref. 4). The soluble Pu-238 concentration criteria of less than or equal to 3.0E-03 Ci/gallon is met for Salt Batch 2.

3.1.3 Nuclear Criticality Safety (DWPF WAC 5.3.3)

The waste to be transferred to 512-S shall have an Eq. U-235 fissile mass less than or equal to a single subcritical U-235 (eq.) mass accumulated within the ARP/MCU boundary.

A Nuclear Criticality Safety Assessment (NCSA) (Ref. 14) was performed that demonstrates that Salt Batch 2 is compliant with the requirements from the Actinide Removal Process/Modular Caustic Side Extraction Unit Nuclear Criticality Safety Evaluation (ARP/MCU NCSE) (Ref. 9). This NCSA demonstrates that, by performing a material balance for the ARP/MCU boundary, no more than a single subcritical ^{235}U equivalent [^{235}U(eq)] mass can be accumulated within the ARP/MCU boundary following processing of the second macro batch. The ^{235}U (eq) enrichment is 3.51 wt%, and the maximum amount of fissile material potentially present within the ARP/MCU boundary is 685.20 g of ^{235}U(eq) following processing of the second macro batch. The material available in Tank 49 for the second macro batch has a ^{235}U(eq) enrichment of 3.25 weight percent and a fissile mass of 602.75 g ^{235}U(eq) (Ref. 14). This is significantly less than a single subcritical mass of 1,980 g ^{235}U(eq) (Ref. 9).

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/hr/gal at 25ºC. 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 (Ref. 16). Results are shown in Attachment 2.

The value of hydrogen generated for Salt Batch 2 material is 1.61E-07 ft^3/hr/gallon and the limit is 1.64E-06 ft^3/hr/gallon at 25^{o}C. The value is 9.8 percent of the limit.

3.1.5 Organic Concentration (DWPF WAC 5.3.5)

The organic material present in the MST/sludge transferred to 512-S shall contribute less than 0.1% to the hydrogen LFL.

Analysis of triplicate samples of Salt Batch 2 material found no significant measurable organic (Ref. 3, 4, and 10). These results indicate a negligibly small amount of organic material is present in the ARP/MCU feed. Previous analyses by Tank Farm Engineering conclude volatile organic content in the waste will not significantly contribute to flammability (Ref. 17). Therefore, the organic material present in ISDP Salt Batch 2 will not exceed 0.1% to the hydrogen LFL (Ref. 17).

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 transfer (Ref. 18).

3.2 Compliance with DWPF WAC (Ref. 11)

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 5 in the SRAT. Compliance with the DWPF WAC is being evaluated against Sludge Batch 5 with the ARP/MCU material. Tank 51H material was blended with Sludge Batch 4 material (heel in Tank 40H) to be processed as Sludge Batch 5. A blend of the Sludge Batches 4 and 5 compositions is used in this evaluation (Ref. 19).

3.2.1 NOx 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 Reference 11. The estimated NO_x emission for the Sludge Batch 5 is 14.6 tons per year. This is approximately 14.1% of the DWPF WAC target of 103.5 tons per year. The algorithm assumes that at least 50% of the acid required will be added as formic acid. This percentage is significantly higher for Sludge Batch 5. Details of predicted NO_x emission calculations for Sludge Batch 5 can be found in Attachment 3.

The NO_x emissions for ARP contribution were calculated to be bounding at 64.8 tons/year, as seen in Attachment 3. This value is higher than the actual predicted ARP contribution. The calculated value does not account that most of the soluble compounds will proceed to Tank 50H or the MST/sludge solids are washed before entering DWPF. The expected NO_x contribution is less than 10 tons/year.

The estimated NO_x emission for the Sludge Batch 5 with the ARP contribution is 79.4 tons per year. This is approximately 77 percent of the DWPF WAC target of 103.5 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 185.53 watts per canister (163.9 W/canister from sludge, 6.6 W/canister from MST sludge solids and 15.1 W/canister from strip effluent at 3.03 Ci/gallon) (see Section 3.2.3 for Cs-137). The calculated value is approximately 185.5 W/canister or 42.5 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 Ci/g dried solids for each radionuclide from the blended Sludge Batch 5 results have been multiplied by a conversion factor and the specific isotope gamma dose constant to obtain the contribution of each radionuclide (Ref. 19). The computed gamma source strength values for the 9 radionuclides are then summed together. In addition, the gamma source strengths were converted to a slurry gallon basis. The computed gamma source strength values for the 9 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 2.64E-01 mR/hr/g insoluble solids or 7.13 percent of the WAC limit of 3.7 mR/hr/g insoluble solids and 1.02E+02 mR/hr/gal or 2.52 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 2 material (0.202 Ci/gal) multiplied by a concentration factor of 15 in accordance with Reference 11. MCU contribution is thus nominally 3.03 Ci/gallon. Periodic sampling of the SE will monitor cesium concentration (Ref. 20).

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 from the Sludge Batch 5 blend calculation was compared to the limit (Ref. 19). Calculations are shown in Attachment 6. The total alpha concentration of 5.82E-04 Ci/g insoluble solids is approximately 38.8 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. The second method resulted in the inhalation dose being approximately 3.33E+07 rem/gallon or 13.5 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 5 well below the DWPF WAC limit for total IDP.

The Cs-137 concentration in the sludge stream is 2.03E-01 Ci/gallon which is 15.5 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 3.03 Ci/gallon (0.202 Ci/gal * 15) is approximately 18 percent of the WAC limit.

3.2.6 Nuclear Criticality Safety (DWPF WAC 5.4.6)

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

Four limits must be satisfied in order to comply with this requirement.

1. The Pu-240 concentration shall exceed the Pu-241 concentration. (Sludge Batch 5 ratio is 24.3:1, therefore criterion is met.)
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. (Sludge Batch 5 ratio is 484:1, therefore criterion is met.)
3. The Eq. Pu-239 concentration shall be ≤ 0.59 g/gallon if non-Tank Farm Pu is included in the sludge batch. There is no Eq. Pu-239 concentration limit if only Tank Farm Pu is included in the sludge batch. (Eq. Pu-239 in Sludge Batch 5 is 0.184 g/gallon, therefore criterion is met.)
4. The Eq. U-235 enrichment shall be ≤ 0.93 wt. %. (Eq. U-235 enrichment for Sludge Batch 5 is 0.67, which is 72.0 percent of the WAC limit.)

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.

Table 1- Comparison of DWPF WAC Glass Solubility to Sludge Batch 5 and ISDP Salt Batch 2 Analyses

Species	Limit Wt. % in glass	Value % in glass	Percent Of Limit
TiO_2	2	0.804	40.18
Cr_2O_3	0.3	0.169	56.41
PO_4	3	1.514	50.47
NaF	1	0.797	79.66
NaCl	1	0.626	62.64
Cu	0.5	0.034	6.73
SO_4^{-2} Na_2SO_4	0.6 (0.88)	0.528	88.01

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.

Sulfate concentration for Sludge Batch 5 was determined in the Sludge Batch 4 and Sludge Batch 5 blend calculation. The concentration is 0.006 M (Ref. 19). The value is approximately 10.3 percent of the WAC limit of 0.058 M.

The quantity of sulfate in the Salt Batch 2 feed is 8,927 mg/l or 0.093 M (Ref. 4). However, the MST/sludge solids will be washed before entering DWPF to reach a sodium concentration of 0.6 M and soluble compounds will proceed in the CSS to MCU and finally to Saltstone. There will be negligible sulfate in the washed MST/sludge slurry.

The quantity of mercury for Sludge Batch 5 was determined from the Sludge Batch 5 blend calculation mass of total solids times the mercury concentration in 1.66 weight percent of total solids (Ref. 19). The mass of mercury was calculated value is 2.39 g/L (see Attachment 10).

The quantity of mercury in the Salt Batch 2 feed is 9.05E-03 g/L (Ref. 4). Combined with the mercury from the sludge slurry, the total quantity of mercury is 2.40 g/L (see Attachment 10). The value is 11.4 percent of the WAC limit of 21 g/L.

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 blended Sludge Batch 5 weight percent dry total solids was determined to be 13.19 weight percent (Ref. 19). The ARP process will transfer five weight percent total solids to the Sludge Receipt and Adjustment Tank (SRAT) via the PRFT (Ref. 21). Therefore, the target weight percent of 12-19 is met.

3.2.10 Glass Quality and Processability (DWPF WAC 5.4.10)

A sample of sludge must be transported to SRNL for analysis and processing in the Shielded Cells. The melter feed must be vitrified and the resulting glass tested using the PCT to confirm that an acceptable glass product can be produced as required by the DWPF Glass Product Control Program (Ref. 11). The vitrified product must be verified to meet the leach rate limits shown below in Table 2. The melter feed must also be verified to meet the predicted properties shown below in the table.

The results of Sludge Batch 5 only (Tank 51H) material was analyzed by SRNL in Reference 22. Impact of blending ARP/MCU product with sludge is minor for Sludge Batch 5 material (Ref. 23 and 24). The amount of sludge solids with the MST is small because the feed to ARP has been clarified by settling in Tank 49. The main impact is the addition of TiO_2 from the MST used in ARP. This is considered separately as a glass solubility requirement.

Using the sludge composition reported and a nominal waste oxide loading of 40% and Frit 418 the following properties are estimated from Production Composition Control System (PCCS). All quality and processing criteria were met at 40% Sludge Oxide Loading (Attachment 11). Table 2 below compares limits with values. PCCS includes statistical offsets for property model and analytical measurement uncertainties.

Table 2 - Comparison of DWPF WAC Glass Quality and Processability to Sludge Batch 5 and ISDP Salt Batch 2 Analyses

Attribute	Limit	Value	Evaluation
Boron Leach Rate	≤16.70 g/L	0.858 g/L	Passes
Lithium Leach Rate	≤ 9.57 g/L	0.872 g/L	Passes
Sodium Leach Rate	≤ 13.35 g/L	0.852 g/L	Passes
Liquidus Temperature -	≤1050° Celsius	961.9° Celsius	Passes
High Viscosity	≤110 poise	38.8 poise	Passes
Low Viscosity	≥ 20 poise	38.8 poise	Passes
Homogeneity Constraint	$Al_2O_3 \geq 4$ wt% **OR**	8.92 wt%	Passes
Homogeneity Constraint	$Na_2O \geq 3$ 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 6000 gallons of SRAT product and the SME shall not exceed 0.223 lb/hr for 6000 gallons of SME product. The nitrous oxide concentration in the SRAT vapor space shall not exceed 15 volume percent.

The blend of Sludge Batch 4 and Sludge Batch 5 has not been run in the Shielded Cells at SRNL. The criteria are met during Shielded Cell testing at SRNL for Sludge Batch 4 (Ref. 25). The criteria were met during Shielded Cell testing at SRNL for Sludge Batch 5 (Ref. 26 and 22). SRNL has performed simulated Sludge Batch 5 only SRAT/SME with the latest estimates of the ARP/MCU compositions (without entrained organics from MCU). The results showed no processing changes for the Sludge Batch 5 Flowsheets and the ARP/MCU additions did not negatively impact DWPF processing (Ref. 27). Similar flowsheet studies were performed on Sludge Batch 4 material with the same result (Ref. 28).

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/hour/gallon at 25ºC.

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. This evaluation was done using feed values for blended Sludge Batch 5 and ISDP Salt Batch 2 material. Calculation results are shown in Attachment 12.

The value of hydrogen generated is 1.37E-05 ft^3/hour/gallon for Sludge Batch 5. This calculated value is 15.3 percent of the DWPF WAC limit of 8.95E-05 ft^3/hour/gallon. The combined value is 1.45E-05 ft^3/hour/gallon and is only 16.3 percent of the DWPF WAC limit of 8.95E-05 ft^3/hour/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 from MCU shall not exceed 87 mg Isopar L per kg (ppm) of Strip Effluent.

The organic material is negligible, as shown in 3.1.5 for ARP/MCU. 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 (Ref. 17).

Prior testing has shown less than 87 ppm carryover (Ref. 29). The criterion for Strip Effluent will be evaluated by analyzing samples after the start of Sludge-Salt coupled operation (Ref. 20).

3.2.14 pH (DWPF WAC 5.4.14)

Transfers from MCU must meet the following pH constraints:

a) Strip effluent shall have a pH ≥ 2 and ≤ 4 (nominally 0.01 M HNO_3)
b) 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 3M HNO_3) is transferred.

The pH criterion will be met by the nitric acid purchase specification and procedural control (Ref. 18). The full line volume water or SE flush will be controlled by procedural measurement (Ref. 18).

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 ≤ 45ºC
b) Strip Effluent transfers from MCU shall be ≤ 40ºC

The temperature limit for sludge transfers from Tank 40 will be met by direct measurement and process knowledge (Ref. 18). The temperature limit for MCU strip effluent will be met by process control (Ref. 18).

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 48H material) that may be transferred to DWPF for disposal. Sludge Batch 5 coupled processing is not expected to contain a non-sludge or non-salt stream.

3.3 Compliance with Tank Farm WAC (Ref. 12)

This section documents WAC compliance based on system feed of the material to be transferred from 512-S to MCU, 512-S to Tank 50 via MCU processing, and 512-S to Tank 50H without MCU processing. The confirmatory analyses (Ref. 4 and Ref. 10) and blend calculation values (Ref. 3) were used in this section.

3.3.1 Requirements for Corrosion Prevention (Tank Farm WAC 11.1)

To prevent unacceptable rates of corrosion, waste solution in the Tank Farms must satisfy the specifications in Sections 11.1.1 through 11.1.4 of the Tank Farm WAC. In the case of MCU, the primary product stream is a decontaminated salt solution (DSS) that will be sent to Tank 50H. Waste accepted by MCU will need to comply with the corrosion prevention requirements for Tank 50H, since there are no corrosion prevention specific requirements for the MCU facility.

After all the transfers were made into Tank 49 for Salt Batch 2, Tank 49 was evaluated in WCS 1.5 (Ref. 5) for corrosion control. WCS 1.5 showed that Tank 49 corrosion chemistry is compliant with the Corrosion Program Description Document (PDD) (Ref. 30). This is documented in Table L-5 of Revision 453 of the Emergency Response Data document (ERD) (Ref. 6).

In addition, a corrosion evaluation was performed for the DSS from MCU sent to Tank 50H (Ref. 31). Recommendations for Tank 50 as a result of adding DSS can be found in Reference 31. Tank 50 was also evaluated in WCS 1.5 (Ref. 5) for corrosion control. WCS 1.5 showed that Tank 50 corrosion chemistry is compliant with the Corrosion Program Description Document (PDD) (Ref. 30). This is documented in Table L-5 of Revision 453 of the Emergency Response Data document (ERD) (Ref. 6).

3.3.2 Organic Vapor Control (Tank Farm WAC 11.2.1)

A waste stream shall have less than, or equal to, a 5% organic contribution to the hydrogen LFL at 100^{o}C. Tank 49H feed material meets this criteria as it is under the Tank Farm Flammability Control Program (Ref. 32), and the organic chemical analyses at less than detection limits support this.

Neither facilities in line, 96H nor 512-S, add volatile organic chemicals to the system.

3.3.3 Hydrogen Generation Rate (Tank Farm WAC 11.2.2)

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 (Ref. 37). The hydrogen generation limit for transfer into Tank 50H is limited to 4.8E-08 ft^3/hr-gal (with a NO_{eff} of 0.89 minimum).

The value of hydrogen generated for Tank 49H material at 43°C is 1.82E-08 ft^3/hr-gallon and the NO_{eff} is 2.24. The hydrogen generation rate value is 37.9 percent of the limit. Applying a 15% dilution factor because of the ARP dilution and the scrub feed and caustic wash in MCU (Ref. 15) the NO_{eff} is 1.90 and the hydrogen generation rate is 2.20E-08 ft^3/hr-gallon. The hydrogen generation rate value is 45.8 percent of the limit. In addition, a maximum dilution factor of 32% was applied to NO_{eff} to account for various dilutions. This evaluation was done using Tank 49H confirmatory and blend calculation values. Results are shown in Attachments 13-A and 13-B. The actual hydrogen generation rate for DSS will be less than this evaluation because the Cs-137 will be removed during MCU processing.

In addition, transfers into MCU from 512-S are to be ≤ 50°C for hydrogen generation rate (other lower temperature limits apply for other parameters). The temperature limit will be met by direct measurement (Ref. 40).

3.3.4 Prevent Formation of Shock Sensitive Compounds (Tank Farm WAC 11.3)

There is an administrative control program prohibiting additional shock sensitive compound transfers into the Tank Farm. Tank 49H and the ARP/MCU process will not introduce any new shock sensitive compounds into the Tank Farm.

3.3.5 Requirements for Radionuclide Content for Waste Receipts (Tank Farm WAC 11.4)

Material transferred into the MCU facility shall be less than or equal to 1.69E+05 rem/gallon. The calculated value for Tank 49H feed is 2.60E+04 rem/gallon (see Attachment 15). The calculated IDP is less than or equal to 15.4 percent of the WAC limit. This feed will decrease in radionuclide concentration in 512-S, prior to transfer to MCU.

In addition, the radionuclide content transferred from 512-S to MCU shall maintain a sum of ratios less than 1 (as defined in Ref. 35) to protect the Hazard Category 3 status of MCU. The sum of fractions is 0.297 (see Attachment 14). The sum of the fractions is less than one when compared to the Hazard Categorization 2 threshold. Therefore, the Tank 49H feed will not compromise the MCU facility hazard categorization of Hazard Category 3.

Material transferred into Tank 50H shall not have an IDP greater than 2.09E+05 rem/gallon. The calculated value is 2.60E+04 rem/gal using the Tank 49H feed material (see Attachment 15). The calculated IDP is 12.4 percent of the WAC limit.

The Tank Farm WAC requires that the Cs-137 concentration be no more than 1.1 Ci/gal. The average Cs-137 content of the Tank 49 confirmatory analyses from Reference 4 is 5.34E+07piCi/mL or 0.202 Ci/gal. The Cs-137 concentration is approximately 18.4% of the TF WAC.

3.3.6 Requirements for Regulatory Compliance (RCRA) (Tank Farm WAC 11.5)

The feed is from Tank 49H material, which is in compliance with the TF WAC and, therefore, RCRA compliant. Neither ARP nor MCU will contribute additional RCRA constituents that have not already been considered (Ref. 36).

3.3.7 Requirements for Criticality Safety (Tank Farm WAC 11.6)

Criticality safety is controlled in ARP and MCU by ensuring that the total quantity of equivalent U-235 that could be within the ARP/MCU boundary at any time is less than a single fissile mass for the associated U-235 (eq) enrichment.

A Nuclear Criticality Safety Assessment (NCSA) (Ref. 14) was performed that demonstrates that the Salt Batch 2 is compliant with the requirements from the Actinide Removal Process/Modular Caustic Side Extraction Unit Nuclear Criticality Safety Evaluation (ARP/MCU NCSE) (Ref. 9). This NCSA demonstrates that, by performing a material balance for the ARP/MCU boundary, no more than a single subcritical ^{235}U equivalent [$^{235}U(eq)$] mass can be accumulated within the ARP/MCU boundary following processing of the second macro batch. The ^{235}U (eq) enrichment is 3.51 wt%, andthe maximum amount of fissile material potentially present within the ARP/MCU boundary is 685.20 g of $^{235}U(eq)$ following processing of the second macro batch. The material available in Tank 49 for the second macro batch has a $^{235}U(eq)$ enrichment of 3.25 weight percent and a fissile mass of 602.75 g $^{235}U(eq)$ (Ref. 14). This is significantly less than a single subcritical mass of 1,980 g $^{235}U(eq)$ (Ref. 9).

3.3.8 Requirements to Protect Heat Generation Rate (Tank Farm WAC 11.7)

The TF DSA (Ref. 37) requires that the waste tanks contain waste with a heat generation rate less than 8.00E+05 Btu/hr. This requirement has been determined to be bounding for all incoming waste streams, so no additional controls are necessary (Ref. 12).

3.3.9 Requirements to Satisfy Downstream Facility Acceptance Criteria (Tank Farm WAC 11.8)

Prior to transferring waste into Tank 50H, a waste generator must demonstrate compliance with the Saltstone WAC Limits. If a waste generator is unable to meet a Saltstone WAC Limit on any single constituent, a deviation request to the Tank Farm WAC will be made.

The concentrated MST/sludge solids will be washed to remove sodium and nitrates. The wash water will bypass MCU and be transferred directly to Tank 50H. For wash water transfers to Tank 50H, some chemical species (e.g., Na^+ molarity, nitrate, nitrite) and some radionuclide concentrations (e.g., Cs-137) may not meet the Saltstone limits. NO_{eff} may be below Tank 50H requirements as well. A deviation is in place for the 512-S to Tank 50H waste stream. (See Section 3.5)

The Cs-137 concentration in Tank 49H will not meet the Saltstone WAC. However, SRNL ESS testing demonstrated acceptable cesium distribution factors (D_{Cs}) for extraction (≥8), scrub (0.6-2), and strip (≤0.16) for the CSS from Tank 49H. D_{Cs} values in these ranges mean a DF greater than 12 is anticipated from MCU (Refs. 4 and 38). The Cs-137 concentration in the experimental DSS stream (6.98+06 pCi/mL) meets the Saltstone WAC limits (4.75E+07 pCi/mL), as shown below in Section 3.4.5.

3.3.10 Industrial Hygiene Safety (Tank Farm WAC 11.9)

This criterion is not applicable to the Tank 49H feed qualification. The feed is from Tank 49H material, which is already compliant with the Industrial Hygiene Safety program.

3.3.11 Tanker Trailer Waste Receipts (Tank Farm WAC 11.10)

This criterion is not applicable to the Tank 49H feed qualification. Waste will not be transferred by tanker trailer.

3.3.12 Transfer Requirements of Radioactive Waste into the Tank Farm (Tank Farm WAC 11.11)

These criteria are not applicable to the Tank 49H feed qualification. Compliance to these criteria is proceduralized and independent of tank make-up.

3.3.13 MCU Process Requirements (Tank Farm WAC 11.12)

Feed to MCU shall meet the following process requirements:

- Potassium molarity shall be less than or equal to 0.05 M. The potassium concentration in Tank 49H material is 242 mg/l, or 0.006 M (242 mg/l / 39000 mg/mol) as reported in Reference 4. This is 12 percent of the WAC limit.
- Feed shall be filtered through a 0.1 micron filter. The direct feed to MCU shall be processed through a 0.1 micron filter. All salt solution transfers to MCU will be made from the Late Wash Hold Tank which collects filtrate from the crossflow filter at 512-S (Ref. 39). The crossflow filter at 512-S has a nominal pore size of 0.1 micron (Ref. 40)
- Analysis is required for the content of lipophilic anions. Trace amounts of lipophilic anions are in the Tank 49H material. The ARP/MCU process will not change the overall chemistry. Phosphate was analyzed for the first confirmatory sample (Ref. 4) and is assumed to be all DBP for the purpose of this evaluation.

TMA value is from the TOC from the blend evaluation (Ref. 3). The value is conservative to use the total organic carbon for TMA. The 1-butanol concentration was analyzed for the second confirmatory sample (Ref. 10) using a lower detection limit than the first confirmatory sample (Ref. 4). The lipophilic anion concentrations are below MCU WAC limits. Formate was analyzed for the first confirmatory sample (Ref. 4).

Table 4 - Comparison of MCU Process Requirement for Lipophilic Anions to ISDP Salt Batch 2 Analyses

Lipophilic Anions	Result (mg/L)	Concentration (mM)	MCU Limit (mM)
TBP	0	0	3.00E+01
DBP	798	8.40E+00*	1.00E+02
TMA	3.03E+02**	5.14E+00**	1.00E+01
Formate	3.26E+02	7.41E+00	1.00E+02
1-Butanol	5.00E-01	6.76E-03	1.00E+01

*Result for phosphate from Reference 4.
**Result for Total Organic Carbon (TOC) from Reference 3 (303 mg/l / 59 mg/mM)

- The sending facility (512-S) shall be in compliance with the Foreign Material Exclusion Program. Maintenance operations upstream and at MCU have the potential to introduce chemicals and other foreign materials that are known to disrupt the MCU process. A foreign material exclusion (FME) program (Ref. 41) has been developed to control these activities and prevent the inclusion of such compounds into streams transferred to MCU. Compliance strategy is procedurally controlled through the WCP (Ref. 40).

3.4 Compliance with Saltstone WAC (Ref. 13)

Because a portion of the treated waste from Salt Batch 2 will be transferred into Tank 50H, it must meet Saltstone waste acceptance criteria. The Cs-137 concentration in Salt Batch 2 does not meet Saltstone WAC without MCU treatment; however, SRNL ESS testing demonstrated acceptable cesium distribution coefficient (see Section 3.3.9).

3.4.1 Inhalation Dose Potential (Saltstone WAC 5.4.1)

The inhalation dose potential (IDP) for material to be transferred to Saltstone shall have a total rem/gallon less than or equal to 2.09E+05 rem/gallon. IDP for Saltstone based on Salt Batch 2 feed without the Cs-137 and actinides removed via ARP/MCU process is 2.60 E+04 rem/gallon. The value is 12.4% of the WAC limit. Also, concentrations for Sr-90, Cs-137, Pu-241, Eu-154 and Total Alpha shall meet the limits in Table 4. Table 4 shows the IDP values calculated in Attachment 15.

Table 4 - Comparison of Saltstone WAC Inhalation Dose Potential to ISDP Salt Batch 2 Analyses

Radionuclide	WAC IDP (rem/gallon)	Salt Batch 2 IDP (rem/gallon)
Sr-90	8.08E+03	1.05E+02
Cs-137	8.55E+03	3.84E+03
Eu-154	1.70E+03	6.28E-02
Pu-241	1.05E+04	9.66E+02
Total Alpha	1.80E+05	2.11E+04
Total	**2.09E+05**	**2.60E+04**

3.4.2 Hazard Categorization (Saltstone WAC 5.4.2)

The material to be transferred to Saltstone shall have a sum of ratios less than 1 to protect the Hazard Category 3 (HC-3) status of the Saltstone Facility. Saltstone's hazard categorization is based on the bounding Design Safety Basis analysis concentration of the radionuclides listed (Ref. 42). In order for Saltstone to remain a HC-3 status, the radionuclides listed in WAC 5.4.9 and WAC 5.4.10 for Radionuclides Criteria Limits and Radionuclides Criteria Targets must be met. Am-242m is above the Target range. Am-242m has been evaluated and documented in Reference 43. The elevated value will not significantly contribute to the sum of fractions.

3.4.3 Limits for Chemical Impacting Vault Flammability (Saltstone WAC 5.4.3)

The concentrations of Isopar L, tetraphenylborate (TPB) and ammonium given in Table 5 below shall not be exceeded to protect the assumptions used in the Saltstone vault explosion credibility calculation. As seen in Table 5, ammonium met this limit without crediting the blending that will take place with other influents to Tank 50H (Ref. 4). Isopar L was not reported in the Salt Batch 2 feed material. Isopar L is introduced to the Salt Batch during MCU processing. The strategy for blending Salt Batch DSS with other influents to Tank 50H is documented in X-ESR-H-00151 (Ref. 44). The WCP states the total mass of TPB to be disposed of in Vault 4 is 4.24 kg and is an acceptable amount per X-ESR-H-00137 (Ref. 44 and 45). The TPB value was measured to be less than 4.00E+00 mg/L during the confirmation sampling (Ref. 10).

Table 5 - Comparison of Saltstone WAC Chemical Impacting Vault Flammability to ISDP Salt Batch 2 Analyses

Chemical	WAC LIMIT	Salt Batch 2
Isopar L	1.10E+01 ppm	Not Reported
Tetraphenylborate**	4.24E+00 kg total mass and 5.00E+00 mg/L	4.00E+00 mg/L
Ammonium*	2.12E+02 mg/L	2.00E+02 mg/L

*Data from Reference 4.
** Data from Reference 10.

3.4.4 Hydrogen Generation Rate (Saltstone WAC 5.4.4)

The hydrogen generation rate for the salt solution to be transferred to Saltstone shall be less than 5.59E-08 ft^3/hour/gallon of salt solution in grout at 95ºC.

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. This evaluation was done using Salt Batch 2 feed values except the cesium isotopes applied a decontamination factor of 12. Calculation results are shown in Attachment 16. The value of hydrogen generated for Salt Batch 2 material is 2.56E-09 ft^3/hour/gallon. The hydrogen generation rate value is 4.6 percent of the limit. The ARP/MCU process will experience a dilution in the range of 15% to 32% (Ref. 15). The hydrogen generation rate is 3.04E-09 ft^3/hour/gallon for 15% dilution or 5.4 percent of Saltstone WAC limit of 5.59E-08 ft^3/hour/gallon. The hydrogen generation rate is 3.75E-09 ft^3/hour/gallon for 32% dilution or 6.7 percent of Saltstone WAC limit of 5.59E-08 ft^3/hour/gallon.

3.4.5 "Other Organics" Contribution to Vault Flammability (Saltstone WAC 5.4.4)

The volatiles in salt solutions shall contribute less than ten percent to the Composite Lower Flammability Limit (CLFL) at peak CLFL concentration. The "Other Organics" include butanol, isopropanol, methanol and NORPAR 13. These organics must be lower the criteria listed in Table 6 or analysis consistent with S-CLC-Z-00067 must be performed to demonstrate the four organics remain below ten percent CLFL. Isopropanol was reported at less than the detection of 0.25 mg/L (Ref. 4); therefore, the criterion is met. Methanol is not directly measurable in a waste tank. Compliance is through limiting the alcohols in MST (Ref. 48). NORPAR 13 was not reported during Salt Batch 2 qualification sampling. NORPAR 13 is found in Canyon transfers to H Tank Farm. Tank 49 is not a direct receipt tank for Canyon wastes.

Table 6 - Comparison of Saltstone WAC "Other Organics" Contribution to Vault Flammability to ISDP Salt Batch 2 Analyses

Chemical	WAC LIMIT (mg/L)	Salt Batch 2 (mg/L)
Butanol**	0.75	5.00E-01
Isopropanol*	0.25	2.50E-01
Methanol	0.25	Not Directly Measured
NORPAR 13	0.1	Not Reported

Data from Reference 3.
*Data from Reference 4.
** Data from Reference 10.

3.4.6 Nuclear Criticality Safety (Saltstone WAC 5.4.6)

In order to ensure no credible criticality scenarios identified for activities involved with the possessing and disposal of salt solution at Saltstone, the concentration of the U-233, U-235, Pu-239 and Pu-241 must meet the concentrations listed in Table 7. The concentrations are met; therefore, no criticality concerns are present for Salt Batch 2 material.

Table 7 - Comparison of Saltstone WAC Nuclear Criticality Safety to ISDP Salt Batch 2 Analyses

Radionuclide	WAC LIMIT (pCi/mL)	Salt Batch 2 (pCi/mL)
U-233**	1.13E+04	3.63E+02
U-235**	1.13E+02	2.57E-01
Pu-239**	2.50E+05	2.29E+02
Pu-241*	8.38E+05	7.73E+04

*Data from Reference 4.
** Data from Reference 10.

3.4.7 Chemical Criteria Limits and Targets (Saltstone WAC 5.4.7 and 5.4.8)

The Limits and Targets concentrations of the chemicals shown in Table 8 and 9, respectively, shall not be exceeded. Table 8 shows that the analytical values for Salt Batch 2 are within Saltstone WAC limits. Table 9 shows that the analytical values for Salt Batch 2 are within the Saltstone WAC targets; however, these are not required to be analyzed prior to transfer into Tank 50H. Tank 50H is analyzed for Saltstone Limits and Targets on a quarterly basis.

Table 8 – Comparison of Saltstone WAC Chemical Contaminant LIMITS to ISDP Salt Batch 2 Analyses

Chemical Name	WAC LIMIT (mg/L)	Salt Batch 2 (mg/L)
Ammonium*	7.13E+03	2.00E+02
Carbonate	1.45E+05	1.98E-01
Chloride*	9.68E+03	2.50E+02
Fluoride*	4.94E+03	2.50E+02
Hydroxide	1.91E+05	2.05E+00
Nitrate*	5.29E+05	2.13E+00
Nitrite*	2.59E+05	2.22E-01
Oxalate*	3.30E+04	2.84E-03
Phosphate*	3.56E+04	8.40E-03
Sulfate*	6.89E+04	9.29E-02
Arsenic	7.50E+02	6.38E-01
Barium	7.50E+02	2.51E+00
Cadmium	3.75E+02	2.71E+00
Chromium*	1.50E+03	5.93E+01
Lead	7.50E+02	2.97E+01
Mercury *	3.25E+02	9.05E+00
Selenium	4.50E+02	1.28E+00
Silver	7.50E+02	2.03E+01
Aluminum*	1.41E+05	7.07E+03
Butanol and Isobutanol**	2.25E+03	5.00E-01
Isopropanol*	2.25E+02	2.50E-01
Phenol	7.50E+02	1.25E+01
Total Organic Carbon	5.00E+03	3.03E+02
Tetraphenylborate (TPB)**	7.50E+02	4.00E+00
Isopar L	1.50E+02	Not Reported

Data from Reference 3.
*Data from Reference 4.
** Data from Reference 10.

Typically, butanol, isobutanol, and isopropanol have been found in concentrations less than 1 mg/L in canyon receipt tanks (Ref. 46). Isopar L is independent of salt batch feed concentrations.

Table 9 – Comparison of Saltstone WAC Chemical Contaminant TARGETS to ISDP Salt Batch 2 Analyses

Chemical Name	Saltstone WAC TARGETS (mg/l)	Tank 49 Analytical Value (mg/l)
Boron	9.00E+02	8.65E+00
Cobalt	9.00E+02	2.90E-01
Copper	9.00E+02	4.01E+00
Iron*	6.00E+03	1.90E+00
Potassium*	3.67E+04	2.42E+02
Lithium	9.00E+02	7.51E+00
Manganese	9.00E+02	2.85E+00
Molybdenum*	9.00E+02	7.60E+00
Nickel	9.00E+02	8.24E+00
Silicon	1.29E+04	4.82E+01
Strontium	9.00E+02	9.47E+00
Zinc*	9.75E+02	1.41E+00
Benzene *	3.75E+02	2.50E-01
Methanol	2.25E+02	Not Directly Measured (see Section 3.4.5)
Toluene*	3.75E+02	1.00E+00
Tributylphosphate	3.00E+02	0.00E+00
EDTA*	3.75E+02	1.00E+02
NORPAR 13	1.00E-01	Not Reported

Data from Reference 3.
* Data from Reference 4.

3.4.8 Radionuclide Criteria Limits and Targets (Saltstone WAC 5.4.9 and 5.4.10)

The limits and targets concentrations of the radionuclides shown in Table 10 and Table 11, respectively, shall not be exceeded. Table 10 shows that the analytical values for Salt Batch 2 are within Saltstone WAC limits. Table 11 shows that the analytical values for Salt Batch 2 are within the Saltstone WAC targets except for Am-242m; however, these are not required to be analyzed prior to transfer into Tank 50H. Tank 50H is analyzed for Saltstone Limits and Targets on a semiannual basis.

Table 10 – Comparison of Saltstone WAC Radionuclide Contaminant LIMITS to ISDP Salt Batch 2 Analyses

Radionuclide	WAC LIMIT (pCi/ml)	Salt Batch 2 (pCi/ml)
H-3*	5.63E+05	7.49E+02
C-14*	1.13E+05	5.82E+02
Ni-63	1.13E+05	1.38E+02
Sr-90*	2.25E+07	2.93E+05
Tc-99*	4.22E+05	6.89E+04
I-129*	1.13E+03	5.00E+01
Cs-137*	4.75E+07	5.34E+07 (see Note 1)
U-233**	1.13E+04	3.63E+02
U-235**	1.13E+02	2.57E-01
Pu-241*	8.38E+05	2.57E-01
Total Alpha*	2.50E+05	7.73E+04

Data from Reference 3.
*Data from Reference 4.
**Data from Reference 10.

Note 1 - The Cs-137 concentration is based on the Salt Batch 2 feed concentration and is therefore higher than the expected DSS stream. Using the design basis of a minimum DF factor of 12 (Ref. 38) and the Salt Batch 2 Cs-137 concentration of 0.202 Ci/gallon, the Cs-137 concentration is expected to be 0.017 Ci/gallon (4.45E+06 pCi/mL).

Table 11 – Comparison of Saltstone WAC Radionuclide Contaminant TARGETS to ISDP Salt Batch 2 Analyses

Radionuclide	WAC Target (pCi/ml)	Salt Batch 2 (pCi/ml)
Na-22	1.25E+04	Not Reported
Al-26	2.88E+03	Not Reported
Co-60	1.13E+06	1.03E+01
Ni-59	1.13E+05	4.04E+02
Se-79	1.90E+04	5.99E+01
Nb-93m	2.85E+06	Not Reported
Nb-94	1.53E+04	1.76E+02
Mo-93	1.18E+07	3.54E+04
Ru-106	1.13E+06	1.41E+02
Sb-125	2.25E+06	6.57E+01
Sn-126	1.80E+04	2.53E+02
Cs-134*	1.13E+06	3.23E+03
Cs-135	1.13E+06	6.84E+02
Ce-144	1.13E+05	1.68E+02
Pm-147	5.63E+06	6.88E+02
Sm-151	2.25E+04	4.43E+02
Eu-152	7.28E+01	Not Reported
Eu-154	2.25E+06	8.30E+01
Eu-155	1.13E+04	2.47E+02
Ra-226	7.97E+03	4.84E+02
Th-229	1.63E+05	Not Reported
Th-230	6.26E+03	2.53E+02
Th-232	2.88E+03	8.97E-03
U-232	1.71E+05	1.58E+00
U-234**	1.13E+04	3.13E+02
U-236**	1.13E+04	3.24E+00
U-238**	1.13E+04	1.74E+00
Np-237**	2.50E+05	3.53E+01
Pu-238**	2.50E+05	2.75E+04
Pu-239**	2.50E+05	2.23E+02
Pu-240**	2.50E+05	2.23E+02
Pu-242	2.50E+05	8.00E+01
Pu-244	7.02E+04	2.40E-01
Am-241	2.50E+05	1.87E+03
Am-242m	3.68E-01	7.78E+02 (see Section 3.4.2)
Am-243	2.50E+05	1.64E+03
Cm-242	1.13E+04	5.22E+01
Cm-244	2.50E+05	6.86E+02
Cm-245	2.25E+05	1.39E+03

Data from Reference 3.
* Data from Reference 4.
**Data from Reference 10.

3.4.9 General Processing Criteria (Saltstone WAC 5.4.11)

Transfers into the Saltstone Facility shall meet the known processing constraints shown below:

pH > 10
2.5 M < $[Na^+]$ < 7.0 M
10^oC < Temperature < 40^oC
Total Insoluble Solids < 1.88E+05 mg/L (15 wt%)
Homogeneous and Consistent Feed

The pH of the DSS stream was measured and is between 13 and 14, which meets the criteria (Ref. 4). The pH of Tank 50H (feed to Saltstone) is maintained to a pH greater than 10 as a part of the Tank Farm Corrosion Control Program (Ref. 45).

ISDP Salt Batch 2 material has a sodium concentration of 5.55 M (Ref. 4). Accounting for the 15% dilution rate when the Salt Batch 2 material is processed (Ref. 34), the sodium concentration is 4.72 M and will meet the sodium concentration criterion. Sodium concentration is monitored using the Tank 50H material balance.

The temperature criterion will be met by procedural control prior to transfer from Tank 50H to Saltstone.

The Tank 49H material has less than 0.753 weight percent of insoluble solids (Ref. 4). The 512-S process concentrates solids up to 5 weight percent. Even if there is a filter breakthrough, this weight percent solids volume is still one third of the Saltstone limit (15 weight percent). Total insoluble solids are monitored on the Tank 50H material balance. The quarterly sampling plan for Tank 50H also monitors for weight percent of insoluble solids.

Homogeneous and consistent feed strategies are discussed in detail in the Waste Compliance Plan (Ref. 45). Tank Farm operations will send feed to Saltstone using slurry pumps while the Isopar L limit of 11 ppm is required (Ref. 45).

3.4.10 Gamma Shielding (Saltstone WAC 5.4.12)

The specific gamma source strength value shall not exceed 9.05E+01 mrem/hr/gallon. Table 12 shows that the gamma source strength values for the DSS stream are within the Saltstone WAC limits. A comparison of Salt Batch 2 material without ARP/MCU treatment is shown in Attachment 17. The gamma source strength of Salt Batch 2 feed material is 7.72E+01 mrem/hr/gallon or 85.3 percent of the Saltstone WAC limit of 9.05E+01 mrem/hr/gallon. The gamma source strength of DSS stream is 6.44E+00 mrem/hr/gallon or 7.11 percent of the Saltstone WAC limit of 9.05E+01 mrem/hr/gallon.

Table 12 – Comparison of Saltstone WAC Gamma Source Strength to ISDP Salt Batch 2 Analyses (DSS stream)

Radionuclide	WAC Gamma Source Strength (mrem/hr/gal)	DSS Gamma Source Strength (mrem/hr/gal)
Co-60	5.84E+00	5.36E-05
Sb-125	5.17E+00	1.51E-04
Cs-134	4.26E+00	1.05E-03
Cs-137	6.88E+01	6.43E+00
Eu-154	6.43E+00	2.38E-04
Total	**9.05E+01**	**6.44E+00**

3.5 WAC Deviations

Deviations may be experienced during transfer of wash water from 512-S to Tank 50H. As described in 3.3.9, wash water transfers to Tank 50H may be below the 2.5-7M Sodium concentration and above the Cesium-137 limit of 0.2 Ci/gal (Ref.13). NO_{eff} may be below Tank 50H requirements as well. Prior to the transfer to Tank 50H, Tank Farm Engineering must evaluate the impact via the Tank 50H Material Balance.

3.6 Other Evaluations

In addition to WAC compliance, the following were evaluated: process test results (Section 3.6.1), calculations that used ARP/MCU feed as key input (Sections 3.6.2 – 3.6.5), and open items identified and closed (Section 3.6.6). This section discusses these evaluations.

3.6.1 Process Test Results

The Tank 49 qualification included actinide removal testing using MST and Extraction, Scrub, and Strip (ESS) testing. Also, the CSS was measured for turbidity to determine solids formation.

The actinide removal testing was performed on the Tank 49 sample material to determine if it would process correctly in the ARP. Tests using MST with the Tank 49 sample material gave acceptable decontamination factors (DF) for plutonium and strontium.

Material from the actinide removal testing was used in an ESS test. This test yielded expected and acceptable distribution values.

The CSS was monitored for turbidity for formation of sodium aluminosilicate (NAS). The resulting turbidity after 16 days was 11.1 NTU (Ref. 4). This indicates a gradual solids formation in the sample material.

3.6.2 Air Emissions Calculation

The air emissions calculation for MCU was revised based on the Salt Batch 1 data (Ref. 50). The estimated radionuclide air emission rates are below 0.1 mrem/yr. The chemical emissions are below the pollutant criteria for the Standard 2 and Standard 8 pollutants. The chemical emissions are less than 0.5 lb/hr for the Standard 2 pollutants and less than 0.05 lb/hr for the Standard 8 pollutants. Reference 50 demonstrates that MCU is a Potential Impact Category (PIC) Level 4, which is the lowest classification under the SRS Radionuclide NESHAP Program and does not require periodic sampling (Reference 51).

Salt Batch 2 was evaluated against the Salt Batch 1 air emissions calculation (Ref. 49). It was determined that since the air emission inputs for Salt Batch 2 were less than those for Salt Batch 1, the Salt Batch 1 calculation is conservative. Therefore, Salt Batch 2 is also a PIC Level 4 and does not require periodic sampling.

3.6.3 Radiological Design Calculations

The radiological source terms for MCU Design Basis, Salt Batch 1, and Salt Batch 2 were compared (Ref 52). Activity results indicate the primary radionuclides of concern for Salt Batch 2 are Cs-137/Ba-137 and Sr-90/Y-90. From an external dose and shielding perspective, the Cs-137/Ba-137 in the Salt Batch 2 source term is less than that in the Design Basis source term. Therefore, the Design Basis is still considered the bounding case, and Salt Batch 2 is not expected to impact the radiological design of the ARP/MCU facilities (Ref. 52).

The design basis feed concentration for MCU shielding is 1.1 Ci/gal Cs-137. All poured concrete shield walls are designed to provide adequate protection for processing waste up to the 1.1 Ci/gal limit (Ref. 54). Due to the concentration of the cesium stream in the strip effluent and the inevitable gaps between shielded cell covers, an increased dose potential exists over the SEHT process cell at MCU. At feed concentrations ≤0.4 Ci/gal, Reference 53 determined only lead wool snakes must be used to fill the gaps between the SEHT cell covers. At feed concentrations less than 1.1 Ci/gal, but greater than 0.4 Ci/gal, Reference 53 requires steel shielding plates in addition to the lead wool snakes.

The contents of Tank 49 fall below the 1.1 Ci/gal limit, so the contents are acceptable feed to MCU from a shielding perspective. The Tank 49 contents are also lower than the 0.4 Ci/gal criteria for additional shielding over the Strip Effluent Hold Tank (SEHT) and Strip Effluent Decanter (SED) cells, so only lead wool snakes are required.

3.6.4 Requirements for 241-96H

The feed stream to 96H shall be less than or equal to 1.4E+06 rem/gal as documented in Chapter 3 (3.3.3.3) of the DSA (Ref. 37) and protected by the Inhalation Dose Potential SAC (5.5.4.2.48) (Ref. 55). The calculated IDP for Tank 49 feed is 2.43E+04 rem/gal (see Attachment 1).

Reference 21 states that "If the soluble Pu-238 activity in the incoming feed is less than or equal to 3.0E-03 Ci/gal, no feed would exceed the dose potential of design basis sludge. If the incoming feed has a higher soluble Pu-238 dose than 3.0E-03 Ci/gal, further calculations should be performed using the actual radiological composition of the feed to ensure that the dose potential does not exceed that of design basis sludge." The soluble Pu-238 concentration in the Tank 49 feed is 1.05E-04 Ci/gal (Ref. 10). Therefore additional calculations need not be performed.

3.6.5 Hydrogen Generation

The bounding calculated hydrogen generation rate for ARP is 3.19E-06 ft^3/hr/gal (Ref. 56), and for MCU feed the rate is 6.29E-07 ft^3/hr/gal (Ref. 57). The calculated hydrogen generation rate for Tank 49 material is 1.90E-08 ft^3/hr/gal (see Section 3.3.3). This is one to two orders of magnitude below the bounding hydrogen generation rates for ARP/MCU.

3.6.6 Comparison of Blend Calculation with Analyses

Constituent concentrations calculated in the Blend Evaluation (Ref. 3) were compared to Tank 49 confirmation analyses (Ref. 4). Table 13 shows this comparison along with the percent standard deviation. Constituents showing a percent standard deviation of twenty or less were considered acceptable due to the varied sources of analytical values used in the blend evaluation. Those constituents showing a greater than twenty percent standard deviation were then evaluated. A majority of these constituents had been reported at or below detection limits, and the detection limits varied among analyses. For example, Cs-134 results were reported below detection limits of 1.46E+05 pCi/ml from the 2007 Tank 49 Salt Batch 1 analyses (Ref. 58), and the Tank 49 Salt Batch 2 confirmatory analyses (Ref. 4) reported a detection limit of 3.30E+03 pCi/ml. These detection limit differences are shown in Table 13.

Table 13 – Blend Calculation Values Versus Confirmatory Sample Analyses for Radionuclides in Tank 49

Radionuclides (pCi/ml)	Blend (Ref. 3)	Confirmatory (Ref. 4 or 10)	Average	Deviation	%Deviation
H-3	2.81E+03	7.49E+02	1.78E+03	1.45E+03	81.84
C-14	9.18E+02	5.82E+02	7.50E+02	2.37E+02	31.65
Sr-90	2.81E+05	2.93E+05	2.87E+05	8.18E+03	2.85
Sr/Y-90	5.63E+05	5.86E+05	5.74E+05	1.64E+04	2.85
Tc-99	5.13E+04	6.89E+04	6.01E+04	1.24E+04	20.71
I-129	1.29E+01	5.00E+00	8.93E+00	5.56E+00	62.25
Cs-137	5.10E+07	5.34E+07	5.22E+07	1.73E+06	3.32
U-233*	1.20E+02	3.63E+02	2.41E+02	1.72E+02	71.35
U-235*	2.09E-01	2.57E-01	2.33E-01	3.39E-02	14.54
Pu-241	6.23E+04	7.73E+04	6.98E+04	1.06E+04	15.21
Total Alpha	3.54E+04	2.94E+04	3.24E+04	4.23E+03	13.05
Cs-134	1.01E+05	3.32E+03	5.20E+04	6.89E+04	132.40
U-234*	5.01E+02	3.13E+02	4.07E+02	1.33E+02	32.66
U-236*	1.95E+00	3.24E+00	2.59E+00	9.15E-01	35.28
U-238*	1.84E+00	1.74E+00	1.79E+00	7.30E-02	4.08
Np-237*	1.75E+01	7.05E+01	4.40E+01	1.26E+01	85.05
Pu-238-total*	3.17E+04	2.75E+04	2.96E+04	2.97E+03	10.02
Pu-239*	8.49E+02	2.23E+02	5.36E+02	4.43E+02	82.60
Pu-240*	8.49E+02	2.23E+02	5.36E+02	4.43E+02	82.60
Pu-238-soluble*	2.36E+04	2.78E+04	2.57E+04	2.98E+03	11.61

Table 14 - Blend Calculation Values Versus Confirmatory Sample Analyses for Chemicals in Tank 49

Chemicals (mg/l unless otherwise noted)	Blend (Ref. 3)	Confirmatory (Ref. 4 or 10)	Average	Deviation	%Deviation
NH4	4.25E+02	2.00E+02	3.12E+02	1.59E+02	50.84
Cl	4.21E+02	2.50E+02	3.36E+02	1.21E+02	36.07
F	4.21E+02	2.50E+02	3.36E+02	1.21E+02	36.07
OH (M)	2.05E+00	2.14E+00	2.10E+00	6.14E-02	2.93
NO3 (M)	2.39E+00	2.13E+00	2.26E+00	1.87E-01	8.26
NO2 (M)	2.22E-01	2.22E-01	2.22E-01	3.61E-04	0.16
C2O4 (M)	4.70E-03	2.60E-03	3.65E-03	1.48E-03	40.63
PO4 (M)	6.94E-03	8.40E-03	7.67E-03	1.04E-03	13.50
SO4 (M)	9.94E-02	9.30E-02	9.62E-02	4.55E-03	4.73
Cr	6.03E+01	5.93E+01	5.98E+01	7.37E-01	1.23
Hg	1.02E+01	9.05E+00	9.61E+00	7.86E-01	8.18
Al	7.70E+03	7.07E+03	7.38E+03	4.50E+02	6.09
TPB*	6.16E+00	4.00E+00	5.08E+00	1.53E+00	30.08
Na (M)	5.66E+00	5.55E+00	5.61E+00	7.80E-02	1.39
Butanol / Isobutanol*	4.62E-01	5.00E-01	4.81E-01	2.69E-02	5.60
Isopropanol	2.30E-01	2.50E-01	2.40E-01	1.42E-02	5.92
K	2.10E+02	2.42E+02	2.26E+02	2.26E+01	10.00
Si	1.52E+02	4.82E+01	9.99E+01	7.31E+01	73.15
Benzene	2.30E-01	2.50E-01	2.40E-01	1.42E-02	5.92
Toluene	2.75E+00	1.00E+00	1.88E+00	1.24E+00	66.00
EDTA	1.21E+01	1.00E+02	5.60E+01	6.22E+01	110.94
P	3.37E+02	3.85E+02	3.61E+02	3.39E+01	9.38

Other constituents that showed a high percent standard deviation were plutonium-238 through -240 and uranium-233. In these cases, the most recent confirmatory values were at least an order of magnitude higher than the blend evaluation values. Further study showed that Salt Batch 1 in Tank 49 had settled for 43 days prior to taking a confirmatory sample for plutonium, but Salt Batch 2 settled no longer than 24 hours prior to confirmatory sampling. This then prompted a second confirmatory sample of Salt Batch 2 to be taken 35 days after the first confirmatory sample, allowing for a longer settling time. The second confirmatory results showed concentrations similar to those expected from the blend evaluation. The second confirmatory sample results are shown in Tables 13 and 14 with an asterisk (*).

4.0 References

1. Campbell, S. E., and A. R. Shafer, Evaluation of ISDP Batch 1 Qualification Compliance to 512-S, DWPF, Tank Farm, and Saltstone Waste Acceptance Criteria", X-ESR-H-00120, Rev. 0, March 10, 2008.

2. Campbell, S. E., "Qualification and Sampling Strategy for ISDP Batch 2 to Obtain Compliance to 512-S, DWPF, Tank Farm, and Saltstone Waste Acceptance Criteria", X-ESR-H-00141, Rev. 0, July 2008.

3. Campbell, S. E., "Blend Evaluation for Tank 49 Feed for ISDP Salt Batch 2", X-ESR-H-00157, Rev. 0, December 4, 2008.

4. Peters, T. B., and S. D. Fink, "ISDP Salt Batch #2 Supernate Qualification", SRNL-STI-2008-00446, Rev. 1, January 5, 2009.

5. WG17/WCS1.5PROD/WCS1.5Prod.xls, March 2008

6. N-ESR-G-00001, Rev. 454, High Level Waste Emergency Response Data and Waste Tank Data, September 11, 2008.

7. Campbell, S. E., "Evaluation of Tanks 41 and 22 Transfer Impacts on Tank 49 for Sodium Concentration", X-ESR-H-00149, Rev. 0, October 2008.

8. Peters, T.B., and S. D. Fink, "Task Technical and Quality Assurance Plan for ISDP Salt Batch 2 Sample Qualification", SRNS-RP-2008-01119, Rev. 0, October 29, 2008.

9. L. M. Abney, "Nuclear Criticality Safety Evaluation: Actinide Removal Process and Modular CSSX Unit (U)", N-NCS-H-00192, Rev. 2, December 2007.

10. Peters, T. B., and S. D. Fink, "ISDP Salt Batch #2 Final Confirmation Sample Results", SRNL-TR-2009-00021, Rev. 0, January 14, 2009.

11. Shafer, A. R., "Waste Acceptance Criteria for Sludge, ARP, and MCU Process Transfers to 512-S and DWPF", X-SD-G-00008, Rev. 3, October 2008.

12. Harrison, E. W., "Waste Acceptance Criteria for Liquid Waste Transfers to the 241-F/H Tank Farms", X-SD-G-00001, Rev. 25, October 2008.

13. Ray, J. W., "Waste Acceptance Criteria for Aqueous Sent to the Z-Area Saltstone Production Facility", X-SD-Z-00001, Rev. 8, December 2008.

14. Le, T. T., "Nuclear Criticality Safety Assessment: Tank 49H Macro Batch 2 to ARP/MCU (U)", N-NCS-H-00245, Rev. 0, January 2009.

15. Campbell, S. G., “ISDP Dilution Bases”, LWO-LWE-2009-00003, Rev. 0, January 5, 2009.

16. Pitka, W. F., “Gamma Source Strength, Inhalation Dose Potential, Heat Rate and Hydrogen Generation Rate for DWPF Processing”, N-CLC-S-00099, Rev. 0, March 15, 2006.

17. Britt, T. E., “Estimated Impact of Tank Farm Organics on Flammability in the Vapor Spaces of DWPF Receipt Vessels”, X-ESR-G-00016, Rev. 0, October 3, 2006.

18. Harrison, E.W., “Waste Compliance Plan for Tank Farm Transfer to DWPF (U)”, X-WCP-H-00019, Rev. 2, November 2008.

19. Gillam, J. M., and D. D. Larsen, “Sludge Batch 5 Summary and Projected Blend Compositions, Post Tank 51 to Tank 40 Transfer”, LWO-LWP-2008-00008, Rev. 1, January 13, 2009.

20. Geeting, M. W., “Interim Salt Disposition Project Sample Plan”, U-ESR-H-00068, Rev. 4, April 2008.

21. Drumm, M. D., “Radionuclide Inventories of the Actinide Removal Process for the Consolidated Hazards Process”, X-CLC-S-00126, Rev. 2, February 23, 2006.

22. Bannochie, C. J., Pareizs, J. M., Ajo, H. M., “Results of the Tank 51 SB5 Qualification SME Cycle and Glass Fabrication,” SRNL-PSE-2008-00186, Rev. 0, September 2008.

23. Fox, K. M., Edwards, T.B., Peeler, D. K “Recommended Frit Compositions of Initial Sludge Batch 5 Processing at the Defense Waste Processing Facility,” WSRC-STI-2008-00338, Rev. 0, June 2008.

24. Raszewski, F. C., Edwards, T. B., and Peeler, D. K., “SB5 Variability Study with Frit 418,” SRNS-STI-2008-00065, Rev. 0, September 2008.

25. Koopman, D. C., Pareizs, J. M., Lambert, D. P., Bannochie, C. J. “Sludge Batch 4 Follow-up Qualification Studies to Evaluate Hydrogen Generation”, WSRC-STI-2007-00212, Rev. 0, June, 2007.

26. Pickenheim, B. R., Pareizs, J. M., Bannochie, C. J., Reboul, S. H., Ajo, H. M., “Data from the SRNL Shielded Cells Demonstration of the DWPF SRAT using SB5 Tank 51 Qualification Sample (SC-6),” SRNL-PSE-2008-00157, Rev. 0, July 2008.

27. Lambert, D. P., Stone, M. E., Pickenhiem, B. R., Best, D. R., Koopman, D. C., "Sludge Batch 5 Simulant Flowsheet Studies," SRNS-STI-2008-00024, Rev. 0, September 2008.

28. Koopman, D. C., Best, D. R., Williams, M. F., "Impact of SB4 Tank 40 Decant And ARP/MCU Additions With/Without Added Caustic On DWPF CPC Performance," WSRC-STI-2008-00147, Rev. 0, April 2008.

29. Campbell, S. G., Brass, E. A., Brown, S.J., Geeting, M.W., "MCU Mass Transfer Test Report", LWO-SPT-2007-00184, Rev, 0, June 2007.

30. Cole, C. M., "CSTF Corrosion Control Program Description Document", WSRC-TR-2003-00327, Rev. 4, December 2007.

31. Wiersma, B. J., "Corrosion Assessment of the Tank 49 Supernate", X-ESR-H-00125, Rev. 0, March 2008.

32. Landeene, B. C., "CSTF Flammability Control Program", WSRC-TR-2003-00087, January 2008.

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

34. Campbell, S. G., "MCU Material Balance", X-CLC-H-00554, Rev. 0, October 4, 2006.

35. DOE-STD-1027-92, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports.

36. Braswell, A. D., "Modified Permit for the Savannah River Site (SRS) Z-Area Saltstone Disposal Facility – Facility ID No. 025500-1603 – Aiken County", September 9, 2008.

37. "Concentration, Storage, and Transfer Facilities Documented Safety Analysis", WSRC-SA-2002-00007, Rev. 9, May 2008.

38. Campbell, S. G., "Engineering Study to Determine the Number of Contactors Used in the Modular CSSX Unit", X-ESR-H-00021, Rev. 0, October 11, 2004.

39. "512-S Process Operating Manual (U)", SW4-15.116, Section 2.3.

40. Shafer, A. R., "Waste Compliance Plan for Radioactive Liquid Waste Transfers from the DWPF to 241-H Tank Farm", X-SD-G-00005, Rev. 15, November 2008.

41. S4 ENG.31, Liquid Waste Operations Foreign Material Exclusion Measures for Protection of MCU.

42. “Saltstone Facility Documented Safety Analysis”, WSRC-2003-00001, Rev. 6, October 2008.

43. Ray, J. W., “Evaluation of Hazard Categorization Impact of Am-242m Exceeding Saltstone WAC TARGET for ISDP Batch 2”, LWO-WSE-2009-00014, January 14, 2009.

44. Harrison, E. W., “Isopar L Blend Strategy for Tank 50 Compliance to Saltstone WAC Limit,” X-CLC-H-00151, Rev. 1, December 2008.

45. Harrison, E. W., “Tank 50 Waste Compliance Plan for Transfers to Saltstone”, X-WCP-H-00014, Rev. 8, December 2008.

46. Britt, T. E., “Resolution of the Organic PISA”, WSRC-TR-2002-00094, Rev. 3, March 25, 2003.

47. Voegtlen, R. O., “Position Paper: Tank 49 Salt Batch #2 Qualification”, LWO-LWE-2008-00411, Rev. 0, December 31, 2008.

48. X-SSP-H-00012, “MST Procurement Specification”.

49. Geeting, M. W., “ISDP Salt Batch #2 Air Emissions”, LWO-SPT-2009-00002, January 15, 2009.

50. Geeting, M. W., “Modular CSSX Unit Air Emissions”, X-CLC-H-00514, Rev. 1, March 2008.

51. SRS Manual 3Q, Environmental Compliance Manual, Procedure 4.15, Radionuclide NESHAP Program, Rev.3.

52. Broome, M. A., “Radiological Design Review for ISDP Salt Batch 2 Feed”, LWO-SHQ-2008-00043, Rev. 0, December 11, 2008.

53. Thames, R. D., “MCU Cs-137 Feed Concentration and Process Cell Shielding”, S-CLC-H-01143, December 2007.

54. Reyes, Javier, “Modular Caustic Side Solvent Extraction Unit (MCU) Cell Cover as Built Gap Dose Evaluation”, N-CLC-H-00668, November 2006.

55. “Technical Safety Requirements, Concentration, Storage, and Transfer Facilities”, S-TSR-G-00001, Rev. 22, October 2008.

56. McKibbin, B. A., “Consolidated Hazard Analyses for the Concentration, Storage, and Transfer Facilities”, WSRC-TR-2006-00404, Rev. 2, October 2007.

57. Campbell, S. G.,Aponte, C. I., “Hydrogen Generation Rates for Modular Caustic Side Solvent Extraction Unit (MCU)”, X-CLC-H-00583, Rev. 1, March 2006.

58. Nash, C. A., and Peters, T. B., “Tank 49H Salt Batch Qualification for ARP/MCU”, SRNL-STI-2008-00117, Rev. 0, August 25, 2008.

59. DOE/RW-0006, Rev. 13, December 1997, Integrated Data Base Report—1996: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics.

60. Shared Work Group, File: SB4-5_120108 Washing model.

61. Bannochie, C. J., “Tank 40 Final SB4 Chemical Characterization Results”, WSRC-STI-2007-00674, Rev. 0, January 2008.

62. Bannochie, C. J., Pareizs, J. M., Ajo, H. M., “Sludge Batch 5 Acceptance Evaluation: Chemical Characterization of the Tank 51 SB5 Qualification Sample Prepared at SRNL,” SRNL-PSE-2008-00126, Rev. 0, June 2008.

63. Bovan, P. L., “Specification for Procurement of DWPF Glass Frit”, X-SPP-S-00018, Rev. 8, June 2008.

64. Campbell, S. E. “Hazard Category Evaluation for the Tank 49 Feed Qualification”, X-ESR-H-00122, Rev. 0, February 2008.

65. Aponte, C. I., “Evaluation of MCU Feed Batch”, X-CLC-H-00685, Rev. A, January 7, 2008.

66. Campbell, S. G., “MCU Hazard Category Determination”, X-CLC-H-00577, Rev. 2, September 2007.

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

Method 1

Radionuclide	Concentration pCi/mL	Concentration Ci/gal	Dose Potential CEDE DCF (rem/Ci)	IDP (rem/gal)
Alpha*	2.94E+04	1.11E-04	1.70E+08	1.89E+04
Sr-90*	2.93E+05	1.11E-03	8.90E+04	9.87E+01
Total Dose				1.90E+04
512-S WAC limit				3.00E+06
% of WAC limit				0.63%

*Data from Reference 4.

Method 2

Radionuclide	Concentration (pCi/mL)	Concentration (Ci/gal)	Dose Potential CEDE DCF (rem/Ci)	IDP (rem/gal)
Sr-90*	2.93E+05	1.11E-03	8.90E+04	9.87E+01
Ru-106	1.41E+02	5.34E-07	2.40E+05	1.28E-01
Cs-137*	5.34E+07	2.02E-01	1.90E+04	3.84E+03
Ce-144	1.68E+02	6.37E-07	2.00E+05	1.27E-01
Pm-147	6.88E+02	1.04E-04	1.90E+04	1.98E+00
Pu-238**	2.75E+04	1.04E-04	1.70E+08	1.77E+04
Pu-239**	2.23E+02	8.44E-07	1.90E+08	1.60E+02
Pu-240**	2.23E+02	8.44E-07	1.90E+08	1.60E+02
Pu-241*	7.73E+04	2.93E-04	3.30E+06	9.66E+02
Am-241	1.87E+03	7.07E-06	1.60E+08	1.13E+03
Cm-244	6.86E+02	2.59E-06	1.00E+08	2.59E+02
Total Dose				2.43E+04
512-S WAC limit				3.00E+06
% of WAC limit				0.81%

Data from Reference 3.
*Data from Reference 4.
**Data from Reference 10.

Dose Potential CEDE DCF references and defined in the DWPF WAC (Ref. 11).

Attachment 2: Hydrogen Generation Rate from Tank 49H 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	1.03E+01	3.91E-08	1.54E-02	48.36	6.03E-10	9.95E-14
Y-90*	2.93E+05	1.11E-03	5.54E-03	48.36	6.14E-06	1.01E-09
Sr-90*	2.93E+05	1.11E-03	1.16E-03	48.36	1.29E-06	2.12E-10
Rh-106	1.41E+02	5.34E-07	1.89E-02	48.36	1.01E-08	1.67E-12
Cs-134*	3.32E+03	1.26E-05	1.02E-02	48.36	1.28E-07	2.11E-11
Cs-137*	5.34E+07	2.02E-01	1.01E-03	48.36	2.04E-04	3.37E-08
Ba-137m	5.05E+07	1.91E-01	3.94E-03	48.36	7.53E-04	1.24E-07
Ce-144	1.68E+02	6.37E-07	6.58E-04	48.36	4.19E-10	6.92E-14
Pr-144	1.68E+02	6.37E-07	7.34E-03	48.36	4.68E-09	7.72E-13
Pm-147	6.88E+02	2.60E-06	3.67E-04	48.36	9.56E-10	1.58E-13
Eu-154	8.30E+01	3.14E-07	9.08E-03	48.36	2.85E-09	4.71E-13
Pu-238**	2.75E+04	1.04E-04	3.26E-02	134.7	3.39E-06	1.56E-09
Pu-239**	2.23E+02	8.44E-07	3.02E-02	134.7	2.55E-08	1.17E-11
Am-241	1.87E+03	7.07E-06	3.28E-02	134.7	2.32E-07	1.07E-10
Cm-244	6.86E+02	2.59E-06	3.44E-02	134.7	8.92E-08	4.10E-11
Total (ft3 H2/hr/gal)						**1.61E-07**
512-S WAC limit (ft3 H2/hr/gal)						**1.64E-06**
% of WAC limit						**9.82%**

Data is from Reference 3.
*Data is from Reference 4.
**Data from Reference 10.

R values are defined in the DWPF WAC (Ref. 11).
Q values are defined in Reference 59.

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 (Ref. 11).

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 (M)	**Factor**	**NO_x contribution**
Hydroxide	0.290	0.7	2.03E-01
Carbonate	0.046	1.4	6.44E-02
Nitrite	0.180	1.86	3.35E-01
Nitrate	0.071	1	7.10E-02
Manganese ion*	9.59E-02	0.84	8.06E-02
Mercury ion*	1.19E-02	0.7	8.33E-03
NO_x emission			7.62E-01
NO_x Total (tons/yr) (NO_x total = 19.1 * NO_x emission)			**14.56**
DWPF WAC Limit			**103.52**
Percent of Limit			**14.06%**

Data from Reference 19.

* Manganese and mercury ion were determined using elemental data.
Mn = 4.61 wt% calcine solids
Hg = 1.66 wt% dry solids

Converting wt% calcine solids to wt% dry solids
Wt% dry solids = wt% calcine solids * Calcine Factor
Calcine Factor = 0.795 (Ref. 19)

Converting wt% dry solids to Molarity in slurry
M slurry = wt% dry solids/100*wt% total solids/100*SpG slurry*1000/MW
Wt% total solids = 13.19% (Ref. 19)
SpG slurry = 1.09 (Ref. 19)

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 (Ref. 33). 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.

	Result	Result (M)	Factor	NO_x contribution
Hydroxide	2.053 M	2.05E+00	0.7	1.44E+00
Carbonate*	0.198 M	1.98E-01	1.4	2.77E-01
Nitrite*	0.222 M	2.22E-01	1.86	4.12E-01
Nitrate*	2.129 M	2.13E+00	1	2.13E+00
Manganese ion	2.85E+00 mg/L	1.20E-03	0.84	1.00E-03
Mercury ion*	9.050 mg/L	1.04E-03	0.7	7.26E-04
Total NO_x contribution (M)				**4.30E+00**
Total NO_x contribution (g/L)				**1.96E+02**

Data from Reference 3.
* Data from Reference 4.
Note: Manganese and mercury are concentrated by 22.65 to account for the feed rate from Tank 49H to ARP (Ref. 33)

The ARP contribution is determined by using total NO_x contribution multiplied by the feed from ARP to DWPF.

NO_x = 1.96E+02 g/L * 3.00E+05 L/yr / 453.6 g/lb /2000 lb/ton

The total NO_x contribution by ARP is 6.48E+01 tons/year.

<u>Total NO_x Emission</u>

DWPF	**1.46E+01 tons/year**
ARP	**6.48E+01 tons/year**
TOTAL	**7.94E+01 tons/year**
WAC LIMIT	**103.52 tons/year**
Percent of Limit	**76.7%**

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 (Ref. 11).

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	Heat Generation factor (W/Ci)	Species Contribution to Canister Heat Generation (W/lb)
Sr-90	1.75E-02	9.99E+00	6.70E-03	6.70E-02
Ru-106	4.61E-07	2.63E-04	1.95E-02	5.13E-06
Cs-137	3.69E-04	2.11E-01	4.74E-03	9.99E-04
Ce-144	1.16E-06	6.62E-04	8.00E-03	5.30E-06
U-233	7.35E-08	4.20E-05	2.86E-02	1.20E-06
Pu-238	2.67E-04	1.52E-01	3.26E-02	4.97E-03
Pu-239	2.04E-05	1.16E-02	3.02E-02	3.52E-04
Pu-240	7.59E-06	4.33E-03	3.06E-02	1.33E-04
Am-241	3.49E-05	1.99E-02	3.28E-02	6.54E-04
Cm-244	2.16E-05	1.23E-02	3.44E-02	4.24E-04
Total Species Contribution (W/canister in lbs)				7.45E-02
Canister Heat Generation (W/canister in tons)				1.63E+02

Data from Reference 19.

Ci/lb calcined sludge solids = Ci/g dried sludge slurry * (454g/lb) / Calcine Factor
Calcine Factor = 0.795 (Ref. 19)

The MST sludge solids are not expected to contribute significantly to canister heat generation. The ARP process is expected to feed each strike tank at a rate of 1.68 gallon/min or a total 3.39E+04 gallons/week (Ref. 33). DWPF nominally produces 5 canisters a week.

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

Species	Salt Feed (pCi/mL)	Salt Feed (Ci/gal)	Heat Generation factor (W/Ci)	Heat Generated (W/gal)
Sr-90*	2.93E+05	1.11E-03	6.70E-03	7.43E-06
Ru-106	1.41E+02	5.34E-07	5.95E-04	3.18E-10
Cs-137*	5.34E+07	2.02E-01	4.74E-03	9.58E-04
Ce-144	1.68E+02	6.37E-07	6.58E-04	4.19E-10
U-233**	3.63E+02	1.37E-06	2.86E-02	3.93E-08
Pu-238**	2.75E+04	1.04E-04	3.26E-02	3.39E-06
Pu-239**	2.23E+02	8.44E-07	3.02E-02	2.55E-08
Pu-240**	2.23E+02	8.44E-07	3.06E-02	2.58E-08
Am-241	1.87E+03	7.07E-06	3.28E-02	2.32E-07
Cm-244	6.86E+02	2.59E-06	3.44E-02	8.92E-08
Heat Generation (W/gallon)				**9.69E-04**
Heat Generation per canister (W/canister)				**6.57**

Data from Reference 3.
*Data from Reference 4.
** Data from Reference 10.
Heat Generation factors are defined in Reference 59.

ARP contribution = 9.69E-04 W/gallon * 3.39E+04 gallon/week / 5 canister/week
= 6.57 W/canister

MCU will feed SE to DWPF at a rate of 0.52 gpm or 5242 gallons/week (Ref. 34). The contribution from Cs-137 is the value of the Salt Batch 2 material (0.202 Ci/gallon) multiplied by a concentration factor of 15 (Ref. 11). MCU contribution is 3.03 Ci/gallon. DWPF nominally produces 5 canisters a week.

MCU contribution = 3.03 Ci/gallon * 4.74E-03 W/Ci * 5242 gallon/week /
5 canister/week = 15.07 W/canister

<u>Total Canister Heat Generation</u>

DWPF	**163.9 W/canister**
ARP	**6.57 W/canister**
MCU	**15.07 W/canister**
TOTAL	**185.53 W/canister**
WAC LIMIT	**437 W/canister**
Percent of Limit	**42.46%**

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

Species	**Ci/g dried sludge**	**Gamma Dose Constant (mR/hr/Ci)**	**Gamma Source Strength (mR/hr/g)**	**Gamma Source Strength (mR/hr/gal)**
Co-60	2.94E-06	1.37E+03	4.03E-03	2.19E+00
Ru-106	4.61E-07	1.38E+02	6.36E-05	3.46E-02
Sb-125	2.05E-07	3.80E+02	7.79E-05	4.24E-02
Cs-134	2.71E-06	9.99E+02	2.71E-03	1.47E+00
Cs-137	3.69E-04	3.82E+02	1.41E-01	7.67E+01
Ce-144	1.16E-06	2.33E+01	2.70E-05	1.47E-02
Eu-154	2.55E-05	7.56E+02	1.93E-02	1.05E+01
Eu-155	6.89E-07	6.67E+01	4.60E-05	2.50E-02
Pu-238	2.67E-04	7.90E+01	2.11E-02	1.15E+01
Gamma Source Strength (mR/hr/g)				**1.88E-01**
Gamma Source Strength (mR/hr/gal)				**1.02E+02**

Data from Reference 19.

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)
= 1.09 * 1000 * 3.785 * (13.19/100) = 544.17
(Ref. 19) (Ref. 19)

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 (13.19 / 9.42) (Ref. 19).

Gamma Source Strength = 1.88E-01 * (1.40) = 2.64E-01 mR/hr/g insoluble solids

Gamma Source Strength	**1.02E+02 mR/hr/gallon**
WAC LIMIT	**4070 mR/hr/gallon**
Percent of Limit	**2.52%**

Gamma Source Strength	**2.64E-01 mR/hr/g insoluble solids**
WAC LIMIT	**3.7 mR/hr/g insoluble solids**
Percent of Limit	**7.13%**

Attachment 6: Neutron Shielding (DWPF WAC 5.4.4)

The contribution from the sludge is the following:
Total Alpha 4.16E-04 Ci/g TS (Ref. 19)

Total Solids (TS) = 13.19 wt% (Ref. 19)
Insoluble Solids (IS) = 9.42 wt% (Ref. 19)

Ci/g insoluble solids
= 4.16E-04 Ci/g TS * (13.19 TS/ 9.42 IS)
= 5.82E-04 Ci/g insoluble solids

Neutron Shielding	**5.82E-04 Ci/g insoluble solids**
WAC LIMIT	**1.50E-03 Ci/g insoluble solids**
Percent of Limit	**38.83%**

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

The Sludge Batch 5 contribution to the IDP WAC limit.

Method 1

Radionuclide	Concentration (Ci/gal)	Dose Potential CEDE DCF (rem/Ci)	IDP (rem/gal)
Alpha	2.29E-01	1.70E+08	3.89E+07
Sr-90	9.61E+00	8.90E+04	8.55E+05
Total Dose			**3.98E+07**
DWPF WAC limit			**2.47E+08**
% of WAC limit			**16.11%**

Method 2

Radionuclide	Concentration (Ci/gal)	Dose Potential CEDE DCF (rem/Ci)	IDP (rem/gal)
Sr-90	9.61E+00	8.90E+04	8.55E+05
Ru-106	2.53E-04	2.40E+05	6.07E+01
Cs-137	2.03E-01	1.90E+04	3.86E+03
Ce-144	6.36E-04	2.00E+05	1.27E+02
Pm-147	3.48E-02	1.90E+04	6.61E+02
Pu-238	1.47E-01	1.70E+08	2.50E+07
Pu-239	1.12E-02	1.90E+08	2.13E+06
Pu-240	4.17E-03	1.90E+08	7.92E+05
Pu-241	7.74E-02	3.30E+06	2.55E+05
Am-241	1.92E-02	1.60E+08	3.07E+06
Cm-244	1.19E-02	1.00E+08	1.19E+06
Total Dose			**3.33E+07**
DWPF WAC limit			**2.47E+08**
% of WAC limit			**13.48%**

Data from Reference 19.
Dose Potential CEDE DCF references and defined in the DWPF WAC (Ref. 11).

Attachment 8: Nuclear Criticality Safety (DWPF WAC 5.4.6)

Radionuclide	Ci/g total dried	Specific Activity (Ci/g)	g/g total solids	wt% dried sludge slurry
U-233	7.35E-08	9.68E-03	7.59E-06	7.59E-04
U-235	7.85E-10	2.16E-06	3.63E-04	3.63E-02
Pu-239	2.04E-05	6.22E-02	3.28E-04	3.28E-02
Pu-240	7.59E-06	2.28E-01	3.33E-05	3.33E-03
Pu-241	1.41E-04	1.03E+02	1.37E-06	1.37E-04
Am-242m	4.86E-07	9.72E+00	5.00E-08	5.00E-06
Cm-244	2.16E-05	8.09E+01	2.67E-07	2.67E-05
Cm-245	7.42E-08	1.72E-01	4.32E-07	4.32E-05

Species	wt% calcine	wt% total dried
Fe	20.58	16.36
U	7.02	5.58

Data from Reference 19.

Converting wt% calcine solids to wt% dry solids
Wt% dry solids = wt% calcine solids * Calcine Factor
Calcine Factor = 0.795 (Ref. 19)

Pu-240 to Pu-241 mass ratio: 3.33E-03 wt%/ 1.37E-04 wt%
= 24.33:1

Eq. Pu-239 = Pu-239 + Pu-241 + Cm-244 + 15(Cm-245) + 35(Am-242m)
= (3.28E-02 + 1.37E-04 + 2.67E-05 + 15 * 4.32E-05 +
35 * 5.00E-06) wt% dried solids
= 3.38E-02 wt% dried solids

Eq. U-235 = U-235 + (1.4*[U-233]) = (3.63E-02 + 1.4 * 7.59E-04) wt% dried solids
= 3.74E-02 wt% dried solids

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

% U-235 Enrichment = (Eq. U-235/U)*100 = (3.74E-02 / 5.58E+00) * 100 = 0.670%

% U-235 Enrichment is 0.670%
WAC Enrichment LIMIT is 0.93%
Percent of Limit = 72.0%

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

Fe/Eq. Pu-239 mass ratio = 1.63E+01 wt% / 3.28E-02 wt% = 4.84E+02

Sludge Batch 5 contains a plutonium drop from H Canyon; therefore, the Eq. Pu-239 concentration shall be ≤0.59 g/gallon requirement does apply.

The weight percent of Eq. Pu-239 is 3.38E-02 wt% dried solids.

To determine the grams Eq. Pu-239
= (wt% Eq. Pu-239 / 100) * SpG slurry * 1000* 3.785 * (wt% total solids/100)
= (3.38E-02 / 100) * 1.09 * 1000 * 3.785 * (13.19 / 100)
= 1.84E-01 g/gallon

0.184 g/gallon is less than 0.59 g/gallon.

Attachment 9: Glass Solubility (DWPF WAC 5.4.7)

Assume DWPF produces 5 canisters a week at 100% attainment. The mass of each canister is assumed at 4000 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. DWPF currently produces nominally 186 canisters annually.

Sludge Species	Wt. % Calcine Basis	Gravimetric Factor	Mass of Oxide (kg)	Percent in Glass (%)
Al	12.03	1.8895	5.48E+04	9.09E+00
Ba	0.02	1.1165	5.38E+01	8.93E-03
Ca	1.78	1.3992	6.00E+03	9.96E-01
Ce	0.02	1.1713	5.65E+01	9.37E-03
Cr	0.08	1.4616	2.82E+02	4.68E-02
Cu	0.07	1.2518	2.11E+02	3.51E-02
Fe	20.58	1.4297	7.09E+04	1.18E+01
K	0	1.2046	0.00E+00	0.00E+00
La	0.01	1.1728	2.83E+01	4.69E-03
Mg	1.06	1.6583	4.24E+03	7.03E-01
Mn	4.61	1.2912	1.44E+04	2.38E+00
Na	17.32	1.348	5.63E+04	9.34E+00
Ni	2.41	1.2726	7.39E+03	1.23E+00
Pb	0.05	1.0772	1.30E+02	2.15E-02
Si	1.21	2.1393	6.24E+03	1.04E+00
Ti	0.02	1.6685	8.05E+01	1.34E-02
U	7.02	1.1792	2.00E+04	3.31E+00
Zn	0	1.2447	0.00E+00	0.00E+00
Zr	0.02	1.3508	6.51E+01	1.08E-02
Total Mass of Oxide Elementals (kg)				**2.41E+05**
Total Mass of Glass at 40 Weight Percent Sludge Oxide Loading (kg)				**6.03E+05**

Data from Reference 19.

To determine the mass of oxide for each element, multiply the mass of Sludge Batch 5 calcine basis by gravimetric factor by weight percent calcine basis divided by 100.

Mass of Sludge Batch 5 calcine basis is 241,092 kg (Ref. 19).

To determine the mass of glass, assume a waste loading of 40 percent.

Divide the total mass of oxided elements by the waste loading.

2.41E+05 / 0.40 = 6.03E+05 kg

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

The concentration of TiO_2
The sludge contribution is 0.013% as seen above in the table.

The Ti includes the mass of Ti from MST, which will increase the mass of the glass. The ARP contribution of TiO_2 is from the MST. ARP will be sending 0.774 lb/hr MST ($NaTi_2O_5H$) (Ref. 33). The feed concentration of 0.395 g MST/L is adjusted to a design basis at 0.6 g MST/L (Ref. 33).

0.774 lb/hr * 24 hr/day * 7 day/wk * (0.6/0.395) =1.98E+02 lb/wk

1.98E+02 lb/week $NaTi_2O_5$ / 199.7 lb/lbmol $NaTi_2O_5H$ * 2 lbmol TiO_2/lbmol $NaTi_2O_5H$ * 79.9 lb/lbmol TiO_2 = 1.58E+02 lb TiO_2 / wk

At the weekly production rate, 20,000 lbs glass is produced.

Percent of TiO_2 in glass:
1.58E+02 lb TiO_2/wk / 2.00E+04 lb glass/wk * 100 = 0.790%

Sludge plus ARP/MCU contribution:
0.0013 % + 0.790 % = 0.804%

TiO_2	**0.804%**
DWPF WAC Limit	**2.000%**
Percent of the Limit	**40.18%**

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

The concentration of Cr_2O_3
The sludge contribution is 0.047% as seen above in the table.

The ARP/MCU contribution:
Using a feed rate of 1.68 gpm for each MST strike tank (Ref. 33):

Feed Rate = 2 * 1.68gpm * 60min/hr * 24 hr/day * 7 day/wk * 3.785 L/gal
= 1.29E+05 L/wk (or 1.77E+06 gal/yr)

The Salt Batch 2 material has 59.3 mg/L or 7.60E+03 g/week (Ref. 4)

Cr_2O_3 = 7.60E+03 g/week Cr / 52 g/mol Cr / 2 mol Cr_2O_3/ mol Cr * (152 g/mol Cr2O3)
= 1.11E+04 g/wk

Percent of Cr_2O_3 in glass
= 1.11E+04 g/wk / 9.07E+06 g/wk *100 = 0.122%

Sludge plus ARP/MCU contribution:
0.047% + 0.122% = 0.169%

Cr_2O_3	**0.169%**
DWPF WAC Limit	**0.300%**
Percent of the Limit	**56.41%**

However, Cr_2O_3 is soluble so the contribution from ARP/MCU is negligible.

Cr_2O_3	0.047%
DWPF WAC Limit	0.300%
Percent of the Limit	15.59%

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

The concentration of PO_4

The sludge contribution:
The amount of P was not determined in the blend of Sludge Batch 5 (Ref. 19). In order to determine the percent of PO_4 in the sludge, a blend Sludge Batch 5 value is needed.

Sludge Batch 4 information:
At WAPS sample date 10/07:
Total Solids: 268,126 kg (Ref. 60)
Insoluble Solids: 196,824 kg (Ref. 60)
P, weight %: 0.297% (Ref. 61)

Before transfer of Tank 51H:
Insoluble Solids: 83,219 kg (Ref. 60)

Determine the amount of P at WAPS sample date:
0.297 wt% / 100 * 2.68E+05 kg = 7.96E+02 kg

Fraction of Sludge Batch 4 remaining:
83,219 kg IS at heel / 196,824 kg IS at WAPS sample date = 0.423

Determine the amount of P at heel:
0.423 * 7.96E+02 kg = 3.37E+02 kg

Sludge Batch 5 information:
Before transfer to Tank 40H
Insoluble Solids: 166,461 kg (Ref. 19)
Insoluble Solids: 144,323 kg (Ref. 60)
Total Solids, weight %: 17.09% (Ref. 62)
Insoluble Solids, weight %: 11.19% (Ref. 62)
Density: 1.14 (Ref. 62)
P, weight %: 0.21% (Ref. 62)

After transfer to Tank 40H:
Insoluble Solids: 152,031 kg (Ref. 19)

Determine the mass of Tank 51H:
Using the sample date for Tank 51H, the total insoluble solids target is 144,323 kg. Tank Farm developed a washing model that SRNL followed to prepare the sample per the plan for results of Tank 51H conditions at the time of transfer. SRNL followed the washing strategy before analyses were performed (Ref. 62). However, the Tank Farm was not able to decant as expected. Therefore, the total mass of Tank 51H right before transfer to Tank 40H cannot be used for purposes of this calculation.

Determine the Volume of Tank 51H at the time of qualification sample:
Insoluble Solids mass at sample date / density / insoluble solids wt % / 100
= 144,323 kg / 1.14 kg/L / 11.19 wt% / 100 = 1.13E+06 L

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

Determine the Mass of Tank 51H at the time of qualification sample:
Volume * Density * total solids wt% / 100
= 1.13E+06 L * 1.14 kg/L * 17.09 wt% /100 = 2.20E+05 kg

Determine the amount of P at Tank 51:
0.21 wt% / 100 * 2.20E+05 kg = 4.62E+02 kg

Fraction of Sludge Batch 5 transferred:
152,031 kg IS at after transfer / 166,461 kg IS before transfer = 0.913

Determine the amount of P transferred:
0.913 * 4.62E+02 kg = 4.22E+02 kg

Amount of P in blended Sludge Batch 5:
3.37E+02 kg + 4.22E+02 kg = 7.59E+02 kg P

The mass of PO_4:
= 7.59E+02 kg P / 30.97 kg/kmol P * 1 kmol PO_4/kmol P * 94.97 kg/kmol PO_4
= 2.33E+03 kg PO_4

Percent of PO_4 in glass:
= 2.33E+03 kg / 6.03E+05 kg * 100 = 0.386%

The ARP/MCU contribution:
The PO_4 in the ARP/MCU feed is 798 mg/L or 1.02E+05g/wk (Ref. 4).

Percent of PO_4 in glass:
= 1.02E+05g/wk / 9.07E+06 g/wk *100 = 1.128%

Sludge plus ARP/MCU contribution:
0.386% + 1.128% = 1.514%

PO_4	**1.514%**
DWPF WAC Limit	**3.000%**
Percent of the Limit	**50.47%**

However, PO_4 is soluble so the contribution from ARP/MCU is negligible.

PO_4	0.386%
DWPF WAC Limit	3.000%
Percent of the Limit	12.88%

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

The concentration of NaF

The sludge contribution (Ref. 19) = 0.001 M F

Determine mass of NaF
= 0.001 mol/L F * 1 mol/L NaF / 1 mol/L F * 6.00E+05 gal * 3.785 L/gal
* 41.98 g/mol NaF / 1000 g/kg
= 9.53E+01 kg NaF

Percent of NaF in glass
= 9.53E+01 kg / 6.03E+05 kg * 100 = 0.016%

ARP/MCU contribution:
The F in the ARP/MCU feed is 250 mg/L or 3.20E+04 g/wk (Ref. 4).

Determine rate of NaF
= 3.20E+04 g/wk / 1.90E+01 g/mol * 1 mol/L NaF / 1 mol/L F * 41.98 g/mol NaF
= 7.08E+04 g/wk

Percent of NaF in glass
= 7.08E+04 g/wk / 9.07E+06 g/wk *100 = 0.781%

Sludge plus ARP/MCU contribution:
0.016% + 0.781% = 0.797%

NaF	**0.797%**
DWPF WAC Limit	**1.000%**
Percent of the Limit	**79.66%**

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

The concentration of NaCl

The sludge contribution
The Molarity of Cl^- (Ref. 19) = 0.002 M

The mass of NaCl
= 0.002 mol/L Cl 1 mol/L NaCl / 1 mol/L Cl * 6.005E+05 gal * 3.785 L/gal * 58.45 NaCl / 1000 g/kg
= 2.65E+02 kg NaCl

Percent of NaCl in glass
= 2.65E+02 kg / 6.03E+05 kg * 100 = 0.044%

ARP/MCU contribution:
The Cl in the ARP/MCU feed is 250 mg/L or 3.20E+04 g/wk (Ref. 4).

Determine rate of NaCl
= 3.20E+04 g/wk / 1.90E+01 g/mol * 1 mol/L NaCl / 1 mol/L F * 41.98 g/mol NaCl = 5.28E+04 g/wk

Percent of NaCl in glass
= 5.28+04 g/wk / 9.07E+06 g/wk *100 = 0.582%

Sludge plus ARP/MCU contribution:
0.044% + 0.582% = 0.626%

NaCl	**0.626%**
DWPF WAC Limit	**1.000%**
Percent of Limit	**62.64%**

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

The concentration of Cu

The sludge contribution:

The percent in glass located in table is the CuO.

Determine the mass of Cu:
Mass of Sludge Batch 5 (Ref. 19) * wt% calcine basis (Ref. 19) / 100
= 241,092 kg * 0.07 wt% / 100 = 1.69E+02 kg

Percent of Cu in glass
= 1.69E+02 kg / 6.03E+05 kg * 100 = 0.028%

The ARP/MCU contribution:

The Tank 49 material has Cu 4.01 mg/L or 5.417E+02 g/week (Ref. 3)

Percent of Cu in glass
= 5.41E+02 g/wk Cu / 9.07E+06 g/wk *100
= 0.006%

Sludge plus ARP/MCU contribution:
0.028% + 0.006% = 0.034%

Cu 0.034%
DWPF WAC Limit 0.500%
Percent of the Limit 6.73%

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

The concentration of SO_4^{-2}

The sludge contribution
The amount of S was not determined in the blend of Sludge Batch 5 (Ref. 19). In order to determine the percent of SO_4 in the sludge, a blend Sludge Batch 5 value is needed.

Sludge Batch 4 information
At WAPS sample date 10/07
Total Solids: 268,126 kg (Ref. 60)
S, weight %: 0.332% (Ref. 61)

Fraction of Sludge Batch 4 remaining in heel before transfer of Tank 51H transfer is 0.423 as determined in PO_4^{-2} section. This method is conservative as Sludge Batch 4 was decanted twice following the WAPS sample analysis.

Determine the amount of S at WAPS sample date:
0.332 wt% / 100 * 2.68E+05 kg = 8.90E+02 kg

Determine the amount of S at heel:
0.423 * 8.90E+02 kg = 3.76E+02 kg

Sludge Batch 5 information
Before transfer to Tank 40H:
S, weight %: 0.31% (Ref. 62)
Total Solids: 220,417 as determined in PO_4^{-2} section

Fraction of Tank 51H transfer to Tank 40H is 0.913 as determined in PO_4^{-2} section.

Determine the amount of S at Tank 51:
0.31 wt% / 100 * 2.20E+05 kg = 6.83E+02 kg

Determine the amount of S transferred:
0.913 * 6.83E+02 kg = 6.24E+02 kg

Amount of S in blended Sludge Batch 5:
3.76E+02 kg + 6.24E+02 kg = 1.00E+03 kg S

The mass of SO_4
= 1.00E+03 kg S / 32.01 kg/kmol S * 1 kmol SO_4/kmol S * 96.1 kg/kmol SO_4
= 3.00E+03 kg SO_4

Percent of SO_4 in glass
= 3.00E+03 kg / 6.03E+05 kg * 100 = 0.497%

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

The ARP/MCU contribution
The SO_4 in the ARP/MCU feed is 8927 mg/L or 1.14E+06g/wk (Ref. 4).

Amount of Time needed to process entire batch using the mass of Sludge Batch 5 calcine basis (241,092 kg, Ref. 19).

To determine the mass of glass assume a waste loading waste loading of 40 percent, divide the total mass of oxided elements.
2.41E+05 / 0.40 = 6.03E+05 kg

Determine the mass of Glass in pounds:
6.03E+05 kg * 1 lb / 0.454 kg = 1.33E+06 lbs

Amount of Time needed to process entire batch:
1.33E+06 lbs / 20,000 lbs/wk = 66.4 wk

Mass of SO_4^{2-} :
1.14E+06 g/wk * 66.4 wk = 7.60E+07 g

Sulfate is a soluble compound. The feed will be washed at 512-S before sending material to DWPF to ensure sodium in the MST/sludge solids is negligible when added to the sludge in the SRAT. Assuming the design basis listed in Reference 33, the feed to ARP for each strike tank 1.68 gpm or 3.36 gpm total, and ARP feeds DWPF at a rate of 0.151 gpm. This design basis is at a feed Sodium concentration of 6.44M that is washed to 0.35M (Ref. 33). The sulfate will be washed as well.

The fraction of the rate of Feed to DWPF to the rate of Feed to ARP/MCU processing
0.151 gpm / 3.36 gpm = 0.0449

The fraction of the concentration of Na to DWPF to the concentration of Na in Feed
0.35 M / 6.44 M = 0.0543

The partition of ARP/MCU material from the feed material is determined by multiplying the ratio of the fraction of the rates (Feed to DWPF: Feed to ARP/MCU) by the ratio of sodium concentrations (DWPF concentration: Feed concentration).
0.0449 * 0.0543 = 0.00244

The amount of SO_4 following washing:
7.60E+07 g * 0.00244 /1000 g/kg = 1.86E+02 kg

Percent of SO_4^{-2} in glass
= 1.86E+02 kg / 6.03E+05 kg * 100 = 0.0308%

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

Sludge plus ARP/MCU contribution:
0.497% + 0.0308% = 0.528%

SO_4^{-2} 0.528%
DWPF WAC Limit 0.600%
Percent of the Limit 88.01%

The concentration of Na_2SO_4 Na_2SO_4 is the same as the percent of limit as the sulfate.

Summary:

Species	Limit Wt. % in glass	Value	Percent Of Limit
TiO_2	2	0.804	40.18
Cr_2O_3	0.3	0.169	56.41
PO_4	3	1.514	50.47
NaF	1	0.797	79.66
NaCl	1	0.626	62.64
Cu	0.5	0.034	6.73
SO_4^{-2} Na_2SO_4	0.6 (0.88)	0.528	88.01

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.

The sludge properties are the following (Ref. 19):
Weight Percent total solids: 13.19%
Density of slurry: 1.09

Sulfate Concentration
Amount in sludge (Ref. 19): 0.006M

ARP/MCU contribution is negligible. Sludge contribution is 10.34% of DWPF WAC limit.

Mercury Concentration
Amount in sludge: 1.66 wt% TS (Ref. 19)

M slurry = wt% dry solids / 100 *wt% total solids / 100 * SpG slurry * 1000
= (1.66 / 100) * (13.19 /100) * 1.09 * 1000
= 2.39 g/L

ARP/MCU contribution is 0.00905 g/L. The total mercury concentration is 2.40 g/L or 11.41 % of DWPF WAC limit.

Attachment 11: Glass Quality and Processability (DWPF WAC 5.4.10)

Assume DWPF produces 5 canisters a week at 100% attainment. The mass of each canister is assumed at 4000 pounds. This produces 20,000 pound of glass a week DWPF currently produces nominally 186 canisters annually.

The mass of Sludge Batch 5 on a calcine basis is 241,092 kg (Ref. 19).

To determine the mass of oxide for each element:

Weight % calcine / 100 * Gravimetric Factor * Mass of Sludge Batch 5 Calcine

Species	Wt. % Calcine Basis	Gravimetric Factor	Mass of Oxide (kg)
Al	12.03	1.8895	5.48E+04
B	0	3.2199	0.00E+00
Ba	0.02	1.1165	5.38E+01
Ca	1.78	1.3992	6.00E+03
Ce	0.02	1.1713	5.65E+01
Cr	0.08	1.4616	2.82E+02
Cu	0.07	1.2518	2.11E+02
Fe	20.58	1.4297	7.09E+04
K	0	1.2046	0.00E+00
La	0.01	1.1728	2.83E+01
Li	0	2.15253	0.00E+00
Mg	1.06	1.6583	4.24E+03
Mn	4.61	1.2912	1.44E+04
Na	17.32	1.348	5.63E+04
Ni	2.41	1.2726	7.39E+03
Pb	0.05	1.0772	1.30E+02
Si	1.21	2.1393	6.24E+03
Ti	0.02	1.6685	8.05E+01
U	7.02	1.1792	2.00E+04
Zn	0	1.2447	0.00E+00
Zr	0.02	1.3508	6.51E+01
Total Mass of Oxide Elementals (kg)			**2.41E+05**
Total Mass of Glass at 40 Weight Percent Sludge Oxide Loading (kg)			**6.03E+05**

Data from Reference 19.

To determine the mass of glass, divide the total mass of oxided elements by the assumed waste loading of 40 percent.

2.41E+05 / 0.40 = 6.03E+05 kg

Attachment 11 (continued): Glass Quality and Processability (DWPF WAC 5.4.10)

Determine the mass of Glass in pounds:

6.03E+05 kg * 1 lb / 0.454 kg = 1.33E+06 lbs

Amount of Time needed to process entire batch:

1.33E+06 lbs / 20,000 lbs/wk = 66.4 wk

The Ti includes the mass of Ti from MST, which will increase the mass of the glass. The ARP contribution of TiO_2 is from the MST. ARP will be sending 0.774 lb/hr MST ($NaTi_2O_5H$) (Ref. 33). The feed concentration of 0.395 g MST/L is adjusted to a design basis of 0.6 g MST/L (Ref. 33).

0.774 lb/hr * 24 hr/day * 7 day/wk * (0.6/0.395) =1.98E+02 lb/wk

1.98E+02 lb/week $NaTi_2O_5$ / 199.7 lb/lbmol $NaTi_2O_5H$ * 2 lbmol TiO_2/lbmol $NaTi_2O_5H$ * 79.9 lb/lbmol TiO_2 = 1.58E+02 lb TiO_2 / wk

At the weekly production rate, 20,000 lbs glass is produced.

Mass of TiO_2 added to Sludge Batch:

1.58E+02 lbs/wk * 66.4 wk = 1.05E+04 lbs or 4.77E+03 kg

The mass of TiO_2 is added to the total mass of oxide elemental before mixing with Frit 418 to obtain a 40 weight percent sludge oxide loading.

Mass of Sludge + ARP:

2.41E+05 kg elemental oxide in sludge + 4.77E+03 kg TiO_2 = 2.46E+05 kg

At 40 weight percent sludge oxide loading, the mass is 6.15E+05 kg. The amount of frit needed is determined by subtracting the amount of elemental oxides by the total mass at 40 weight percent.

6.15E+05 kg - 2.46E+05 kg = 3.69E+05 kg of Frit

The nominal Frit 418 compositions are listed below (Ref. 63). To determine the mass of each elemental multiply the weight percent times the mass of frit needed.

Components	Wt% in Frit	Mass Added to Glass (kg)
B_2O_3	8	3.17E+04
Li_2O	8	3.17E+04
MgO	0	0.00E+00
Na_2O	8	3.17E+04
SiO_2	76	3.02E+05

Attachment 11 (continued): Glass Quality and Processability (DWPF WAC 5.4.10)

Total mass and weight percents of elementals in glass:

Species	Gravimetric Factor	Sludge Batch 5 Mass of Oxide (kg)	Mass of Oxide w/ ARP addition (kg)	Mass of Oxide w/ Frit addition (kg)	Mass of Oxide (kg)	Elemental weight % in glass
Al	1.8895	5.48E+04	5.480E+04	5.48E+04	2.90E+04	4.72%
B	3.2199	0.00E+00	0.000E+00	2.95E+04	9.16E+03	1.49%
Ba	1.1165	5.38E+01	5.384E+01	5.38E+01	4.82E+01	0.01%
Ca	1.3992	6.00E+03	6.005E+03	6.00E+03	4.29E+03	0.70%
Ce	1.1713	5.65E+01	5.648E+01	5.65E+01	4.82E+01	0.01%
Cr	1.4616	2.82E+02	2.819E+02	2.82E+02	1.93E+02	0.03%
Cu	1.2518	2.11E+02	2.113E+02	2.11E+02	1.69E+02	0.03%
Fe	1.4297	7.09E+04	7.094E+04	7.09E+04	4.96E+04	8.07%
K	1.2046	0.00E+00	0.000E+00	0.00E+00	0.00E+00	0.00%
La	1.1728	2.83E+01	2.828E+01	2.83E+01	2.41E+01	0.00%
Li	2.15253	0.00E+00	0.000E+00	2.95E+04	1.37E+04	2.23%
Mg	1.6583	4.24E+03	4.238E+03	4.24E+03	2.56E+03	0.42%
Mn	1.2912	1.44E+04	1.435E+04	1.44E+04	1.11E+04	1.81%
Na	1.348	5.63E+04	5.629E+04	8.58E+04	6.36E+04	10.35%
Ni	1.2726	7.39E+03	7.394E+03	7.39E+03	5.81E+03	0.95%
Pb	1.0772	1.30E+02	1.299E+02	1.30E+02	1.21E+02	0.02%
Si	2.1393	6.24E+03	6.241E+03	2.87E+05	1.34E+05	21.79%
Ti	1.6685	8.05E+01	4.848E+03	4.85E+03	2.91E+03	0.47%
U	1.1792	2.00E+04	1.996E+04	2.00E+04	1.69E+04	2.75%
Zn	1.2447	0.00E+00	0.000E+00	0.00E+00	0.00E+00	0.00%
Zr	1.3508	6.51E+01	6.513E+01	6.51E+01	4.82E+01	0.01%
Total Mass of Oxide Elementals (kg) (sludge)						**2.41E+05**
Total Mass of Oxide Elementals sludge w/ ARP addition (kg)						**2.46E+05**
Total Mass of Oxide Elementals sludge + ARP w/ Frit addition (kg)						**6.15E+05**

To determine the weight percent of the oxide elementals in the glass add in the TiO_2 from the ARP addition and the mass of B_2O_3, Li_2O, Na_2O, and SiO_2 from the frit addition to determine the mass of each element and divide by the total mass following the frit addition.

Attachment 11 (continued): Glass Quality and Processability (DWPF WAC 5.4.10)

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 45 weight percent, 39 weight percent, and 1.37 specific gravity respectively for Sludge Batch 5. The results of January 14, 2009, run of PCCS with the elemental weight percents of Sludge Batch 5 coupled processing are listed below:

B Leaching:	0.858 g/L
Li Leaching:	0.872 g/L
Na Leaching:	0.852 g/L
Liquidus:	961.9º C
Viscosity:	38.77 poise
Homogeneity:	233.575 wt% oxide
Al_2O_3:	8.918 wt% oxide
Conserv:	99.96 wt% oxide
Frit:	70.17 wt% oxide
R_2O:	18.75 wt% oxide
Nepheline:	0.671 ratio

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

Radionuclide	**Results (Ci/gal)**	**Heat Generation Factors (W/Ci)**	**R (ft^3 $H_2/10^6$ BTU)**	**Heat Generation (W/gal)**	**Hydrogen Generation (ft^3 H_2/hr/gal)**
Co-60	1.62E-03	1.54E-02	48.36	2.50E-05	4.12E-09
Y-90	9.61E+00	5.54E-03	48.36	5.32E-02	8.79E-06
Sr-90	9.61E+00	1.16E-03	48.36	1.11E-02	1.84E-06
Ru-106	2.53E-04	5.95E-04	48.36	1.51E-07	2.48E-11
Rh-106	2.53E-04	1.89E-02	48.36	4.79E-06	7.91E-10
Sb-125	1.13E-04	3.37E-03	49.36	3.81E-07	6.42E-11
Cs-134	1.49E-03	1.02E-02	48.36	1.52E-05	2.51E-09
Cs-137	2.03E-01	1.01E-03	48.36	2.05E-04	3.38E-08
Ba-137m	1.94E-01	3.94E-03	48.36	7.64E-04	1.26E-07
Ce-144	6.36E-04	6.58E-04	48.36	4.18E-07	6.91E-11
Pr-144	4.97E-04	7.34E-03	48.36	3.65E-06	6.02E-10
Pm-147	3.48E-02	3.67E-04	48.36	1.28E-05	2.11E-09
Eu-154	1.40E-02	9.08E-03	48.36	1.27E-04	2.10E-08
Pu-238	1.47E-01	3.26E-02	134.7	4.79E-03	2.20E-06
Pu-239	1.12E-02	3.02E-02	134.7	3.39E-04	1.56E-07
Pu-240	4.17E-03	3.06E-02	134.7	1.27E-04	5.86E-08
Am-241	1.92E-02	3.28E-02	134.7	6.30E-04	2.90E-07
Cm-244	1.19E-02	3.44E-02	134.7	4.09E-04	1.88E-07
Total (ft3 H2/hr/gal)					**1.37E-05**
DWPF WAC limit (ft3 H2/hr/gal)					**8.95E-05**
% of WAC limit					**15.32%**

Data from Reference 19.
R values are defined in the DWPF WAC (Ref. 11).
Heat Generation Factor values are defined in Reference 59.

To determine the total hydrogen generation rate for DWPF coupled operations

Tank 40H had the following properties (Ref. 19):

Level	599,508 gallons
Total Solids	13.09 wt%
Specific Gravity	1.09 kg/L

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

To determine the concentration of each radionuclide for Sludge Batch 5 contribution, multiply the concentration in Ci/gal by the volume in Tank 40H following the Tank 51H transfer. Assume the entire volume is processed and no heel remains.

For Sludge Batch 5:

Radionuclide	(Ci/gal)	(Ci/batch)
Co-60	1.62E-03	9.71E+02
Y-90	9.61E+00	5.76E+06
Sr-90	9.61E+00	5.76E+06
Ru-106	2.53E-04	1.52E+02
Rh-106	2.53E-04	1.52E+02
Sb-125	1.13E-04	6.77E+01
Cs-134	1.49E-03	8.93E+02
Cs-137	2.03E-01	1.22E+05
Ba-137m	1.94E-01	1.16E+05
Ce-144	6.36E-04	3.81E+02
Pr-144	4.97E-04	2.98E+02
Pm-147	3.48E-02	2.09E+04
Eu-154	1.40E-02	8.39E+03
Pu-238	1.47E-01	8.81E+04
Pu-239	1.12E-02	6.71E+03
Pu-240	4.17E-03	2.50E+03
Am-241	1.92E-02	1.15E+04
Cm-244	1.19E-02	7.13E+03

For the ARP and MCU contribution, use the feed to ARP to determine the concentration of Ci/yr for each radionuclide.

The Ci/yr is determined using the Salt Batch 2 feed material with the feed rate to ARP/MCU from Tank 49H.
ARP feed rate is 1.68 gpm for each MST strike tank (Ref. 33).

Feed Rate = 2 * 1.68gpm * 60min/hr * 24 hr/day * 7 day/wk = 3.40E+04 gal/wk

The concentration of the ARP/MCU contribution to the hydrogen generation is determined by multiplying the results in References 3, 4, and 10 by the feed rate to ARP from Tank 49H by 1000 mL/L and by 1E+12 pCi/Ci by amount of time needed to process Sludge Batch 5.

Amount of mass in calcine is 241,092 kg (Ref. 19).

To determine the mass of glass assume a waste loading waste loading of 40 percent, divide the total mass of oxided elements.

2.41E+05 / 0.40 = 6.430E+05 kg

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

Determine the mass of Glass in pounds

6.03E+05 kg * 1 lb / 0.454 kg = 1.33E+06 lbs

Amount of Time needed to process entire batch

1.33E+06 lbs / 20,000 lbs/wk = 66.4 wk

The contribution over the entire salt batch is determined by multiplying the concentration of the radionuclide in Ci/yr by the ratio of estimated canister production at 40% waste loading to the nominal number of canisters produced in a year.

Radionuclide	Salt Batch (pCi/mL)	Salt Batch (Ci/batch)	Sludge Batch 5 (Ci/batch)	Total Concentration (Ci/batch)
Co-60	1.03E+01	8.83E-02	9.71E+02	9.71E+02
Y-90*	2.93E+05	2.50E+03	5.76E+06	5.76E+06
Sr-90*	2.93E+05	2.50E+03	5.76E+06	5.76E+06
Ru-106	1.41E+02	1.20E+00	1.52E+02	1.53E+02
Rh-106	1.41E+02	1.20E+00	1.52E+02	1.53E+02
Sb-125	6.57E+01	5.61E-01	6.77E+01	6.83E+01
Cs-134*	3.32E+03	2.84E+01	8.93E+02	9.22E+02
Cs-137*	5.34E+07	4.56E+05	1.22E+05	1.41E+06
Ba-137m	5.05E+07	4.31E+05	1.16E+05	5.48E+05
Ce-144	1.68E+02	1.44E+00	3.81E+02	3.83E+02
Pr-144	1.68E+02	1.44E+00	2.98E+02	2.99E+02
Pm-147	6.88E+02	5.87E+00	2.09E+04	2.09E+04
Eu-154	8.30E+01	7.09E-01	8.39E+03	8.39E+03
Pu-238**	2.75E+04	2.35E+02	8.81E+04	8.84E+04
Pu-239**	2.23E+02	1.90E+00	6.71E+03	6.72E+03
Pu-240**	2.23E+02	1.90E+00	2.50E+03	2.50E+03
Am-241	1.87E+03	1.60E+01	1.15E+04	1.15E+04
Cm-244	6.86E+02	5.85E+00	7.13E+03	7.14E+03

Data from Reference 3.
*Data from Reference 4.
**Data from Reference 10.

The total concentration is determined by combining the concentrations of Sludge Batch 5 and ARP/MCU in Ci/batch.

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

Hydrogen generation rate can be determined using the method above with the results of ft^3 H_2 /hr/batch. The sum of the radionuclide contribution is determined using the volume of the Tank 40H (entire volume of Sludge Batch 5).

Radionuclide	**Total Concentration (Ci/batch)**	**"Q" Value (W/Ci)**	**R (ft^3 $H_2/10^6$ BTU)**	**Heat Generation (W/batch)**	**Hydrogen Generation (ft^3 H_2 /hr/batch)**
Co-60	9.71E+02	1.54E-02	48.36	1.50E+01	2.47E-03
Y-90	5.76E+06	5.54E-03	48.36	3.19E+04	5.27E+00
Sr-90	5.76E+06	1.16E-03	48.36	6.69E+03	1.10E+00
Ru-106	1.53E+02	5.951E-04	48.36	9.10E-02	1.50E-05
Rh-106	1.53E+02	1.894E-02	48.36	2.90E+00	4.78E-04
Sb-125	6.83E+01	3.37E-03	49.36	2.30E-01	3.88E-05
Cs-134	9.22E+02	1.02E-02	48.36	9.39E+00	1.55E-03
Cs-137	1.41E+06	1.01E-03	48.36	1.42E+03	2.34E-01
Ba-137m	5.48E+05	3.94E-03	48.36	2.16E+03	3.56E-01
Ce-144	3.83E+02	6.580E-04	48.36	2.52E-01	4.16E-05
Pr-144	2.99E+02	7.340E-03	48.36	2.20E+00	3.63E-04
Pm-147	2.09E+04	3.67E-04	48.36	7.66E+00	1.26E-03
Eu-154	8.39E+03	9.08E-03	48.36	7.62E+01	1.26E-02
Pu-238	8.84E+04	3.26E-02	134.7	2.88E+03	1.32E+00
Pu-239	6.72E+03	3.02E-02	134.7	2.03E+02	9.34E-02
Pu-240	2.50E+03	3.06E-02	134.7	7.65E+01	3.51E-02
Am-241	1.15E+04	3.28E-02	134.7	3.78E+02	1.74E-01
Cm-244	7.14E+03	3.44E-02	134.7	2.45E+02	1.13E-01
Hydrogen Generation (ft^3 H_2 /hr/batch)					**8.72+00**
Total Hydrogen Generation (ft3 H2/hr/gal)					**1.45E-05**
DWPF WAC limit (ft3 H2/hr/gal)					**8.95E-05**
% of WAC limit					**16.26%**

Q values are defined in Reference 59.

Attachment 13-A: Hydrogen Generation Rate from Salt Batch 2 Material for Tank 50H (Tank Farm WAC 11.2.2)

The hydrogen generation rate shall be calculated using the following formulas (Ref. 37):

For alpha particles:

$$R_{\alpha} = 134.7 - 82.3 * \left[NO_{eff}^{-}\right]^{1/3} - 13.6 * \left[NO_{eff}^{-}\right]^{2/3} + 11.8 * \left[NO_{eff}^{-}\right]$$

where $\left[NO_{eff}^{-}\right] = \left[NO_{3}^{-}\right] + 0.5 * \left[NO_{2}^{-}\right]$

For beta/gamma:

$$R_{\beta/\gamma} = 48.36 - 52.78 * \left[NO_{eff}^{-}\right]^{1/3} + 14.1 * \left[NO_{eff}^{-}\right]^{2/3} + 0.572 * \left[NO_{eff}^{-}\right]$$

where R is expressed as ft^3 $H_2/10^6$ Btu.

NO_{eff} = 2.13 M + 0.5 (0.22 M) = 2.24 M

$R\alpha = 134.7 - 82.3 * [2.24M]^{1/3} - 13.6 * [2.24M]^{2/3} + 11.8 * [2.42M]$ =3.02E+01

$R_{\beta/\gamma} = 48.36 - 52.78 * [2.24M]^{1/3} + 14.1 * [2.24M]^{2/3} + 0.572 * [2.24M]$ = 4.62E+00

Q values are the Heat Generation factors and are defined in Reference 59.

In the following tables:
Data from Reference 3
* Data from Reference 4
**Data from Reference 10

Attachment 13-A: Hydrogen Generation Rate from Salt Batch 2 Material for Tank 50H (Tank Farm WAC 11.2.2)

Radionuclide	Results (pCi/ml)	Results (Ci/gal)	"Q" Value (W/Ci)	R_{α} (ft^3 H_2/10^6 BTU)	$R_{\beta\text{-}\gamma}$ (ft^3 H_2/10^6 BTU)	Heat Generation (W/gal)	Hydrogen Generation ft^3 H_2/hr/gal
H-3*	7.49E+02	2.83E-06	3.37E-05		4.62E+00	9.55E-11	1.51E-15
C-14*	5.82E+02	2.20E-06	2.93E-04		4.62E+00	6.45E-10	1.02E-14
Co-60	1.03E+01	3.91E-08	1.54E-02		4.62E+00	6.03E-10	9.51E-15
Ni-59	4.04E+02	1.53E-06	3.98E-05		4.62E+00	6.09E-11	9.60E-16
Ni-63	1.38E+02	5.22E-07	1.01E-04		4.62E+00	5.28E-11	8.32E-16
Se-79	5.99E+01	2.27E-07	3.13E-04		4.62E+00	7.09E-11	1.12E-15
Sr-90*	2.93E+05	1.11E-03	1.16E-03		4.62E+00	1.29E-06	2.03E-11
Y-90*	2.93E+05	1.11E-03	5.54E-03		4.62E+00	6.14E-06	9.69E-11
Tc-99*	6.89E+04	2.61E-04	5.01E-04		4.62E+00	1.31E-07	2.06E-12
Sb-125	6.57E+01	2.49E-07	3.37E-03		4.62E+00	8.38E-10	1.32E-14
Sn-126	2.53E+02	9.58E-07	1.08E-03		4.62E+00	1.03E-09	1.63E-14
I-129*	5.00E+01	1.89E-07	4.77E-04		4.62E+00	9.03E-11	1.42E-15
Cs-134*	3.32E+03	1.26E-05	1.02E-02		4.62E+00	1.28E-07	2.02E-12
Cs-135*	6.84E+02	1.23E-06	3.32E-04		4.62E+00	4.09E-10	6.45E-15
Cs-137*	5.34E+07	2.02E-01	1.01E-03		4.62E+00	2.04E-04	3.22E-09
Ba-137m	5.05E+07	1.91E-01	3.94E-03		4.62E+00	7.53E-04	1.19E-08
Pm-147	6.88E+02	2.60E-06	3.67E-04		4.62E+00	9.56E-10	1.51E-14
Eu-154	8.30E+01	3.14E-07	9.08E-03		4.62E+00	2.85E-09	4.50E-14
Th-232	8.97E-03	3.40E-11	2.38E-02	3.02E+01		8.07E-13	8.31E-17
U-233**	3.63E+02	1.37E-06	2.86E-02	3.02E+01		3.93E-08	4.04E-12
U-234**	3.13E+02	1.18E-06	2.83E-02	3.02E+01		3.35E-08	3.45E-12
U-235**	2.57E-01	9.73E-10	2.71E-02	3.02E+01		2.64E-11	2.72E-15
U-236**	3.24E+00	1.23E-08	2.66E-02	3.02E+01		3.26E-10	3.36E-14
U-238**	1.74E+00	6.59E-09	2.49E-02	3.02E+01		1.64E-10	1.69E-14
Np-237**	3.53E+01	1.34E-07	2.88E-02	3.02E+01		3.85E-09	3.96E-13
Pu-238**	2.75E+04	1.04E-04	3.26E-02	3.02E+01		3.39E-06	3.49E-10
Pu-239**	2.23E+02	8.44E-07	3.02E-02	3.02E+01		2.55E-08	2.63E-12
Pu-240**	2.23E+02	8.44E-07	3.06E-02	3.02E+01		2.58E-08	2.66E-12
Pu-241*	7.73E+04	2.93E-04	3.20E-05		4.62E+00	9.36E-09	1.48E-13
Pu-242	8.00E+01	2.50E-05	2.90E-02	3.02E+01		7.26E-07	7.47E-11
Am-241	1.87E+03	7.07E-06	3.28E-02	3.02E+01		2.32E-07	2.39E-11
Cm-244	6.86E+02	2.59E-06	3.44E-02	3.02E+01		8.92E-08	9.18E-12
Cm-245	1.39E+03	5.24E-06	3.33E-02	3.02E+01		1.75E-07	1.80E-11
Sm-151	4.43E+02	1.68E-06	7.41E-04		4.62E+00	1.24E-09	1.96E-14
Ra-226	4.84E+02	1.83E-06	2.84E-02	3.02E+01		5.19E-08	5.34E-12
Eu-155	2.47E+02	9.36E-07	7.59E-04		4.62E+00	7.10E-10	1.12E-14
Th-230	2.53E+02	9.59E-07	2.77E-02	3.02E+01		2.65E-08	2.73E-12
Pu-244	2.40E-01	9.08E-10	2.71E-02	3.02E+01		2.46E-11	2.54E-15
Am-242m	7.78E+02	2.94E-06	4.05E-04	3.02E+01		1.19E-09	1.23E-13
Am-243	1.64E+03	6.22E-06	3.15E-02	3.02E+01		1.96E-07	2.02E-11
Cm-242	5.22E+01	1.98E-07	3.59E-02	3.02E+01		7.09E-09	7.30E-13
Ce-144	1.68E+02	6.37E-07	6.580E-04		4.62E+00	4.19E-10	6.61E-15
Pr-144	1.68E+02	6.37E-07	7.34E-02		4.62E+00	4.68E-08	7.37E-13
Ru-106	1.41E+02	5.34E-07	5.951E-04		4.62E+00	3.18E-10	5.01E-15
Rh-106	1.41E+02	5.34E-07	1.894E-02		4.62E+00	1.01E-08	1.59E-13
					TOTAL	**at 0°C**	**1.57E-08**
						at 43°C	**1.82E-08**
						at 25°C	**1.72E-08**

Attachment 13-B: Hydrogen Generation Rate from Diluted Salt Batch 2 Feed Material for Tank 50H (Tank Farm WAC 11.2.2)

With the 15% dilution rate expected with the ARP/MCU process, the following apply:

NO_{eff} = 1.81 M + 0.5 (0.187 M) = 1.90 M
$R\alpha$ = 3.43E+01
$R_{\beta/\gamma}$ = 5.61E+00

With the 32% dilution rate expected as the bounding condition for the ARP/MCU process, the following apply:

NO_{eff} = 1.45 M + 0.5 (0.150 M) = 1.52 M
$R\alpha$ = 4.00E+01
$R_{\beta/\gamma}$ = 7.10E+00

Attachment 13-B (continued): H2 Generation Rate for Tank 50H (15% Dilution)

Radionuclide	Results (pCi/ml)	Results (Ci/gal)	"Q" Value (W/Ci)	R_α (ft^3 $H_2/10^6$ BTU)	$R_{\beta-\gamma}$ (ft^3 $H_2/10^6$ BTU)	Heat Generation (W/gal)	Hydrogen Generation (ft^3 H_2 /hr/gal)
H-3*	7.49E+02	2.83E-06	3.37E-05		5.61E+00	9.55E-11	1.83E-15
C-14*	5.82E+02	2.20E-06	2.93E-04		5.61E+00	6.45E-10	1.24E-14
Co-60	1.03E+01	3.91E-08	1.54E-02		5.61E+00	6.03E-10	1.15E-14
Ni-59	4.04E+02	1.53E-06	3.98E-05		5.61E+00	6.09E-11	1.17E-15
Ni-63	1.38E+02	5.22E-07	1.01E-04		5.61E+00	5.28E-11	1.01E-15
Se-79	5.99E+01	2.27E-07	3.13E-04		5.61E+00	7.09E-11	1.36E-15
Sr-90*	2.93E+05	1.11E-03	1.16E-03		5.61E+00	1.29E-06	2.46E-11
Y-90*	2.93E+05	1.11E-03	5.54E-03		5.61E+00	6.14E-06	1.18E-10
Tc-99*	6.89E+04	2.61E-04	5.01E-04		5.61E+00	1.31E-07	2.50E-12
Sb-125	6.57E+01	2.49E-07	3.37E-03		5.61E+00	8.38E-10	1.60E-14
Sn-126	2.53E+02	9.58E-07	1.08E-03		5.61E+00	1.03E-09	1.98E-14
I-129*	5.00E+01	1.89E-07	4.77E-04		5.61E+00	9.03E-11	1.73E-15
Cs-134*	3.32E+03	1.26E-05	1.02E-02		5.61E+00	1.28E-07	2.45E-12
Cs-135*	6.84E+02	2.59E-06	3.32E-04		5.61E+00	8.59E-10	1.64E-14
Cs-137*	5.34E+07	2.02E-01	1.01E-03		5.61E+00	2.04E-04	3.91E-09
Ba-137m	5.05E+07	1.91E-01	3.94E-03		5.61E+00	7.53E-04	1.44E-08
Pm-147	6.88E+02	2.60E-06	3.67E-04		5.61E+00	9.56E-10	1.83E-14
Eu-154	8.30E+01	3.14E-07	9.08E-03		5.61E+00	2.85E-09	5.46E-14
Th-232	8.97E-03	3.40E-11	2.38E-02	3.43E+01		8.07E-13	9.44E-17
U-233**	3.63E+02	1.37E-06	2.86E-02	3.43E+01		3.93E-08	4.59E-12
U-234**	3.13E+02	1.18E-06	2.83E-02	3.43E+01		3.35E-08	3.92E-12
U-235**	2.57E-01	9.73E-10	2.71E-02	3.43E+01		2.64E-11	3.09E-15
U-236**	3.24E+00	1.23E-08	2.66E-02	3.43E+01		3.26E-10	3.82E-14
U-238**	1.74E+00	6.59E-09	2.49E-02	3.43E+01		1.64E-10	1.92E-14
Np-237**	3.53E+01	1.34E-07	2.88E-02	3.43E+01		3.85E-09	4.50E-13
Pu-238**	2.75E+04	1.04E-04	3.26E-02	3.43E+01		3.39E-06	3.97E-10
Pu-239**	2.23E+02	8.44E-07	3.02E-02	3.43E+01		2.55E-08	2.99E-12
Pu-240**	2.23E+02	8.44E-07	3.06E-02	3.43E+01		2.58E-08	3.02E-12
Pu-241*	7.73E+04	2.93E-04	3.20E-05		5.61E+00	9.36E-09	1.79E-13
Pu-242	8.00E+01	3.03E-07	2.90E-02	3.43E+01		8.80E-09	1.03E-12
Am-241	1.87E+03	7.07E-06	3.28E-02	3.43E+01		2.32E-07	2.72E-11
Cm-244	6.86E+02	2.59E-06	3.44E-02	3.43E+01		8.92E-08	1.04E-11
Cm-245	1.39E+03	5.24E-06	3.33E-02	3.43E+01		1.75E-07	2.04E-11
Sm-151	4.43E+02	1.68E-06	7.41E-04		5.61E+00	1.24E-09	2.38E-14
Ra-226	4.84E+02	1.83E-06	2.84E-02	3.43E+01		5.19E-08	6.07E-12
Eu-155	2.47E+02	9.36E-07	7.59E-04		5.61E+00	7.10E-10	1.36E-14
Th-230	2.53E+02	9.59E-07	2.77E-02	3.43E+01		2.65E-08	3.10E-12
Pu-244	2.40E-01	9.08E-10	2.71E-02	3.43E+01		2.46E-11	2.88E-15
Am-242m	7.78E+02	2.94E-06	4.05E-04	3.43E+01		1.19E-09	1.39E-13
Am-243	1.64E+03	6.22E-06	3.15E-02	3.43E+01		1.96E-07	2.29E-11
Cm-242	5.22E+01	1.98E-07	3.59E-02	3.43E+01		7.09E-09	8.29E-13
Ce-144	1.68E+02	6.37E-07	6.580E-04		5.61E+00	4.19E-10	8.02E-15
Pr-144	1.68E+02	6.37E-07	7.340E-03		5.61E+00	4.68E-09	8.95E-14
Ru-106	1.41E+02	5.34E-07	5.951E-04	5.61E+00	3.18E-10	6.08E-15	5.61E+00
Rh-106	1.41E+02	5.34E-07	1.894E-02	5.61E+00	1.01E-08	1.93E-13	5.61E+00
					Total	**at 0°C**	**1.90E-08**
						at 43°C	**2.20E-08**
						at 25°C	**2.07E-08**

Attachment 13-B (continued): H2 Generation Rate for Tank 50H (32% Dilution)

Radionuclide	Results (pCi/ml)	Results (Ci/gal)	"Q" Value (W/Ci)	R_{α} (ft^3 $H_2/10^6$ BTU)	$R_{\beta-\gamma}$ (ft^3 $H_2/10^6$ BTU)	Heat Generation (W/gal)	Hydrogen Generation (ft^3 H_2 /hr/gal)
H-3*	7.49E+02	2.83E-06	3.37E-05		7.10E+00	9.55E-11	2.32E-15
C-14*	5.82E+02	2.20E-06	2.93E-04		7.10E+00	6.45E-10	1.56E-14
Co-60	1.03E+01	3.91E-08	1.54E-02		7.10E+00	6.03E-10	1.46E-14
Ni-59	4.04E+02	1.53E-06	3.98E-05		7.10E+00	6.09E-11	1.48E-15
Ni-63	1.38E+02	5.22E-07	1.01E-04		7.10E+00	5.28E-11	1.28E-15
Se-79	5.99E+01	2.27E-07	3.13E-04		7.10E+00	7.09E-11	1.72E-15
Sr-90*	2.93E+05	1.11E-03	1.16E-03		7.10E+00	1.29E-06	3.12E-11
Y-90*	2.93E+05	1.11E-03	5.54E-03		7.10E+00	6.14E-06	1.49E-10
Tc-99*	6.89E+04	2.61E-04	5.01E-04		7.10E+00	1.31E-07	3.17E-12
Sb-125	6.57E+01	2.49E-07	3.37E-03		7.10E+00	8.38E-10	2.03E-14
Sn-126	2.53E+02	9.58E-07	1.08E-03		7.10E+00	1.03E-09	2.51E-14
I-129*	5.00E+01	1.89E-07	4.77E-04		7.10E+00	9.03E-11	2.19E-15
Cs-134*	3.32E+03	1.26E-05	1.02E-02		7.10E+00	1.28E-07	3.10E-12
Cs-135*	6.84E+02	2.59E-06	3.32E-04		7.10E+00	8.59E-10	2.08E-14
Cs-137*	5.34E+07	2.02E-01	1.01E-03		7.10E+00	2.04E-04	4.95E-09
Ba-137m	5.05E+07	1.91E-01	3.94E-03		7.10E+00	7.53E-04	1.83E-08
Pm-147	6.88E+02	2.60E-06	3.67E-04		7.10E+00	9.56E-10	2.32E-14
Eu-154	8.30E+01	3.14E-07	9.08E-03		7.10E+00	2.85E-09	6.91E-14
Th-232	8.97E-03	3.40E-11	2.38E-02	4.00E+01		8.07E-13	1.10E-16
U-233**	3.63E+02	1.37E-06	2.86E-02	4.00E+01		3.93E-08	5.36E-12
U-234**	3.13E+02	1.18E-06	2.83E-02	4.00E+01		3.35E-08	4.57E-12
U-235**	2.57E-01	9.73E-10	2.71E-02	4.00E+01		2.64E-11	3.60E-15
U-236**	3.24E+00	1.23E-08	2.66E-02	4.00E+01		3.26E-10	4.45E-14
U-238**	1.74E+00	6.59E-09	2.49E-02	4.00E+01		1.64E-10	2.24E-14
Np-237**	3.53E+01	1.34E-07	2.88E-02	4.00E+01		3.85E-09	5.25E-13
Pu-238**	2.75E+04	1.04E-04	3.26E-02	4.00E+01		3.39E-06	4.63E-10
Pu-239**	2.23E+02	8.44E-07	3.02E-02	4.00E+01		2.55E-08	3.48E-12
Pu-240**	2.23E+02	8.44E-07	3.06E-02	4.00E+01		2.58E-08	3.52E-12
Pu-241*	7.73E+04	2.93E-04	3.20E-05		7.10E+00	9.36E-09	2.27E-13
Pu-242	8.00E+01	3.03E-07	2.90E-02	4.00E+01		8.80E-09	1.20E-12
Am-241	1.87E+03	7.07E-06	3.28E-02	4.00E+01		2.32E-07	3.17E-11
Cm-244	6.86E+02	2.59E-06	3.44E-02	4.00E+01		8.92E-08	1.22E-11
Cm-245	1.39E+03	5.24E-06	3.33E-02	4.00E+01		1.75E-07	2.38E-11
Sm-151	4.43E+02	1.68E-06	7.41E-04		7.10E+00	1.24E-09	3.01E-14
Ra-226	4.84E+02	1.83E-06	2.84E-02	4.00E+01		5.19E-08	7.08E-12
Eu-155	2.47E+02	9.36E-07	7.59E-04		7.10E+00	7.10E-10	1.72E-14
Th-230	2.53E+02	9.59E-07	2.77E-02	4.00E+01		2.65E-08	3.62E-12
Pu-244	2.40E-01	9.08E-10	2.71E-02	4.00E+01		2.46E-11	3.36E-15
Am-242m	7.78E+02	2.94E-06	4.05E-04	4.00E+01		1.19E-09	1.63E-13
Am-243	1.64E+03	6.22E-06	3.15E-02	4.00E+01		1.96E-07	2.67E-11
Cm-242	5.22E+01	1.98E-07	3.59E-02	4.00E+01		7.09E-09	9.67E-13
Ce-144	1.68E+02	6.37E-07	6.580E-04		7.10E+00	4.19E-10	1.02E-14
Pr-144	1.68E+02	6.37E-07	7.340E-03		7.10E+00	4.68E-09	1.13E-13
Ru-106	1.41E+02	5.34E-07	5.951E-04		7.10E+00	3.18E-10	7.70E-15
Rh-106	1.41E+02	5.34E-07	1.894E-02		7.10E+00	1.01E-08	2.45E-13
					Total	**at 0°C**	**2.40E-08**
						at 43°C	**2.78E-08**
						at 25°C	**2.62E-08**

Attachment 14: Hazard Categorization Evaluation Salt Batch 2 Feed Qualification

Using the selection of isotopes for Hazard Category determination as defined in Reference 64, the Hazard Category for Salt Batch 2 was determined. Total gamma, cesium-removed total alpha, and cesium-removed total beta results were not used in this calculation. Since the isotopic concentrations are derived from a blend calculation (Ref. 3), and some of the radioisotopic analytical values were reported as less than the detection limit, the sum of the calculated blend value of the contributing isotopes is greater than the calculated total blend value for some cases. The radioisotopes addressed for the referenced hazard category calculation comprised approximately 80% to 90% of the total contribution, and it is assumed that a similar distribution exists in Salt Batch 2. Thus, it is conservatively assumed that other alpha, beta, and gamma contributors equal 25% of the total contribution.

Upon review of the analyses, Pu-238 accounts for a majority of the total alpha (see Table 1). In addition, Pu-239, -240, and -242 were included as alpha contributors. For gamma-contributing constituents, Cs-137 is typically considered equal to the total gamma. However, other species known to contribute to total gamma include Cs-134, Cs-135, Eu-154, Eu-155, Co-60, I-129, and Sb-125. These constituents are shown in Table 1. Sr-90 is the major contributor to total beta, but it is in secular equilibrium with Y-90, which is another beta-contributor. Thus, Sr-90/Y-90 combination accounts for the majority of the total beta. Other species known to contribute one percent or more to total beta include Pu-241 and Tc-99.

For the dominant alpha, beta, and gamma emitters listed in Table 2, the threshold values are listed for the specific radioisotope. For the remaining alpha, gamma, and beta activity (listed as "other α, γ, β") the appropriate lowest listed threshold value is applied. Also note that for cesium, the Cs in the strip effluent is estimated by increasing the feed Cs activity by a factor of 15, which is the maximum concentration factor expected for the process (Ref. 65). Likewise, the decontaminated salt stream is estimated by decreasing the Cs feed activity by a factor of 12, which is the minimum dilution factor for the MCU (Ref. 65). Actinide removal in 96H/512-S was not considered in this evaluation.

Sum of the ratios is determined by:

$(Inv_A/T_A) + (Inv_B/T_B)+\ldots(Inv_n/T_n)$ = Sum of the Ratios

Where:
$Inv_{A, B\ldots n}$ = the inventory of the radionuclide in Tank 49
T = the threshold quantity of the radionuclide
Sum of the Ratios = the summation of radionuclide threshold ratios

Attachment 14 (continued): Hazard Categorization Evaluation Salt Batch 2 Feed Qualification

When using Hazard Category 2 thresholds, if the sum of the ratios is less than one, then the facility is Hazard Category 3. If the sum of the ratios is greater than one, then the Hazard Category is 2.

The inventory of the individual nuclides is determined by multiplying the curie concentration in Tank 49 by the maximum volume of material that could be present in MCU. This volume is based on the overflow volumes of all waste containing tanks in MCU (Ref. 65).

The results are presented in Table 2. The sum of the ratios is 0.297. This correlates with the expected outcome demonstrated in Reference 66. The same dominant radionuclides are the same expected from fission yield, elemental solubility in salt solutions, and prior sample analyses of waste. As demonstrated in Reference 66, when Cs-137 is low, the expected sum of fractions would be low, especially in aged waste. This is true even though plutonium is near its saturation concentration.

The sum of the fractions is less than one when compared to the Hazard Categorization 2 thresholds. Therefore, the Tank 49 feed will not compromise the MCU facility hazard categorization of Hazard Category 3.

Attachment 14 (continued): Hazard Categorization Evaluation Salt Batch 2 Feed Qualification

Table 1 – Radioisotopic Results

Radionuclides	pCi/ml	Ci/gal
Alpha		
Pu-238**	2.75E+04	1.04E-04
Pu-239**	2.23E+02	8.44E-07
Pu-240**	2.23E+02	8.44E-07
Pu-242	8.00E+01	3.03E-07
sum Pu	2.80E+04	1.06E-04
Other α		2.65E-05
Gamma		
Cs-134*	3.32E+03	1.26E-05
Cs-135*	6.84E+02	2.59E-06
Cs-137*	5.34E+07	2.02E-01
Eu-155	2.47E+02	9.37E-07
Co-60	1.03E+01	3.90E-08
Eu-154	8.30E+01	3.14E-07
Sb-125	6.57E+01	2.49E-07
I-129*	5.00E+01	1.89E-07
Sum known γ's	5.34E+07	2.02E-01
Other γ		5.05E-02
Beta		
Sr-90/Y-90*	5.86E+05	2.22E-03
Pu-241*	7.73E+04	2.93E-04
Tc-99*	6.89E+04	2.61E-04
Sum known β's	7.32E+05	2.77E-03
Other β		6.93E-04

Data from Reference 3
* Data from Reference 4
**Data from Reference 10

Attachment 14 (continued): Hazard Categorization Evaluation Salt Batch 2 Feed Qualification

Table 2 – Hazard Category Determination for Tank 49

Radionuclide	Ci/gal	Vol. overflow (gal)	DSS Ci/gal	DSS vol. (gal)	Strip (Ci/gal)	Strip vol. (gal)	Ci	HC2 Threshold (Ci)	Fraction
Cs-134*	1.26E-05	2.45E+04	1.05E-06	8.23E+03	1.89E-04	1.33E+03	5.68E-01	6.00E+04	9.47E-06
Cs-135*	2.59E-06	2.45E+04	2.16E-07	8.23E+03	3.88E-05	1.33E+03	1.17E-01	6.35E+05	1.84E-07
Cs-137*	2.02E-01	2.45E+04	1.68E-02	8.23E+03	3.03E+00	1.33E+03	9.11E+03	8.90E+04	1.02E-01
Pu-238**	1.04E-04	2.45E+04	1.04E-04	8.23E+03	1.04E-04	1.33E+03	3.54E+00	6.20E+01	5.71E-02
Pu-239**	8.44E-07	2.45E+04	8.44E-07	8.23E+03	8.44E-07	1.33E+03	2.87E-02	5.60E+01	5.13E-04
Pu-240**	8.44E-07	2.45E+04	8.44E-07	8.23E+03	8.44E-07	1.33E+03	2.87E-02	5.60E+01	5.13E-04
Pu-242	3.03E-07	2.45E+04	3.03E-07	8.23E+03	3.03E-07	1.33E+03	1.03E-02	5.95E+01	1.73E-04
Other α	2.65E-05	2.45E+04	2.65E-05	8.23E+03	2.65E-05	1.33E+03	9.03E-01	1.80E+01	5.01E-02
Eu-155	9.37E-07	2.45E+04	9.37E-07	8.23E+03	9.37E-07	1.33E+03	3.19E-02	7.30E+05	4.37E-08
Co-60	3.90E-08	2.45E+04	3.90E-08	8.23E+03	3.90E-08	1.33E+03	1.33E-03	1.90E+05	6.98E-09
Eu-154	3.14E-07	2.45E+04	3.14E-07	8.23E+03	3.14E-07	1.33E+03	1.07E-02	1.10E+05	9.72E-08
Sb-125	2.49E-07	2.45E+04	2.49E-07	8.23E+03	2.49E-07	1.33E+03	8.46E-03	4.30E+05	1.97E-08
I-129*	1.89E-07	2.45E+04	1.89E-07	8.23E+03	1.89E-07	1.33E+03	6.43E-03	3.17E+02	2.03E-05
Other γ	5.05E-02	2.45E+04	5.05E-02	8.23E+03	5.05E-02	1.33E+03	1.72E+03	2.20E+04	7.81E-02
Sr-90/Y-90*	2.22E-03	2.45E+04	2.22E-03	8.23E+03	2.22E-03	1.33E+03	7.56E+01	2.20E+04	3.43E-03
Pu-241*	2.93E-04	2.45E+04	2.93E-04	8.23E+03	2.93E-04	1.33E+03	9.97E+00	2.90E+03	3.44E-03
Tc-99*	2.61E-04	2.45E+04	2.61E-04	8.23E+03	2.61E-04	1.33E+03	8.88E+00	3.80E+06	2.34E-06
Other β	6.93E-04	2.45E+04	6.93E-04	8.23E+03	6.93E-04	1.33E+03	2.36E+01	2.20E+04	1.07E-03
								SUM	**2.97E-01**

Data from Reference 3
* Data from Reference 4
**Data from Reference 10

Attachment 15: IDP to Meet Saltstone WAC (Saltstone WAC 5.4.1 and Tank Farm WAC 11.4)

IDP Based on Salt Batch 2 Feed Material

Radionuclide	Concentration pCi/mL	Concentration Ci/gal	Dose Potential CEDE DCF (rem/Ci)	rem/gal
Sr-90*	2.93E+05	1.11E-03	9.50E+04	1.05E+02
Cs-137*	5.34E+07	2.02E-01	1.90E+04	3.84E+03
Eu-154	8.30E+01	3.14E-07	2.00E+05	6.28E-02
Pu-241*	7.73E+04	2.93E-04	3.30E+06	9.66E+02
Total alpha*	2.94E+04	1.11E-04	1.90E+08	2.11E+04
Total Dose				2.60E+04
Saltstone WAC limit				2.09E+05
% of WAC limit				12.42%

Data from Reference 3
* Data from Reference 4

Attachment 16-A: Hydrogen Generation Rate from Salt Batch 2 Feed Material for Saltstone (Saltstone WAC 5.4.4)

The hydrogen generation rate shall be calculated using the following formulas (Ref. 13):

For alpha particles:

$$R_{\alpha} = 134.7 - 82.3 * \left[NO^{-}_{eff}\right]^{1/3} - 13.6 * \left[NO^{-}_{eff}\right]^{2/3} + 11.8 * \left[NO^{-}_{eff}\right]$$

where $\left[NO^{-}_{eff}\right] = \left[NO^{-}_{3}\right] + 0.25 * \left[NO^{-}_{2}\right]$

For beta/gamma:

$$R_{\beta/\gamma} = 48.36 - 52.78 * \left[NO^{-}_{eff}\right]^{1/3} + 14.1 * \left[NO^{-}_{eff}\right]^{2/3} + 0.572 * \left[NO^{-}_{eff}\right]$$

where R is expressed as ft^3 $H_2/10^6$ Btu.

NO_{eff} = 2.13 M + 0.25 (0.22 M) = 2.18 M

$R\alpha = 134.7 - 82.3 * [2.18M]^{1/3} - 13.6 * [2.18M]^{2/3} + 11.8 * [2.18M]$ = 3.08E+01

$R_{\beta/\gamma} = 48.36 - 52.78 * [2.18M]^{1/3} + 14.1 * [2.18M]^{2/3} + 0.572 * [2.18M]$ = 4.87E+00

See Table below:

Hydrogen Generation	**2.56E-09 ft^3 H_2/hour/gallon @ 95ºC**
Saltstone WAC Limit	**5.59E-08 ft^3 H_2/hour/gallon @ 95ºC**
Percent of Limit	**4.58%**

Q values are the Heat Generation factors and are defined in Reference 59.

In the following tables:
Data from Reference 3
* Data from Reference 4
**Data from Reference 10

Attachment 16-A (continued): Hydrogen Generation Rate from Salt Batch 2 Feed Material for Saltstone (Saltstone WAC 5.4.4)

Radionuclide	Results (pCi/ml)	Results (Ci/gal)	"Q" Value (W/Ci)	R_α (ft^3 $H_2/10^6$ BTU)	$R_{\beta-\gamma}$ (ft^3 $H_2/10^6$ BTU)	Heat Generation (W/gal)	Hydrogen Generation ft^3 H_2/hr/gal
H-3*	7.49E+02	2.83E-06	3.37E-05		4.87E+00	9.55E-11	1.59E-15
C-14*	5.82E+02	2.20E-06	2.93E-04		4.87E+00	6.45E-10	1.07E-14
Co-60	1.03E+01	3.91E-08	1.54E-02		4.87E+00	6.03E-10	1.00E-14
Ni-59	4.04E+02	1.53E-06	3.98E-05		4.87E+00	6.09E-11	1.01E-15
Ni-63	1.38E+02	5.22E-07	1.01E-04		4.87E+00	5.28E-11	8.76E-16
Se-79	5.99E+01	2.27E-07	3.13E-04		4.87E+00	7.09E-11	1.18E-15
Sr-90*	2.93E+05	1.11E-03	1.16E-03		4.87E+00	1.29E-06	2.14E-11
Y-90*	2.93E+05	1.11E-03	5.54E-03		4.87E+00	6.14E-06	1.02E-10
Tc-99*	6.89E+04	2.61E-04	5.01E-04		4.87E+00	1.31E-07	2.17E-12
Ru-106	1.41E+02	5.34E-07	5.95E-04		4.87E+00	3.18E-10	5.28E-15
Rh-106	1.41E+02	5.34E-07	1.89E-02		4.87E+00	1.01E-08	1.68E-13
Sb-125	6.57E+01	2.49E-07	3.37E-03		4.87E+00	8.38E-10	1.39E-14
Sn-126	2.53E+02	9.58E-07	1.08E-03		4.87E+00	1.03E-09	1.72E-14
I-129*	5.00E+01	1.89E-07	4.77E-04		4.87E+00	9.03E-11	1.50E-15
Cs-134*	2.77E+02	1.05E-06	1.02E-02		4.87E+00	1.07E-08	1.77E-13
Cs-135*	5.70E+01	2.16E-07	3.32E-04		4.87E+00	7.16E-11	1.19E-15
Cs-137*	4.45E+06	1.68E-02	1.01E-03		4.87E+00	1.70E-05	2.82E-10
Ba-137m	4.21E+06	1.59E-02	3.94E-03		4.87E+00	6.28E-05	1.04E-09
Ce-144	1.68E+02	6.37E-07	6.58E-04		4.87E+00	4.19E-10	6.96E-15
Pr-144	1.68E+02	6.37E-07	7.34E-03		4.87E+00	4.68E-09	7.76E-14
Pm-147	6.88E+02	2.60E-06	3.67E-04		4.87E+00	9.56E-10	1.59E-14
Eu-154	8.30E+01	3.14E-07	9.08E-03		4.87E+00	2.85E-09	4.74E-14
Th-232	8.97E-03	3.40E-11	2.38E-02	3.08E+01		8.07E-13	8.48E-17
U-233**	3.63E+02	1.37E-06	2.86E-02	3.08E+01		3.93E-08	4.13E-12
U-234**	3.13E+02	1.18E-06	2.83E-02	3.08E+01		3.35E-08	3.52E-12
U-235**	2.57E-01	9.73E-10	2.71E-02	3.08E+01		2.64E-11	2.77E-15
U-236**	3.24E+00	1.23E-08	2.66E-02	3.08E+01		3.26E-10	3.43E-14
U-238**	1.74E+00	6.59E-09	2.49E-02	3.08E+01		1.64E-10	1.72E-14
Np-237**	3.53E+01	1.34E-07	2.88E-02	3.08E+01		3.85E-09	4.04E-13
Pu-238**	2.75E+04	1.04E-04	3.26E-02	3.08E+01		3.39E-06	3.57E-10
Pu-239**	2.23E+02	8.44E-07	3.02E-02	3.08E+01		2.55E-08	2.68E-12
Pu-240**	2.23E+02	8.44E-07	3.06E-02	3.08E+01		2.58E-08	2.71E-12
Pu-241*	7.73E+04	2.93E-04	3.20E-05		4.87E+00	9.36E-09	1.55E-13
Pu-242	8.00E+01	3.03E-07	2.90E-02	3.08E+01		8.80E-09	9.25E-13
Am-241	1.87E+03	7.07E-06	3.28E-02	3.08E+01		2.32E-07	2.44E-11
Cm-244	6.86E+02	2.59E-06	3.44E-02	3.08E+01		8.92E-08	9.37E-12
Cm-245	1.39E+03	5.24E-06	3.33E-02	3.08E+01		1.75E-07	1.84E-11
Sm-151	4.43E+02	1.68E-06	7.41E-04	3.08E+01		1.24E-09	1.30E-13
Ra-226	4.84E+02	1.83E-06	2.84E-02	3.08E+01		5.19E-08	5.46E-12
Eu-155	2.47E+02	9.36E-07	7.59E-04		4.87E+00	7.10E-10	1.18E-14
Th-230	8.97E-03	3.40E-11	2.77E-02	3.08E+01		9.39E-13	9.87E-17
Pu-244	2.40E-01	9.08E-10	2.71E-02	3.08E+01		2.46E-11	2.59E-15
Am-242m	7.78E+02	2.94E-06	4.05E-04	3.08E+01		1.19E-09	1.25E-13
Am-243	1.64E+03	6.22E-06	3.15E-02	3.08E+01		1.96E-07	2.06E-11
Cm-242	5.22E+01	1.98E-07	3.59E-02	3.08E+01		7.09E-09	7.45E-13
						Total	**1.90E-09**
						at 95°C	**2.56E-09**

Q values are defined in Ref. 59.

Attachment 16-B: Hydrogen Generation Rate from Salt Batch 2 Feed Material for Saltstone (Saltstone WAC 5.4.4)

With the 15% dilution rate expected with the ARP/MCU process, the following apply:

NO_{eff} = 1.81 M + 0.25 (0.187 M) = 1.86 M
R_{α} = 3.49E+01
$R_{\beta/\gamma}$ = 5.85E+00

Hydrogen Generation	**3.04E-09 ft^3 H_2/hour/gallon @ 95ºC**
Saltstone WAC Limit	**5.59E-08 ft^3 H_2/hour/gallon @ 95ºC**
Percent of Limit	**5.44%**

With the 32% dilution rate expected as the bounding condition for the ARP/MCU process, the following apply:

NO_{eff} = 1.45 M + 0.25 (0.150 M) = 1.49 M
R_{α} = 4.06E+01
$R_{\beta/\gamma}$ = 7.34E+00

Hydrogen Generation	**3.75E-09 ft^3 H_2/hour/gallon @ 95ºC**
Saltstone WAC Limit	**5.59E-08 ft^3 H_2/hour/gallon @ 95ºC**
Percent of Limit	**6.71%**

Attachment 16-B (continued): Hydrogen Generation Rate from Salt Batch 2 Feed Material for Saltstone at 15% Dilution (Saltstone WAC 5.4.4)

Radionuclide	Results (pCi/ml)	Results (Ci/gal)	"Q" Value (W/Ci)	R_α (ft^3 H_2/10^6 BTU)	$R_{\beta-\gamma}$ (ft^3 H_2/10^6 BTU)	Heat Generation (W/gal)	Hydrogen Generation ft^3 H_2/hr/gal
H-3*	7.49E+02	2.83E-06	3.37E-05		5.85E+00	9.55E-11	1.91E-15
C-14*	5.82E+02	2.20E-06	2.93E-04		5.85E+00	6.45E-10	1.29E-14
Co-60	1.03E+01	3.91E-08	1.54E-02		5.85E+00	6.03E-10	1.20E-14
Ni-59	4.04E+02	1.53E-06	3.98E-05		5.85E+00	6.09E-11	1.22E-15
Ni-63	1.38E+02	5.22E-07	1.01E-04		5.85E+00	5.28E-11	1.05E-15
Se-79	5.99E+01	2.27E-07	3.13E-04		5.85E+00	7.09E-11	1.42E-15
Sr-90*	2.93E+05	1.11E-03	1.16E-03		5.85E+00	1.29E-06	2.57E-11
Y-90*	2.93E+05	1.11E-03	5.54E-03		5.85E+00	6.14E-06	1.23E-10
Tc-99*	6.89E+04	2.61E-04	5.01E-04		5.85E+00	1.31E-07	2.61E-12
Ru-106	1.41E+02	5.34E-07	5.95E-04		5.85E+00	3.18E-10	6.34E-15
Rh-106	1.41E+02	5.34E-07	1.89E-02		5.85E+00	1.01E-08	2.02E-13
Sb-125	6.57E+01	2.49E-07	3.37E-03		5.85E+00	8.38E-10	1.67E-14
Sn-126	2.53E+02	9.58E-07	1.08E-03		5.85E+00	1.03E-09	2.07E-14
I-129*	5.00E+01	1.89E-07	4.77E-04		5.85E+00	9.03E-11	1.80E-15
Cs-134*	2.77E+02	1.05E-06	1.02E-02		5.85E+00	1.07E-08	2.13E-13
Cs-135*	5.70E+01	2.16E-07	3.32E-04		5.85E+00	7.16E-11	1.43E-15
Cs-137*	4.45E+06	1.68E-02	1.01E-03		5.85E+00	1.70E-05	3.40E-10
Ba-137m	4.21E+06	1.59E-02	3.94E-03		5.85E+00	6.28E-05	1.25E-09
Ce-144	1.68E+02	6.37E-07	6.58E-04		5.85E+00	4.19E-10	8.37E-15
Pr-144	1.68E+02	6.37E-07	7.34E-03		5.85E+00	4.68E-09	9.34E-14
Pm-147	6.88E+02	2.60E-06	3.67E-04		5.85E+00	9.56E-10	1.91E-14
Eu-154	8.30E+01	3.14E-07	9.08E-03		5.85E+00	2.85E-09	5.70E-14
Th-232	8.97E-03	3.40E-11	2.38E-02	3.49E+01		8.07E-13	9.61E-17
U-233**	3.63E+02	1.37E-06	2.86E-02	3.49E+01		3.93E-08	4.68E-12
U-234**	3.13E+02	1.18E-06	2.83E-02	3.49E+01		3.35E-08	3.99E-12
U-235**	2.57E-01	9.73E-10	2.71E-02	3.49E+01		2.64E-11	3.14E-15
U-236**	3.24E+00	1.23E-08	2.66E-02	3.49E+01		3.26E-10	3.89E-14
U-238**	1.74E+00	6.59E-09	2.49E-02	3.49E+01		1.64E-10	1.96E-14
Np-237**	3.53E+01	1.34E-07	2.88E-02	3.49E+01		3.85E-09	4.58E-13
Pu-238**	2.75E+04	1.04E-04	3.26E-02	3.49E+01		3.39E-06	4.04E-10
Pu-239**	2.23E+02	8.44E-07	3.02E-02	3.49E+01		2.55E-08	3.04E-12
Pu-240**	2.23E+02	8.44E-07	3.06E-02	3.49E+01		2.58E-08	3.07E-12
Pu-241*	7.73E+04	2.93E-04	3.20E-05		5.85E+00	9.36E-09	1.87E-13
Pu-242	8.00E+01	3.03E-07	2.90E-02	3.49E+01		8.80E-09	1.05E-12
Am-241	1.87E+03	7.07E-06	3.28E-02	3.49E+01		2.32E-07	2.77E-11
Cm-244	6.86E+02	2.59E-06	3.44E-02	3.49E+01		8.92E-08	1.06E-11
Cm-245	1.39E+03	5.24E-06	3.33E-02	3.49E+01		1.75E-07	2.08E-11
Sm-151	4.43E+02	1.68E-06	7.41E-04	3.49E+01		1.24E-09	1.48E-13
Ra-226	4.84E+02	1.83E-06	2.84E-02	3.49E+01		5.19E-08	6.19E-12
Eu-155	2.47E+02	9.36E-07	7.59E-04		5.85E+00	7.10E-10	1.42E-14
Th-230	8.97E-03	3.40E-11	2.77E-02	3.49E+01		9.39E-13	1.12E-16
Pu-244	2.40E-01	9.08E-10	2.71E-02	3.49E+01		2.46E-11	2.93E-15
Am-242m	7.78E+02	2.94E-06	4.05E-04	3.49E+01		1.19E-09	1.42E-13
Am-243	1.64E+03	6.22E-06	3.15E-02	3.49E+01		1.96E-07	2.33E-11
Cm-242	5.22E+01	1.98E-07	3.59E-02	3.49E+01		7.09E-09	8.45E-13
						Total	**2.26E-09**
						at 95°C	**3.04E-09**

Q values are defined in Ref. 59.

Attachment 16-B (continued): Hydrogen Generation Rate from Salt Batch 2 Feed Material for Saltstone at 32% Dilution (Saltstone WAC 5.4.4)

Radionuclide	Results (pCi/ml)	Results (Ci/gal)	"Q" Value (W/Ci)	R_α (ft^3 $H_2/10^6$ BTU)	$R_{\beta-\gamma}$ (ft^3 $H_2/10^6$ BTU)	Heat Generation (W/gal)	Hydrogen Generation ft^3 H_2/hr/gal
H-3*	7.49E+02	2.83E-06	3.37E-05		7.34E+00	9.55E-11	2.39E-15
C-14*	5.82E+02	2.20E-06	2.93E-04		7.34E+00	6.45E-10	1.62E-14
Co-60	1.03E+01	3.91E-08	1.54E-02		7.34E+00	6.03E-10	1.51E-14
Ni-59	4.04E+02	1.53E-06	3.98E-05		7.34E+00	6.09E-11	1.53E-15
Ni-63	1.38E+02	5.22E-07	1.01E-04		7.34E+00	5.28E-11	1.32E-15
Se-79	5.99E+01	2.27E-07	3.13E-04		7.34E+00	7.09E-11	1.78E-15
Sr-90*	2.93E+05	1.11E-03	1.16E-03		7.34E+00	1.29E-06	3.22E-11
Y-90*	2.93E+05	1.11E-03	5.54E-03		7.34E+00	6.14E-06	1.54E-10
Tc-99*	6.89E+04	2.61E-04	5.01E-04		7.34E+00	1.31E-07	3.28E-12
Ru-106	1.41E+02	5.34E-07	5.95E-04		7.34E+00	3.18E-10	7.96E-15
Rh-106	1.41E+02	5.34E-07	1.89E-02		7.34E+00	1.01E-08	2.53E-13
Sb-125	6.57E+01	2.49E-07	3.37E-03		7.34E+00	8.38E-10	2.10E-14
Sn-126	2.53E+02	9.58E-07	1.08E-03		7.34E+00	1.03E-09	2.59E-14
I-129*	5.00E+01	1.89E-07	4.77E-04		7.34E+00	9.03E-11	2.26E-15
Cs-134*	2.77E+02	1.05E-06	1.02E-02		7.34E+00	1.07E-08	2.67E-13
Cs-135*	5.70E+01	2.16E-07	3.32E-04		7.34E+00	7.16E-11	1.79E-15
Cs-137*	4.45E+06	1.68E-02	1.01E-03		7.34E+00	1.70E-05	4.26E-10
Ba-137m	4.21E+06	1.59E-02	3.94E-03		7.34E+00	6.28E-05	1.57E-09
Ce-144	1.68E+02	6.37E-07	6.58E-04		7.34E+00	4.19E-10	1.05E-14
Pr-144	1.68E+02	6.37E-07	7.34E-03		7.34E+00	4.68E-09	1.17E-13
Pm-147	6.88E+02	2.60E-06	3.67E-04		7.34E+00	9.56E-10	2.40E-14
Eu-154	8.30E+01	3.14E-07	9.08E-03		7.34E+00	2.85E-09	7.15E-14
Th-232	8.97E-03	3.40E-11	2.38E-02	4.06E+01		8.07E-13	1.12E-16
U-233**	3.63E+02	1.37E-06	2.86E-02	4.06E+01		3.93E-08	5.44E-12
U-234**	3.13E+02	1.18E-06	2.83E-02	4.06E+01		3.35E-08	4.65E-12
U-235**	2.57E-01	9.73E-10	2.71E-02	4.06E+01		2.64E-11	3.66E-15
U-236**	3.24E+00	1.23E-08	2.66E-02	4.06E+01		3.26E-10	4.53E-14
U-238**	1.74E+00	6.59E-09	2.49E-02	4.06E+01		1.64E-10	2.28E-14
Np-237**	3.53E+01	1.34E-07	2.88E-02	4.06E+01		3.85E-09	5.33E-13
Pu-238**	2.75E+04	1.04E-04	3.26E-02	4.06E+01		3.39E-06	4.70E-10
Pu-239**	2.23E+02	8.44E-07	3.02E-02	4.06E+01		2.55E-08	3.54E-12
Pu-240**	2.23E+02	8.44E-07	3.06E-02	4.06E+01		2.58E-08	3.58E-12
Pu-241*	7.73E+04	2.93E-04	3.20E-05		7.34E+00	9.36E-09	2.35E-13
Pu-242	8.00E+01	3.03E-07	2.90E-02	4.06E+01		8.80E-09	1.22E-12
Am-241	1.87E+03	7.07E-06	3.28E-02	4.06E+01		2.32E-07	3.22E-11
Cm-244	6.86E+02	2.59E-06	3.44E-02	4.06E+01		8.92E-08	1.24E-11
Cm-245	1.39E+03	5.24E-06	3.33E-02	4.06E+01		1.75E-07	2.42E-11
Sm-151	4.43E+02	1.68E-06	7.41E-04	4.06E+01		1.24E-09	1.72E-13
Ra-226	4.84E+02	1.83E-06	2.84E-02	4.06E+01		5.19E-08	7.20E-12
Eu-155	2.47E+02	9.36E-07	7.59E-04		7.34E+00	7.10E-10	1.78E-14
Th-230	8.97E-03	3.40E-11	2.77E-02	4.06E+01		9.39E-13	1.30E-16
Pu-244	2.40E-01	9.08E-10	2.71E-02	4.06E+01		2.46E-11	3.41E-15
Am-242m	7.78E+02	2.94E-06	4.05E-04	4.06E+01		1.19E-09	1.65E-13
Am-243	1.64E+03	6.22E-06	3.15E-02	4.06E+01		1.96E-07	2.72E-11
Cm-242	5.22E+01	1.98E-07	3.59E-02	4.06E+01		7.09E-09	9.83E-13
						Total	**2.78E-09**
						at 95°C	**3.75E-09**

Q values are defined in Ref. 59.

Attachment 17: Gamma Source Strength to Meet Saltstone WAC (Saltstone WAC 5.4.12)

Gamma Source Strength Based on the DSS Material

	DSS Concentration		**Dose constant**	**Gamma Source Strength**
Radionuclide	pCi/ml	Ci/gal	mrem/hr/Ci	mrem/hr/gal
Co-60	1.03E+01	3.91E-08	1.37E+03	5.36E-05
Sb-125	6.57E+01	2.49E-07	6.08E+02	1.51E-04
Cs-134*	2.77E+02	1.05E-06	9.99E+02	1.05E-03
Cs-137*	4.45E+06	1.68E-02	3.82E+02	6.43E+00
Eu-154	8.30E+01	3.14E-07	7.56E+02	2.38E-04
Gamma Source Strength				6.44E+00
Saltstone WAC limit				9.05E+01
% of WAC limit				7.11%

Data from Reference 3.
* Data from Reference 4.
* Data using a DF factor of 12 on feed material.

Gamma Source Strength Based on the Feed Material

	Feed Concentration		**Dose constant**	**Gamma Source Strength**
Radionuclide	pCi/ml	Ci/gal	mrem/hr/Ci	mrem/hr/gal
Co-60	1.03E+01	3.91E-08	1.37E+03	5.36E-05
Sb-125	6.57E+01	2.49E-07	6.08E+02	1.51E-04
Cs-134*	3.32E+03	1.26E-05	9.99E+02	1.26E-02
Cs-137*	5.34E+07	2.02E-01	3.82E+02	7.72E+01
Eu-154	8.30E+01	3.14E-07	7.56E+02	2.38E-04
Gamma Source Strength				7.72E+01
Saltstone WAC limit				9.05E+01
% of WAC limit				85.33%

Data from Reference 3.
* Data from Reference 4.

Attachment 18: Technical Reviews

Section	Reviewers	
1.0	H. H. Elder	E. W. Harrison
2.0	H. H. Elder	E. W. Harrison
3.0	H. H. Elder	E. W. Harrison
3.1	H. H. Elder	
3.2	H. H. Elder	
3.3	E. W. Harrison	
3.4	H. H. Elder	
3.5	H. H. Elder	E. W. Harrison
3.6	E. W. Harrison	
4.0	H. H. Elder	E. W. Harrison