# X-ESR-H-00377, Rev. 0

# Evaluation of ISDP Batch 5 Qualification Compliance to 512-S, DWPF, Tank Farm, and Saltstone Waste Acceptance Criteria

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# TABLE OF CONTENTS

# LIST OF ACRONYMS

| | |
|---|---|
| ARP | Actinide Removal Process |
| CEDE | Committed Effective Does Equivalent |
| CLFL | Composite Lower Flammability Limit |
| CPC | Chemical Process Cell |
| CSS | Clarified Salt Solution |
| CSSX | Caustic Side Solvent Extraction |
| CSTF | Concentration, Storage and Transfer Facility |
| DBP | Dibutylphosphate |
| $D_{cs}$ | Distribution Factor |
| DCF | Dose Conversion Factor |
| DF | Decontamination Factor |
| DSA | Documented Safety Analysis |
| DSS | Decontaminated Salt Solution |
| DWPF | Defense Waste Processing Facility |
| EA | Enviormental Assessment |
| EDE | Effective Dose Equivalent |
| EDTA | Ethylenediaminetetraacetic acid |
| ERD | Emergency Response Document |
| ESS | Extract Strip Scrub |
| FME | Foreign Material Exclusion |
| HGR | Hydrogen Generation Rate |
| IDP | Inhalation Dose Potential |
| ISDP | Interim Salt Disposition Project |
| LFL | Lower Flammability Limit |
| LPPP | Low Point Pump Pit |
| LWO | Liquid Waste Organization |
| LWHT | Late Wash Hold Tank |
| LWPT | Late Wash Precipitate Tank |
| MCU | Modular CSSX Unit |
| MST | Monosodium Titanate |
| MW | Molecular Weight |
| NCSA | Nuclear Criticality Safety Assessment |
| NCSE | Nuclear Criticality Safety Evaluation |
| NESHAP | National Emissions Standards for Hazardous Air Pollutants |
| $NO_{eff}$ | $NO_{effective}$ |
| $NO_x$ | Nitrate/Nitrite |
| PCCS | Production Composition Control System |
| PCT | Product Consistency Test |
| PDD | Program Description Document |
| PEDE | Potential Effective Dose Equivalend |
| PIC | Potential Impact Category |
| PIP | Process Improvement Project |
| PODD | Performance Objectives Demonstration Document |
| PRFT | Precipitate Reactor Feed Tank |
| RCRA | Resource Conservation and Recovery Act |
| RSD | Relative Standard Devation |
| SAC | Specific Administrative Control |
| SE | Strip Effluent |
| SED | Strip Effluent Decanter |
| SEFT | Strip Effluent Feed Tank |
| SEHT | Strip Effluent Hold Tank |
| SG | Specific Gravity |
| SME | Slurry Mix Evaporator |
| SRAT | Sludge Receipt and Adjustment Tank |
| SRNL | Savannah River National Laboratory |

| | |
|---|---|
| SRS | Savannah River Site |
| TBP | Tributylphosphate |
| TMA | Trimethylamine |
| TOC | Total Organic Carbon |
| TPB | Tetraphenylborate |
| TS | Total Solids |
| TTQAP | Task Technical and Quality Assurance Plan |
| WAC | Waste Acceptance Criteria |
| WCP | Waste Compliance Plan |
| wt% | Weight percent |

# 1.0 PURPOSE

The purpose of this report is to document the acceptability of the fifth macrobatch (Salt Batch 5) of Tank 49 waste for feed to the Tank Farm, Defense Waste Processing Facility (DWPF), and Saltstone for operation of the Interim Salt Disposition Project (ISDP). For DWPF processing, this document evaluates Sludge Batch 7b coupled with Salt Batch 5.

# 2.0 SUMMARY AND BACKGROUND

## 2.1 Summary

Salt Batch 5 feed meets the Waste Acceptance Criteria (WAC) requirements specified by References 1, 2, and 3. Salt Batch 5 material is qualified and ready to be processed through the Actinide Removal Process/Modular Caustic Side Solvent Extraction Unit (ARP/MCU) to the final disposal facilities.

The following key attributes of the Salt Batch 5 feed to ARP/MCU are noted:

- The sum of the fractions for determining Hazard Category for MCU is calculated to be 0.266.
- 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 (Ref. 3).
- Nuclear Criticality Safety Evaluation (NCSE) criteria are met.
- Extraction, Scrub, and Strip (ESS) tests for Cesium removal criteria are met.
- Monosodium Titanate (MST) testing demonstrates expected DFs for Pu and Sr.
- The Salt Batch 5 contents are also lower than the 0.4 Ci/gal Cs-137 criteria for additional shielding over the Strip Effluent Hold Tank (SEHT) and Strip Effluent Decanter (SED) cells.

## 2.2 Background

ISDP consists of two flowsheets that have been developed based on two technologies: ARP and MCU. The ARP flowsheet involves two strike tanks where 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, a clarified salt solution (CSS), and solid wash water. The MST/sludge solids 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 50. 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 50 for final disposition. The SE is transferred to the Strip Effluent Feed Tank (SEFT) in 221-S for eventual incorporation into the final glass product.

The following transfers have occurred to prepare for Tank 49 (Salt Batch 5) feed:

1. Tank 12 supernate was transferred to Tank 21.
2. Tank 22 DWPF recycle material was transferred to Tank 21.
3. Tank 8 supernate was transferred to Tank 21.
4. Tank 23 salt solution was then transferred to Tank 21.
5. Sodium hydroxide (19 M) was added to Tank 21 to achieve a hydroxide concentration of approximately 2.0 M
6. Tank 21 contents were mixed using mixing pumps.
7. Tank 21 supernate will be transferred to Tank 49.

Salt Batch 5, like Salt Batch 4, used Tank 21 as a preparation tank (or blend tank) prior to transferring its contents to Tank 49. Initial samples were pulled from Tank 21 to determine that sufficient 19 M sodium hydroxide had been added to the blend tank to maintain a free hydroxide concentration necessary for Salt Batch 5 to prevent aluminum solid precipitation. After all transfers and chemical additions were made into Tank 21, the tank was sampled and analyzed for the same list of constituents as previous salt batches. In addition, analyses were performed to satisfy the Saltstone Performance Objectives Demonstration Document (PODD) (Ref. 4). Results from the PODD sample are not required for Salt Batch 5 qualification. The Monosodium Titanate/Extraction, Scrub, Strip (MST/ESS) testing was performed on a blend using the Tank 21 material and residual Tank 49 Salt Batch 4 material, with the blend composition provided by Tank Farm Process Engineering. In addition, a confirmatory sample will be pulled from Tank 49 for constituents to include the following: sodium, potassium, aluminum, cesium-137, silicon, free hydroxide, and oxalate (not required for qualification).

The Nuclear Criticality Safety Evaluation (NCSE) was revised allowing use of the Blend Tank sample analyses to ensure that NCSE and qualification requirements are met (Ref. 5). The transfer of qualified feed from the blend tank into the qualified feed in the feed tank will provide a qualified feed regardless of the degree of mixing. A material balance will be performed after the final transfer from Tank 21 to 49 is completed.

## 3.0 DISCUSSION OF RESULTS

The salt solution for Salt Batch 5 consists of a heel of Tank 49 (Salt Batch 4); material from the Tank 21 blend tank, which consists of the Tank 21 heel, Tank 23 supernate (Tank 41 supernate containing dissolved saltcake from Tank 25), Tank 22 supernate, Tank 8 supernate, and Tank 12 supernate; and 19 M sodium hydroxide solution (caustic) for hydroxide adjustment.

The Tank Farm pulled five samples from Tank 21 on October 13, 2011. Tank 21 material arrived at the Savannah River National Laboratory (SRNL) in five bottles (HTF-

21-11-114, -115, -116, -117, and -118). Two samples were obtained at variable depths and three samples were taken at pump suction. These samples were handled in the manner described in the Task Technical and Quality Assurance Plan (TTQAP) (Ref. 6) and results documented by SRNL technical report (Refs. 7 and 8).

Upon receipt of analyses, Engineering performed OLI modeling and determined that the hydroxide concentration was insufficient to prevent aluminum solids from forming in MCU. An additional 20,000 gallons of 50 weight percent sodium hydroxide was added, thereby reducing the concentrations of all radiological constituents, as well as all chemical constituents except for sodium and hydroxide. A blend calculation was performed to determine the new values for certain cations and anions (including sodium and hydroxide) to use in this qualification evaluation. These values are shown in Table 1. All other constituents are evaluated using SRNL sample data.

The Tank 21 supernate level on March 28, 2012, was 352.8 inches (Ref. 50). With 15.1 inches of solids in the bottom of Tank 49 (Ref. 51), the resultant supernate height is approximately 338 inches. At 3,540 gallons per inch in Tank 21 (Ref. 29), the supernate volume is 1,196,520 gallons. Using the data from Reference 7, a blend evaluation was performed.

Table 1 shows the final calculated blend concentrations of certain chemicals for Salt Batch 5 in Tank 21 with a 20,000 gallon 50 weight percent sodium hydroxide addition.

**Table 1 – Chemical Values Resulting from the Blend Evaluation**

| **Chemical** | **Salt Batch 5 Tank 21 (Ref. 7)** | **50 weight percent Sodium Hydroxide** | **Final Tank 21** |
|---|---|---|---|
| **Volume (gallons)** | **1,196,520** | **20,000** | **1,216,520** |
| $CO_3$ (M) | 2.38E-01 | | 2.34E-01 |
| Cl (M)* | 1.41E-02 | | 1.39E-02 |
| F (mg/L) | 1.00E+01 | | 9.84E+00 |
| OH (M) | 2.08E+00 | 19.0 | 2.36E+00 |
| $NO_3$ (M)* | 2.82E+00 | | 2.78E+00 |
| $NO_2$ (M)* | 5.60E-01 | | 5.51E-01 |
| $C_2O_4$ (M)* | 2.75E-03 | | 2.70E-03 |
| $PO_4$ (M)* | 5.11E-03 | | 5.02E-03 |
| $SO_4$ (M)* | 7.61E-02 | | 7.48E-02 |
| Al (M)* | 2.64E-01 | | 2.60E-01 |
| TOC (mg/L) | 2.20E+02 | | 2.16E+02 |
| TPB (mg/L) | 1.00E+01 | | 9.84E+00 |
| Na (M)* | 6.35E+00 | 19.0 | 6.56E+00 |
| K (M)* | 8.31E-03 | | 8.17E-03 |
| TBP (mg/L) | 1.00E+00 | | 9.84E-01 |
| Si (mg/L) | 4.68E+01 | | 4.60E+01 |

* Data was reported in mg/L in Reference 7. A basic conversion is applied using molecular weight of the ion.

The following assumptions were applied to the tank data: (1) if only a detection limit was reported, the maximum detection limit was used; and (2) for actual measured values, the average was reported by SRNL and used. The average was used in calculations and comparisons except where noted. Qualification was performed without crediting the ARP/MCU process where possible. Cesium limits for the Saltstone evaluation did use process knowledge (i.e., a decontamination factor (DF) of 12 was used to show compliance with the Saltstone WAC). Some chemical analytes used the process dilution (Ref. 9) or partitioning (Ref. 10) to CSS or MST/sludge solids streams where appropriate. Process knowledge is credited for specific analytes not analyzed.

## 3.1 Compliance with 512-S WAC (Ref. 2)

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 qualification value of the Salt Batch 5 material, the Cs-137 is 5.90E+07 pCi/mL or 0.223 Ci/gallon (Ref. 7). The Cs-137 concentration is approximately 20 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 Salt Batch 5. The reported Ci/gallon values are multiplied by the dose conversion factors (DCFs) to obtain a final rem per gallon value. For total alpha, the dose conversion factor is the conversion factor for Pu-238. The rem per gallon values for total alpha and Sr-90 are then summed and compared to the 512-S WAC limit.

The second method compares the eleven major inhalation dose radionuclides in the Salt Batch 4 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 4.89E+03 rem/gallon or 0.16 percent of the 512-S WAC limit of 3.00E+06 rem/gallon. The second method resulted in the inhalation dose being approximately 1.59E+04 rem/gallon or 0.53 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 0.223 Ci/gal meets the requirements of the 512-S WAC for inhalation dose potential. The Cs-137 value is approximately 20 percent of the limit specified in the 512-S WAC.

The soluble Pu-238 was found to be 1.49E+04 pCi/mL or 5.64E-05 Ci/gal (Ref. 7). The soluble Pu-238 concentration criteria of less than or equal to 3.0E-03 Ci/gallon is met for Salt Batch 5. The soluble Pu-238 is approximately 1.88 percent of the 512-S WAC of 3.0E-03 Ci/gallon.

### 3.1.3 Nuclear Criticality Safety (DWPF WAC 5.3.3)

The waste to be transferred to 512-S shall have the following: a soluble uranium concentration less than or equal to 50 mg/L, a soluble plutonium concentration less than or equal to 0.5 mg/L, and U-235 (eq_sol) enrichment less than or equal to 3.0 wt.%.

An Engineering Level 1 Calculation (Ref. 11) was performed that demonstrates that the Salt Batch 5 is compliant with the requirements from the ARP/MCU NCSE (Ref. 5). This calculation demonstrates that the soluble uranium (U) and plutonium (Pu) concentrations and the U-235(eq_sol) enrichment are no more than the limits of 50 mg/L, 0.3 mg/L, and 3 wt%, respectively.

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

The total radiolytic hydrogen generation rate (HGR) shall not exceed 1.64E-06 $ft^3$ $H_2$/hr/gal at 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. 12). Results are shown in Attachment 2.

The value of hydrogen generated for Salt Batch 5 material is 1.77E-07 $ft^3$ $H_2$/hr/gallon and the limit is 1.64E-06 $ft^3$ $H_2$ hr/gallon at 25$^o$C. The value is 10.8 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 Lower Flammability Limit (LFL).

The comparison of Tank 21 samples for Salt Batch 5 qualification found no significant measurable organic constituents (Ref. 7). These results indicate a negligibly small amount of organic material is present in the ARP/MCU feed. Previous analyses by Tank Farm Engineering concluded volatile organic content in the waste will not significantly contribute to flammability (Ref. 13). Therefore, the organic material present in ISDP Salt Batch 5 will not exceed the 0.1% contribution limit to the hydrogen LFL (Ref. 13).

#### 3.1.6 Temperature (DWPF WAC 5.3.6)

The waste to be transferred to 512-S shall be less than or equal to 45°C. The Waste Compliance Plan (WCP) compliance strategy is direct measurement prior to and during transfer (Ref. 14).

### 3.2 Compliance with DWPF WAC (Ref. 2)

MST/sludge solids will be sent from ARP to the DWPF. The SE will be sent from MCU to the DWPF. These streams will be added to Sludge Batch 7b in the Sludge Receipt and Adjustment Tank (SRAT). Compliance with the DWPF WAC is being evaluated against Sludge Batch 7b with the ARP/MCU material from Salt Batch 5.

Sludge Batch 7b was qualified previously with Salt Batch 4 material and documented in X-ESR-S-00052 (Ref. 15). Upon completion of Salt Batch 4 material at the DWPF, X-ESR-S-00052 will no longer be valid for WAC compliance, and this qualification report will be used for WAC compliance.

#### 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 2. The estimated $NO_x$ emission for Sludge Batch 7b is 18.61 tons per year. This is approximately 18 percent 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 7b. Details of predicted $NO_x$ emission calculations for Sludge Batch 7b can be found in Attachment 3.

The $NO_x$ emissions for ARP contribution were calculated to be at 30.24 tons/year, as seen in Attachment 3.

The estimated $NO_x$ emission for Sludge Batch 7b with the ARP contribution is 48.85 tons per year. This is approximately 47.2 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 167.4 watts per canister (143.49 W/canister from sludge, 7.23W/canister from MST sludge solids, and 16.64 W/canister from strip effluent at 3.35 Ci/gallon) (see Section 3.2.3 for Cs-137). The calculated value is approximately 167.4 W/canister or 38 percent of the DWPF WAC limit of 437 W/canister. Calculations for canister heat generation can be found in Attachment 4.

### 3.2.3 Gamma Shielding (DWPF WAC 5.4.3)

The sludge to be transferred to DWPF shall not exceed specific gamma source strength values of 4070 mR/hr/gallon and 3.7 mR/hr/gram insoluble solids. Transfers from MCU are limited to 16.5 Ci/gallon Cs-137.

A list of radionuclides, which were previously determined to be all inclusive of the radionuclides that contribute to 1% or more of the total gamma dose in the sludge slurry, is used to show that the design basis for shielding is not exceeded. The radionuclides are Co-60, Ru-106, Sb-125, Cs-134, Cs-137, Ce-144, Eu-154, Eu-155, and Pu-238. The reported µCi/g dried solids for each radionuclide from the blended Sludge Batch 7b results have been multiplied by a conversion factor and the specific isotope gamma dose constant to obtain the contribution of each radionuclide (Ref. 16). The computed gamma source strength values for the nine radionuclides are then summed together. In addition, the gamma source strengths were converted to a slurry gallon basis. This is shown in Attachment 5. The calculated value for the sludge is 3.71E-01 mR/hr/g insoluble solids or 10.0 percent of the WAC limit of 3.7 mR/hr/g insoluble solids and 1.92E+02 mR/hr/gal or 4.73 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 5 material (0.223 Ci/gal) multiplied by a concentration factor of 15 in accordance with Reference 2. MCU contribution is thus nominally 3.35 Ci/gallon. Periodic sampling of the SE will monitor cesium concentration (Refs. 14 and 17).

### 3.2.4 Neutron Shielding (DWPF WAC 5.4.4)

The total alpha curie per gram of solids value for the sludge feed to DWPF shall not exceed 1.5E-03 Ci/gram insoluble solids.

The neutron production rate is related to the total amount of alpha emitters. The total alpha value calculated from adding the individual alpha contributors from the Sludge Batch 7b blend calculation was compared to the limit (Ref. 16). Calculations are shown in Attachment 6. The total alpha concentration of 3.16E-04 Ci/g insoluble solids is approximately 21.1 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 3.03E+07 rem/gallon or 12.3

percent of the WAC limit using total alpha value calculated from adding the individual alpha contributors from the Sludge Batch 7b blend calculation was compared to the limit (Ref. 16). The second method resulted in the inhalation dose being approximately 2.92E+07 rem/gallon or 11.8 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 7b well below the DWPF WAC limit for total IDP.

The Cs-137 concentration in the sludge stream is 4.95E-01 Ci/gallon (Ref. 16) which is 36.9 percent of the DWPF WAC limit of 1.34 Ci/gallon.

The MCU contribution is limited to 16.5 Ci/gallon of Cs-137. The concentration of 3.35 Ci/gallon (0.223 Ci/gal * 15 (Ref. 2)) is approximately 20.3 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 7b ratio is 36.27:1; therefore, the 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 7b ratio is 772:1; therefore, the 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. Non-Tank Farm Pu was added to Sludge Batch 7a which was blended with Sludge Batch 7b; therefore the limit is applicable to Sludge Batch 7b. (Eq. Pu-239 in Sludge Batch 7b is 0.141 g/gallon; therefore, the criterion is met.)
4. The Eq. U-235 enrichment shall be ≤ 0.93 wt%. (Eq. U-235 enrichment for Sludge Batch 7b is 0.604 wt%, which is 65.0 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 2- Comparison of DWPF WAC Glass Solubility to Sludge Batch 7b and ISDP Salt Batch 5**

| Species | Limit Wt. % in glass | Value % in glass | Percent Of Limit |
|---|---|---|---|
| $TiO_2$ | 2 | 0.790% | 39.51% |
| $Cr_2O_3$ | 0.3 | 0.123% | 40.97% |
| $PO_4$ | 3 | 0.0330% | 1.10% |
| NaF | 1 | 0.010% | 1.02% |
| NaCl | 1 | 0.022% | 2.20% |
| Cu | 0.5 | 0.0594% | 11.88% |
| $SO_4^{-2}$<br>$Na_2SO_4$ | 0.6<br>(0.88) | 0.5944% | 99.06% |

While this qualification effort uses 40 wt% waste loading to determine solubilities of the glass, the DWPF is actually processing at a target of 36 wt% waste loading (Ref. 17). The calculated sulfate solubility in 36 wt% WL glass is 0.536% or 89.4% of the DWPF WAC limit of 0.6%.

### 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 7b was determined to be 0.0225 M (as seen in Attachment 10). The value is approximately 38.8 percent of the WAC limit of 0.058 M. The quantity of sulfate in the Salt Batch 5 feed is 0.0748 M (Table 1). 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 2.64E+01 kilograms of sulfate in the washed MST/sludge slurry (as seen in Attachment 9). The combined sulfate concentration is 0.0226 M or 39.0 percent of the WAC limit of 0.58 M.

The quantity of mercury for Sludge Batch 7b was measured to be 1.56 weight percent of total solids (Ref. 16). The concentration of mercury was calculated as 3.04 g/L (see Attachment 10). The value is 14.5 percent of the WAC limit of 21 g/L.

The quantity of mercury in the Salt Batch 5 feed is 8.82E+01 mg/L (Ref. 7). Combined with the mercury from the sludge slurry, the total quantity of mercury is 3.13 g/L (see Attachment 10). The value is 14.9 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 7b weight percent dry total solids was determined to be 17.08 weight percent (Ref. 16). The ARP process will transfer five weight percent total solids to the SRAT via the PRFT (Ref. 18). 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 Product Consistency Test (PCT) to confirm that an acceptable glass product can be produced as required by the DWPF Glass Product Control Program (Ref. 2). The vitrified product must be verified to meet the leach rate limits shown below in Table 3. The melter feed must also be verified to meet the predicted properties shown below in the table.

SRNL verified the quality and processability of blended Sludge Batch 7b material. The sample was processed at SRNL to match the planned processing in ESP for DWPF. A glass variability study was performed for SB7b (Ref. 19) prior to vitrifying the glass at SRNL. The study demonstrated applicability of the current durability models to the SB7b composition region of interest, as well as, acceptability of the SB7b glasses with respect to the Environmental Assessment (EA) glass. Two frit recommendations for SB7b were made from the glass variability study—Frit 418 and Frit 702. Frit 702 was used to make glass with the prepared sludge based on SRNL recommendation for qualification (Ref. 20). The targeted waste loading was 36 weight percent sludge oxides (Ref. 21).

The impact of the ARP stream and the MCU strip effluent stream on glass quality and the DWPF operating window has been evaluated for Sludge Batch 7b (Ref. 22). There are minimal impacts (e.g., minimum compositional changes) on the DWPF flowsheet from these two streams compared to the sludge stream. Reference 22 identified Frit 418 as the recommendation for DWPF processing Sludge Batch 7b.

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 3 below compares limits with values. PCCS includes statistical offsets for property model and analytical measurement uncertainties.

**Table 3 - Comparison of DWPF WAC Glass Quality and Processability to Sludge Batch 7b and ISDP Salt Batch 5**

| Attribute | Limit | Value | Evaluation |
|---|---|---|---|
| Boron Leach Rate | ≤16.70 g/L | 0.893 g/L | Passed |
| Lithium Leach Rate | ≤ 9.57 g/L | 0.901 g/L | Passed |
| Sodium Leach Rate | ≤ 13.35 g/L | 0.885 g/L | Passed |
| Liquidus Temperature | ≤1050° Celsius | 979.231° Celsius | Passed |
| High Viscosity | ≤110 poise | 38.718 poise | Passed |
| Low Viscosity | ≥ 20 poise | 38.718 poise | Passed |
| Homogeneity Constraint | $Al_2O_3$ ≥ 4 wt% **OR** | 8.664 wt% | Passed |
| Homogeneity Constraint | $Na_2O$ ≥ 3 wt% **AND** $\sum M_2O$ < 19.3 wt% where $\sum M_2O$ = $Na_2O + Li_2O + Cs_2O + K_2O$ wt% > | 226.180 wt% | Not Required, Primary Constraint Met |
| Nepheline (Mass) Ratio | $SiO_2 / (SiO_2 + Na_2O + Al_2O_3) > 0.62$ | 0.672 | Passed |

### 3.2.11 $H_2$ Generation/$N_2O$ Concentration (DWPF WAC 5.4.11)

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

The criteria were met during Shielded Cells testing at SRNL for Sludge Batch 7b (Ref. 23). The SRAT cycle during the Shielded Cells run yielded a hydrogen generation rate of 0.012 lb/hr and a nitrous oxide concentration of 1.6 volume percent (Ref. 23). The SME cycle during the Shielded Cell run yielded a hydrogen generation rate of 0.022 lb/hr (Ref. 23).

SRNL has performed simulated Sludge Batch 7b SRAT/SME with the latest estimates of the ARP/MCU compositions (without entrained organics from MCU). The results showed no processing changes for Sludge Batch 7b. Flowsheets and the ARP/MCU additions did not negatively impact DWPF processing (Ref. 24); however, SRAT acid stoichiometry may need modification.

### 3.2.12 Radiolytic Hydrogen Generation (DWPF WAC 5.4.12)

The total radiolytic HGR shall not exceed 8.95E-05 $ft^3$ $H_2$/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 7b and ISDP Salt Batch 5 material. Calculation results are shown in Attachment 12.

The value of hydrogen generated is 1.58E-05 $ft^3$ $H_2$/hour/gallon for Sludge Batch 7b. This calculated value is 17.7 percent of the DWPF WAC limit of 8.95E-05 $ft^3$ $H_2$/hour/gallon. The combined value is 1.72E-05 $ft^3$ $H_2$/hour/gallon and is only 19.3 percent of the DWPF WAC limit of 8.95E-05 $ft^3$ $H_2$/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 of strip effluent from MCU shall be tracked and characterized by the sending facility prior to entering the DWPF Chemical Process Cell (CPC):

a) Transfers of strip effluent from MCU shall not exceed 87 ppm Isopar L accounting for analytical uncertainty.

b) In the event of a process upset, transfers of strip effluent from MCU may be greater than 87 ppm Isopar L but shall not exceed 600 ppm Isopar L accounting for analytical uncertainty.

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. 13). The organic material is negligible in Salt Batch 5, as shown in Section 3.1.5 for ARP/MCU.

The criterion for Strip Effluent will be tracked and characterized by MCU prior to entering the DWPF CPC (Ref. 14).

### 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 $\geq 2$ and $\leq 4$ (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 3 M $HNO_3$) is transferred.

The pH criterion will be met by the nitric acid purchase specification and procedural control (Ref. 14). The full line volume water or SE flush will be controlled by procedural measurement (Ref. 14).

### 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 $\leq 45$ºC

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. 14). The temperature limit for MCU strip effluent will be met by process control (Ref. 14).

### 3.2.16 Particle Size (DWPF WAC 5.4.16)

New product streams entering the DWPF facilities shall have a maximum particle size of 80 mesh sieve or equivalent. This criterion is for future non-sludge and non-salt streams (e.g., product stream from treatment of Tank 48 material) that may be transferred to DWPF for disposal. Sludge Batch 7b coupled processing is not expected to contain a non-sludge or non-salt stream.

### 3.2.17 Fissile Concentration in Glass (DWPF WAC 5.4.17)

The sum of the concentrations of $^{233}$U, $^{235}$U, $^{239}$Pu and $^{241}$Pu shall not exceed 897 gram per cubic meter of glass. The Department of Energy required that DWPF control waste loading such that the total concentration of the specified radionuclides be less than 897 grams per cubic meter (Ref. 25). This limit was set to be consistent with the License Application for the Geological Repository at Yucca Mountain. The Savannah River National Laboratory has developed a method by calculation that ensures that this criterion is met, allowing for uncertainties in the analytical measurements and the density of the glass. During initial processing of Sludge Batch 7b (i.e., prior to analysis of the Sludge Batch 7b WAPS sample and obtaining the Sludge Batch 7b SME production data), WS Engineering will monitor and calculate fissile loading as documented in Reference 26. Reference 26 concludes that DWPF will not exceed 897 grams per cubic meter during initial Sludge Batch 7b processing. Coupled operation with Salt Batch 5 is deemed negilble for fissile contribution compared to Sludge Batch 7b.

## 3.3 Compliance with Tank Farm WAC (Ref. 1)

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 50 without MCU processing.

### 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 DSS that will be sent to Tank 50. Waste accepted by MCU will need to comply with the corrosion prevention requirements for Tank 50, since there are no corrosion prevention specific requirements for the MCU facility.

After all the transfers were made into Tank 21 for Salt Batch 5, Tank 21 was evaluated in WCS 1.5 (Ref. 27) for corrosion control. WCS 1.5 showed that Tank 21 corrosion chemistry is compliant with the Corrosion Control Program Description Document (PDD) (Ref. 28). This is documented in Table L-5 of the Emergency Response Data document (ERD) (Ref. 29). In addition, Tank 49 will be evaluated for corrosion control prior to transferring Tank 21 into Tank 49.

The minimum pH of waste that can be transferred into a facility governed by the Tank Farm WAC is 12 (Ref. 1). The transfer of the CSS to MCU must comply with this requirement. As the only change to the salt solution is the dilution experienced as 241-96H. Reference 9 documented a 5.81% dilution at 241-96H. Applying the dilution to the hydroxide concentration and calculating the pH, the pH is 14.35.

$$pH = 14 - (-\log [OH]) = 14 - (-\log [2.36 \times (1- 0.0581)])$$

A corrosion evaluation was performed for the DSS from MCU sent to Tank 50 (Ref. 30). Recommendations for Tank 50 as a result of adding DSS can be found in Reference 30. A minimum pH of 10.3 for influents into the waste tanks was established in the Corrosion Control Program (Ref. 28). The DSS stream that will be sent to Tank 50 has a pH of 14 (Ref. 8), meeting the requirement and thus the WAC requirement of 12 (Ref. 1). Tank 50 was also evaluated in WCS 1.5 (Ref. 27) for corrosion control. WCS 1.5 showed that Tank 50 corrosion chemistry is compliant with the Corrosion Control PDD (Ref. 28). This is documented in Table L-5 of the ERD (Ref. 29).

### 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. Tanks 21 and 49 feed material meet this criteria as it is under the Tank Farm Flammability Control Program (Ref. 31), and the organic chemical analyses at less than detection limits support this.

The comparison of Tank 21 samples for Salt Batch 5 qualification found no significant measurable organic constituents (Ref. 7). These results indicate a negligibly small amount of organic material is present in the ARP/MCU feed. Previous analyses by Tank Farm Engineering concluded volatile organic content in the waste will not significantly contribute to flammability (Ref. 13). Therefore, the organic material present in ISDP Salt Batch 5 will not exceed 0.1% contribution to the hydrogen LFL and are within the 5% limit (Ref. 13).

The methanol value shown in Table 5 of Reference 7 is calculated from Total Organic Carbon (TOC) and is grossly conservative. The calculated results should be considered a gross upper bound and most likely do not represent a realistic value.

Volatile organic chemicals are added to the system both at ARP and MCU. The MST that is added at 241-96H contains small amounts of isopropanol and methanol as byproducts of MST manufacturing. Each batch of MST is analyzed for these alcohols and the results are typically below Tank 50 limits, thus not challenging the 5% LFL limit.

Isopar added at MCU in analyzed in the DSS stream and a mathematical average is taken for contribution to Tank 50. Also, Isopar concentration in Tank 50 is periodically rebaselined by sampling Tank 50 and analyzing for Isopar. These organic contributions are all addressed in Reference 32.

### 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. The hydrogen generation limit for transfer into Tank 50 is limited to 2.90E-08 $ft^3$ $H_2$/hr-gal (with an $NO_{eff}$ of 1.70 minimum) at 43°C.

The value of hydrogen generated for Salt Batch 5 material at 43°C is 1.37E-09 $ft^3$ $H_2$/hr-gallon and the $NO_{eff}$ is 3.06. The hydrogen generation rate value is 4.72 percent of the limit. Applying a 28.5% dilution factor because of the ARP dilution and the scrub feed and caustic wash in MCU (Ref. 9), the $NO_{eff}$ is 2.18 and the hydrogen generation rate is 2.00E-09 $ft^3$ $H_2$/hr-gallon. The hydrogen generation rate value is 6.91 percent of the limit. In addition, a maximum dilution factor of 32.5% was applied to $NO_{eff}$ to account for various dilutions (Ref. 9). The $NO_{eff}$ is 2.06 and the hydrogen generation rate is 2.14E-09 $ft^3$ $H_2$/hr-gallon. The hydrogen generation rate value is 7.39 percent of the limit. Results are shown in Attachments 13-A and 13-B. The hydrogen generation rates calculated at no dilution and with 28.5% and 32.5% dilution all meet the WAC criteria. The actual hydrogen generation rate for DSS will be less than this evaluation because the Cs-137 will be removed during MCU processing.

Hydrogen generation rate is directly controlled by complying with the feed composition controls for radionuclide constituents in Section 11.4 of Reference 1. In addition, transfers into MCU from 512-S are to be $\leq 50^oC$ for hydrogen generation rate (other lower temperature limits apply for other parameters). The temperature limit will be met by direct measurement (Ref. 33). Further discussion is in Section 3.6.5.

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

There is Waste Acceptance Criteria prohibiting additional shock sensitive compound transfers into the Tank Farm (e.g., significant quantity of silver). Tanks 21 and 49 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 Salt Batch 5 feed is 9.77E+03 rem/gallon (see Attachment 15). The calculated IDP is less than or equal to 5.78 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 Reference 34) to protect the Hazard Category 3 status of MCU. The sum of fractions is 0.266 (see Attachment 14). The sum of the fractions is less than one when compared to the Hazard Categorization 2 threshold. Therefore, the Salt Batch 5 feed will not compromise the MCU facility hazard categorization of Hazard Category 3.

The Tank Farm WAC requires that the Cs-137 concentration be no more than 1.1 Ci/gal for salt batch material. The average Cs-137 content shown in Table 1 is 5.90E+07 pCi/mL or 0.233 Ci/gal. The Cs-137 concentration is approximately 21.2% of the Tank Farm WAC.

Material transferred into Tank 50 shall not have an IDP greater than 2.09E+05 rem/gallon. The calculated value is 9.77E+03 rem/gal using the Tank 49 feed material (see Attachment 15). The calculated IDP is 4.68 percent of the WAC limit.

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

The feed is from Tank 49 material and prior to that, it is from Tank 21. These tanks are in compliance with the Tank Farm WAC; therefore, RCRA criteria are met. Neither ARP nor MCU will contribute additional RCRA constituents that have not already been considered (Ref. 35, Part B).

### 3.3.7 Requirements for Criticality Safety (Tank Farm WAC 11.6)

A Level 1 Engineering Calculation (Ref. 11) was performed that demonstrates that the Salt Batch 5 is compliant with the requirements from the ARP/MCU NCSE (Ref. 5). This calculation demonstrates that the soluble uranium (U) and plutonium (Pu) concentrations and the U-235(eq_sol) enrichment are no more than the limits of 50 mg/L, 0.3 mg/L, and 3 wt%, respectively.

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

The Tank Farm Documented Safety Analysis (DSA) (Ref. 36) requires that the waste tanks contain waste with a heat generation rate less than 8.00E+05 BTU/hr, and the pump tanks in the facility contain waste with less than 2.1E+04 BTU/hr. This requirement has been determined to be bounding for all incoming waste streams, so no additional controls are necessary (Ref. 1).

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

Prior to transferring waste into Tank 50, a waste generator must demonstrate compliance with the Saltstone WAC Limits. The minimum characterization is available for Salt Batch 5 material in accordance with Attachment 13.1 of Reference 1. Saltstone WAC compliance is demonstrated in Section 3.4. 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 Cs-137 concentration in Salt Batch 5 will not meet the Saltstone WAC. However, SRNL Extraction-Scrub-Strip (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 49. $D_{Cs}$ values in these ranges mean a DF greater than 12 is anticipated from MCU (Ref. 8). The Cs-137 concentration in the experimental DSS stream (6.19E+06 pCi/mL, Ref. 8) meets the Saltstone WAC limits (4.75E+07 pCi/mL), as shown below in Section 3.4. All other requirements are met based on the salt batch qualification values except $NO_{eff}$ as discussed in 3.3.3.

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 50. Filter wash water, the chemical cleanings of the secondary filter, will also bypass MCU and be transferred directly to Tank 50. For wash water and filter wash water transfers to Tank 50, 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 50 requirements as well. A deviation is in place for the 512-S to Tank 50 waste stream (see Section 3.5) (Ref. 33).

For DWPF recycle waste being transferred to Tank Farm, the material must be free of the chemical Petro AG. The material specification for DWPF recycle specifies sodium nitrite that does not contain Petro AG (Ref. 33).

As salt batch material enters the DWPF and can be transferred back to the Tank Farm in the DWPF reycle. DWPF recycle material is fed to the evaporator systems. A comparison to the ETP WAC limits (Ref. 37) to ensure no detrimental impacts to ETP must be done. Historically, evaporator-processed DWPF recycle has not exceeded the ETP WAC limits (Ref. 38). Furthermore, DWPF limits salt solution in the Recycle Collection Tank to 20 gallons (Ref. 39). DWPF samples the recycle for ammonia every $10^{th}$ batch (Ref. 33).

### 3.3.10 Industrial Hygiene Safety (Tank Farm WAC 11.9)

This criterion is not applicable to the Tanks 21 and 49 feed qualification. The feed is from Tanks 21 and 49 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 Tanks 21 and 49 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)

Transfers to the Tank Farm must meet the following interface control requirements in order to protect the Concentration, Storage and Transfer Facility (CSTF) safety anaylsis (Ref. 36):

1. Notification shall be provided to the CSTF Shift Manager prior to intended transfers to the CSTF.
2. The equipment needed to stop transfers, siphons, and liquid additions to the CSTF shall be available to respond to indications of a primary containment waste release.
3. When transferring material to the CSTF with an inhalation dose potential greater than 2.0E+08 rem/gal (High-Rem Waste Transfer), the following shall be required:
    a. For facilities that own the leak detection capability of a CSTF owned transfer line (e.g., H-Canyon transfers to the CSTF), leak detection with control room alarm shall be operable within the LDBs associated with the Transfer Path.
    b. Two physically separated functional transfer isolation devices shall be identified. The transfer isolation devices shall be sufficiently separated (by distance) such that the availability of one isolation device is maintained.
4. Transfers into the CSTF shall be secured as a result of a tornado warning, tornado watch, or high wind warning for the CSTF as issued by the SRS Operations Center.
5. Transfers into the CSTF shall be secured following a seismic event.
6. Transfers into the CSTF shall be secured following notification of a CSTF wildland fire event.
7. Transfers into the CSTF shall be secured following notification of a CSTF control room abandonment event.
8. For evolutions not intended for the CSTF, sound isolation (single leak-tested valve, double valve isolation, blank, or jumper removal) shall be required. Where sound isolation is not possible, notification shall be given to the CSTF Shift Manager of the potential for an unintended Waste Transfer prior to the intended transfer.
9. Notification shall be given to the CSTF Shift Manager prior to performing excavations potentially affecting CSTF transfer lines.

The only transfer into the Tank Farm is from 512-S to MCU. Compliance with these requirements is documented in the Waste Compliance Plan (Ref. 33). Reference 33 describes interface controls # 3, 8, and 9 included in the CSTF DSA and Tank Farm

WAC that were determined not to apply to DWPF. The justification is documented in Section 11.7.2.2 of the DWPF Final Safety Analysis Report (Ref. 40).

### 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 the qualification Tank 21 Salt Batch 5 is 0.0082 M as shown in Table 1. This is 16.3 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. 33). The crossflow filter at 512-S has a nominal pore size of 0.1 micron (Ref. 33)
- Analysis is required for the content of lipophilic anions. Trace amounts of lipophilic anions are in the Salt Batch 5 material. The ARP/MCU process will not change the overall chemistry. Phosphate is assumed to be all dibutyl phosphate (DBP) for the purpose of this evaluation. The trimethylamine (TMA) value is from the TOC from Reference 7. The value is conservative to use the total organic carbon for TMA. The lipophilic anion concentrations are below MCU WAC limits (see Table 4).

**Table 4 - Comparison of MCU Process Requirement for Lipophilic Anions to ISDP Salt Batch 5**

| Lipophilic Anions | Result (mg/L) | Concentration (mM) | MCU Limit (mM) |
|---|---|---|---|
| Tributylphosphate (TBP) | <1.00E+00 | <3.75E-02 | 3.00E+01 |
| DBP | NA* | 0.026* | 2.00E+00 |
| TMA | 2.20E+02** | 3.73E+00** | 1.00E+01 |
| Formate | <1.00E+01 | <2.27E-01 | 1.00E+02 |
| 1-Butanol | <7.50E-01 | <1.01E-02 | 1.00E+01 |

All values are from Reference 7.

*The Organic Potential Inadequacy in the Safety Analysis (PISA) report states that the TBP content from the Canyon operation will be <7 mg/L or less (Ref. 41). The MW of TBP is 266.32 grams per mole, so the influent stream from the canyon will contain $2.62 \times 10^{-5}$ mole of TPB per L of Canyon waste. Swingle, et al., (Ref. 42) reported that TBP degrades to butanol and dibutyl phosphate in a caustic environment. There will be one mole of DBP for every mole of TBP degraded. Swingle also observed that the hydrolysis was rapid to one butanol and no perceptible change beyond this. This means that the concentration of DBP is bound by $2.62 \times 10^{-5}$ mole DBP per L or 0.026 milli-mol per L.

**Result for TOC from Reference 7 (220 mg/L / 59 mg/mM)

- The sending facility (512-S) shall be in compliance with the Foreign Material Exclusion Program (FME). Maintenance operations upstream and at MCU have the potential to introduce chemicals and other foreign materials that are known to disrupt the MCU process. An FME program (Ref. 43) has been developed to control these activities and prevent the inclusion of such compounds into streams transferred to MCU. The 512-S facility is configured in a way to prevent FME added to the process (Ref. 33). In the event of needed additions to the process, Waste Solidification and Tank Farm Engineering will jointly evaluate the material to be added.

## 3.4 Compliance with Saltstone WAC (Ref. 3)

Because a portion of the treated waste from Salt Batch 5 will be transferred into Tank 50, it must meet the Saltstone Waste Acceptance Criteria. The Cs-137 concentration in Salt Batch 5 does not meet the 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 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 5 feed without the Cs-137 and actinides removed via ARP/MCU process is 9.77E+03 rem/gallon. The value is 4.7% of the WAC limit. Also, concentrations for Sr-90, Cs-137, Pu-241, Eu-154, and Total Alpha shall meet the limits in Table 5. Table 5 shows the IDP values calculated in Attachment 15.

**Table 5 - Comparison of Saltstone WAC Inhalation Dose Potential to ISDP Salt Batch 5**

| Radionuclide | WAC IDP (rem/gallon) | Salt Batch 5 IDP (rem/gallon) |
|---|---|---|
| Sr-90 | 8.08E+03 | 9.28E+01 |
| Cs-137 | 8.55E+03 | 4.24E+03 |
| Eu-154 | 1.70E+03 | 1.16E-02 |
| Pu-241 | 1.05E+04 | 6.52E+01 |
| Total Alpha | 1.80E+05 | 5.37E+03 |
| **Total** | **2.09E+05** | **9.77E+03** |

### 3.4.2 Limits for Chemicals Impacting Vault Flammability (Saltstone WAC 5.4.3)

The concentrations of Isopar L, tetraphenylborate (TPB), and ammonium given in Table 6 below shall not be exceeded to protect the assumptions used in the Saltstone vault explosion credibility calculation. As seen in Table 6, ammonium (Ref. 7) meets this limit without crediting the blending that will take place with other influents to Tank 50. Isopar L was not reported in the Salt Batch 5 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 50 is documented in X-ESR-H-00151 (Ref. 44). The WCP states the total mass of TPB to be disposed in Vault 4 is 4.24 kg and is an acceptable amount per X-ESR-H-00137 (Refs. 44 and 32). The TPB value was measured to be less than 1.00E+01 mg/L (Ref. 7) and estimated as less than 9.84E+00 mg/L following the sodium hydroxide addition to Tank 21 after the qualficiation sample was pulled. Tank 21 has no history of material containing TPB, nor do the influents into Tank 21 for Salt Batch 5 make up, Tanks 8, 12, 22, and 23.

**Table 6 - Comparison of Saltstone WAC Chemical Impacting Vault Flammability to ISDP Salt Batch 5**

| Chemical | WAC LIMIT | Salt Batch 5 |
|---|---|---|
| Isopar L | 1.10E+01 ppm | Not Reported, Strategy given in X-ESR-H-00151 |
| Tetraphenylborate | 4.24E+00 kg total mass and 5.00E+00 mg/L | <10.00E+00 mg/L |
| Ammonium | 2.12E+02 mg/L | 5.00E+01 mg/L |

Data from Reference 7.

### 3.4.3 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 $ft^3$ $H_2$/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 5 qualification values except for the cesium isotopes and Ba-137m (the daughter product of Cs-137) for which a decontamination factor of 12 was applied. Calculation results are shown in Attachment 16. The value of hydrogen generated for Salt Batch 5 material is 1.73E-09 $ft^3$ $H_2$/hour/gallon. The hydrogen generation rate value is 3.03 percent of the limit. The ARP/MCU process will experience a dilution in the range of 28.5% to 32.5% (Ref. 9). The hydrogen generation rate is 3.08E-09 $ft^3$ $H_2$/hour/gallon for 28.5% dilution or 5.50 percent of the Saltstone WAC limit of 5.59E-08 $ft^3$ $H_2$/hour/gallon. The hydrogen generation rate is 3.27E-09 $ft^3$ $H_2$/hour/gallon for 32.5% dilution or 5.85 percent of Saltstone WAC limit of 5.59E-08 $ft^3$ $H_2$/hour/gallon. The calculation for hydrogen generation should be considered conservative when dilution is allied as the only the

$NO_{effective}$ is diluted and not the radionuclides. In reality, both chemicals and radionuclides will experience dilution through the ARP/MCU process.

### 3.4.4 "Other Organics" Contribution to Vault Flammability (Saltstone WAC 5.4.5)

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, NORPAR 13, and tributylphosphate (TBP). These organics must be lower than the criteria listed in Table 7 or analysis consistent with S-CLC-Z-00067 must be performed to demonstrate the five organics remain below ten percent CLFL (Ref. 45).

**Table 7 - Comparison of Saltstone WAC "Other Organics" Contribution to Vault Flammability to ISDP Salt Batch 5**

| Chemical | WAC Value (mg/L) | Salt Batch 5 (mg/L) |
|---|---|---|
| Butanol | 0.75 | 7.50E-01 |
| Tributylphosphate* | 1.0 | 9.84E-01 |
| Isopropanol | 0.25 | 2.50E-01 |
| Methanol | 0.25 | Not Directly Measured |
| NORPAR 13 | 0.1 | Not Reported |

Data from Reference 7.
*Data from Table 1.

Compliance is through limiting the alcohols in MST, the source of isopropanol and methanol for Tank 50 (Refs. 46 and 47). An evaluation performed on the Tank 50 material demonstrated isopropanol to be below the Saltstone WAC limit (Ref. 47); while this evaluation was performed during ISDP Salt Batch 2, the influent stream to Tank 50 compositions are projected to be consistent during ISDP Salt Batch 5 and would remain valid. Methanol is a byproduct of the formation of MST which appears in a 1:8 stoichiometric ratio to propanol (Ref. 46). The methanol content is below the isopropanol concentration in Tank 50 (Ref. 47). NORPAR 13 was not reported during Salt Batch 5 qualification sampling. NORPAR 13 is found in Canyon transfers to H Tank Farm. Tank 49 is not a direct receipt tank for Canyon wastes.

### 3.4.5 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 (assumed to be the value of total alpha), and Pu-241 must meet the concentrations listed in Table 8. The concentrations are met; therefore, no criticality concerns are present for Salt Batch 5 material.

**Table 8 - Comparison of Saltstone WAC Nuclear Criticality Safety to ISDP Salt Batch 5**

| Radionuclide | WAC LIMIT (pCi/mL) | Salt Batch 5 (pCi/mL) |
|---|---|---|
| U-233 | 1.13E+04 | 9.68E+01 |
| U-235 | 1.13E+02 | 1.94E-01 |
| Pu-241 | 8.38E+05 | 5.22E+03 |
| Pu-239 (Total alpha) | 2.50E+05 | 7.47E+03 |

Data from Reference 7.

### 3.4.6 Chemical Criteria Limits and Targets (Saltstone WAC 5.4.7 and 5.4.8)

The limits and targets concentrations of the chemicals shown in Tables 9 and 10, respectively, shall not be exceeded. Table 9 shows that the qualification values for Salt Batch 5 are within Saltstone WAC limits. Table 10 shows that the qualification values of the selected targets analyzed for Salt Batch 5 qualification are within the Saltstone WAC targets that were reported; however, these are not required to be analyzed prior to transfer into Tank 50. Tank 50 is analyzed for Saltstone Limits and Targets on a quarterly basis to verify the requirements are being met. Salt Batch 5 qualification strategy required limits to be analyzed as well as certain targets that were required for other facilities' requirements (Ref. 48). Isopar L was not reported in the Salt Batch 5 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 50 is documented in X-ESR-H-00151 (Ref. 44).

**Table 9 – Comparison of Saltstone WAC Chemical Contaminant LIMITS to ISDP Salt Batch 5**

| Chemical Name | WAC LIMIT (mg/L) | Salt Batch 5 (mg/L) |
|---|---|---|
| Ammonium | 7.13E+03 | 5.00E+01 |
| Carbonate*β | 1.45E+05 | 1.40E+04 |
| Chloride*β | 9.68E+03 | 4.93E+02 |
| Fluoride* | 4.94E+03 | 9.84E+00 |
| Hydroxide*β | 1.91E+05 | 4.01E+04 |
| Nitrate*β | 5.29E+05 | 1.72E+05 |
| Nitrite*β | 2.59E+05 | 2.53E+04 |
| Oxalate*β | 3.30E+04 | 2.38E+02 |
| Phosphate*β | 3.56E+04 | 4.77E+02 |
| Sulfate*β | 6.89E+04 | 7.18E+03 |
| Arsenic | 7.50E+02 | 3.22E-01 |
| Barium | 7.50E+02 | 5.20E-01 |
| Cadmium | 3.75E+02 | 8.50E-01 |
| Chromium | 1.50E+03 | 4.10E+01 |
| Lead | 7.50E+02 | 7.16E+00 |
| Mercury | 3.25E+02 | 8.82E+01 |
| Selenium | 4.50E+02 | 2.01E-01 |
| Silver | 7.50E+02 | 1.46E+00 |
| Aluminum | 1.41E+05 | 7.00E+03 |
| Potassium*β | 3.67E+04 | 3.19E+02 |
| Nickel Hydroxide | 3.95E+03 | 2.53E+00 |
| Butanol and Isobutanol | 2.25E+03 | 7.50E-01 |
| Isopropanol | 2.25E+03 | 2.50E-01 |
| Phenol | 7.50E+02 | 1.00E+01 |
| Isopar L | 1.50E+02 | Not Reported |
| Total Organic Carbon* | 5.00E+03 | 2.16E+02 |
| Tetraphenylborate (TPB)* | 7.50E+02 | 9.84E+00 |

Data from Reference 7.
* Data from Table 1.
β Data was reported in moles/liter. A basic conversion is applied using molecular weight of the ion.

**Table 10 – Comparison of Saltstone WAC Chemical Contaminant TARGETS to ISDP Salt Batch 5**

| Chemical Name | WAC TARGETS (mg/L) | Salt Batch 5 (mg/L) |
|---|---|---|
| Boron | 9.00E+02 | 3.58E+01 |
| Cobalt | 9.00E+02 | Not Reported |
| Copper | 9.00E+02 | 1.29E+00 |
| Iron | 6.00E+03 | 5.54E+00 |
| Lithium | 9.00E+02 | 1.04E+01 |
| Manganese | 9.00E+02 | 5.30E-01 |
| Molybdenum | 9.00E+02 | 7.79E+00 |
| Nickel | 9.00E+02 | 1.60E+00 |
| Silicon* | 1.29E+04 | 4.60E+01 |
| Strontium | 9.00E+02 | 5.00E-02 |
| Zinc | 9.75E+02 | 4.40E+00 |
| Benzene | 3.75E+02 | Not Reported |
| Methanol | 2.25E+02 | 1.90E+02 |
| Tributylphosphate * | 3.00E+02 | 9.84E-01 |
| Toluene | 3.75E+02 | Not Reported |
| Ethylenediaminetetraacetic Acid (EDTA) | 3.75E+02 | Not Reported |
| NORPAR 13 | 1.00E-01 | Not Reported |

Data from Refernce 7.
*Data from Table 1.

### 3.4.7 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 11 and Table 12, respectively, shall not be exceeded. Table 11 shows that the qualification values for Salt Batch 5 are within Saltstone WAC limits. Table 12 shows that the qualification values for Salt Batch 5 are within the Saltstone WAC targets for the targets that were reported; however, these are not required to be analyzed prior to transfer into Tank 50. Tank 50 is analyzed for Saltstone Limits and Targets on a semiannual basis to verify the requirements are being met. Salt Batch 5 qualification strategy required limits to be analyzed as well as certain targets that were required for other facilities' requirements (Ref. 48).

**Table 11 – Comparison of Saltstone WAC Radionuclide Contaminant LIMITS to ISDP Salt Batch 5**

| Radionuclide | WAC LIMIT (pCi/mL) | Salt Batch 5 (pCi/mL) |
|---|---|---|
| H-3 | 5.63E+05 | 9.46E+02 |
| C-14 | 1.13E+05 | 7.20E+02 |
| Ni-63 | 1.13E+05 | 4.06E+02 |
| Sr-90 | 2.25E+07 | 2.58E+05 |
| Tc-99 | 4.22E+05 | 2.28E+04 |
| I-129 | 1.13E+03 | 1.30E+01 |
| Cs-137 | 4.75E+07 | 5.90E+07 (see Note 1) |
| U-233 | 1.13E+04 | 9.68E+01 |
| U-235 | 1.13E+02 | 1.94E-01 |
| Pu-241 | 8.38E+05 | 5.22E+03 |
| Total Alpha | 2.50E+05 | 7.47E+03 |

Data from Reference 7.

Note 1 - The Cs-137 concentration is based on the Salt Batch 5 feed concentration and is therefore higher than the expected DSS stream. Using the design basis of a minimum DF factor of 12 (Ref. 49) and the Salt Batch 5 Cs-137 concentration of 0.223 Ci/gallon, the Cs-137 concentration is expected to be 0.016 Ci/gallon (4.92E+06 pCi/mL).

**Table 12 – Comparison of Saltstone WAC Radionuclide Contaminant TARGETS to ISDP Salt Batch 5**

| Radionuclide | WAC TARGET (pCi/mL) | Salt Batch 5 (pCi/mL) |
|---|---|---|
| Al-26 | 2.88E+03 | Not Reported |
| Co-60 | 1.13E+06 | 5.63E+00 |
| Ni-59 | 1.13E+05 | 2.00E+01 |
| Se-79 | 1.90E+04 | Not Reported |
| Nb-93m | 2.85E+06 | Not Reported |
| Nb-94 | 1.53E+04 | 6.08E+00 |
| Mo-93 | 1.18E+07 | Not Reported |
| Ru-106 | 1.13E+06 | 8.19E+01 |
| Sb-125 | 2.25E+06 | 5.99E+01 |
| Sn-126 | 1.80E+04 | 1.93E+02 |
| Cs-134 | 1.13E+06 | 5.54E+03 |
| Cs-135 | 1.13E+06 | 2.81E+02 |
| Ce-144 | 1.13E+05 | 7.70E+01 |
| Pm-147 | 5.63E+06 | 1.80E+02 |
| Sm-151 | 2.25E+04 | 1.53E+02 |
| Eu-154 | 2.25E+06 | 1.53E+01 |
| Eu-155 | 1.13E+04 | 3.62E+01 |
| Ra-226 | 7.97E+03 | 3.12E+02 |
| Th-229 | 1.63E+05 | Not Reported |
| Th-230 | 6.26E+03 | Not Reported |
| Th-232 | 2.88E+03 | Not Reported |
| U-232 | 1.71E+05 | 7.25E+00 |
| U-234 | 1.13E+04 | 9.00E+01 |
| U-236 | 1.13E+04 | 1.08E+00 |
| U-238 | 1.13E+04 | 3.70E+00 |
| Np-237 | 2.50E+05 | 3.39E+00 |
| Pu-238 | 2.50E+05 | 1.46E+04 |
| Pu-239 | 2.50E+05 | 1.49E+03 |
| Pu-240 | 2.50E+05 | 1.49E+03 |
| Pu-242 | 2.50E+05 | 3.82E+01 |
| Pu-244 | 7.02E+04 | 1.77E-01 |
| Am-241 | 2.50E+05 | 7.60E+00 |
| Am-242m | 4.50E+05 | Not Reported |
| Am-243 | 2.50E+05 | 3.98E+00 |
| Cm-242 | 1.13E+04 | Not Reported |

Data from Reference 7.

### 3.4.8 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 14, which meets the criteria (Ref. 8). The pH of Tank 50 (feed to Saltstone) is maintained to a pH greater than 10 as a part of the Tank Farm Corrosion Control Program (Ref. 28).

ISDP Salt Batch 5 material has a sodium concentration of 6.56 M (Table 1). Accounting for the 28.5% and 32.5% dilution rate when the Salt Batch 5 material is processed (Ref. 9), the sodium concentration is 4.69 M and 4.44 M, respectively, and will meet the sodium concentration criterion. Sodium concentration is monitored using the Tank 50 material balance.

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

The Salt Batch 5 material has less than 0.32 weight percent of insoluble solids (Ref. 7). 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 50 material balance. The quarterly sampling plan for Tank 50 also monitors for weight percent of insoluble solids.

Homogeneous and consistent feed strategies are discussed in detail in the Waste Compliance Plan (Ref. 32).

### 3.4.9 Gamma Shielding (Saltstone WAC 5.4.12)

The specific gamma source strength value shall not exceed 9.05E+01 mrem/hr/gallon. Table 13 shows that the gamma source strength values for the DSS stream are within the Saltstone WAC limits. A comparison of Salt Batch 5 material without ARP/MCU treatment is shown in Attachment 17. The gamma source strength of Salt Batch 5 feed material is 8.53E+01 mrem/hr/gallon or 94 percent of the Saltstone WAC limit of 9.05E+01 mrem/hr/gallon. The gamma source strength of the DSS stream using the design basis of a minimum DF factor of 12 is 5.93E+00 mrem/hr/gallon or 0.66 percent of the Saltstone WAC limit of 9.05E+01 mrem/hr/gallon.

**Table 13 – Comparison of Saltstone WAC Gamma Source Strength to ISDP Salt Batch 5 (DSS stream)**

| Radionuclide | WAC Gamma Source Strength (mrem/hr/gal) | DSS Gamma Source Strength (mrem/hr/gal) |
|---|---|---|
| Co-60 | 5.84E+00 | 2.92E-05 |
| Sb-125 | 5.17E+00 | 1.38E-04 |
| Cs-134 | 4.26E+00 | 1.75E-03 |
| Cs-137 | 6.88E+01 | 5.92E-01 |
| Eu-154 | 6.43E+00 | 4.38E-05 |
| **Total** | **9.05E+01** | **5.94E-01** |

### 3.5 WAC Deviations

Deviations may be experienced during transfer of wash water from 512-S to Tank 50. As described in 3.3.9, wash water transfers to Tank 50 may be below the 2.5-7 M Sodium concentration and above the Cesium-137 limit of 0.2 Ci/gal (Ref. 33). $NO_{eff}$ may be out of the Tank 50 requirements as well. Prior to the transfer to Tank 50, Tank Farm Engineering must evaluate the impact via the Tank 50 Material Balance.

### 3.6 Other Evaluations

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

#### 3.6.1 Process Test Results

The Salt Batch 5 qualification included actinide removal testing using MST and ESS testing (Ref. 8).

The actinide removal testing was performed on a blend of Tank 21 and Tank 49 sample material (current Salt Batch 4 material) to determine if it would process correctly in the ARP. Tests using MST with the blended sample material gave acceptable DFs for plutonium and strontium. Material from the actinide removal testing was used in an ESS test. This test yielded expected and acceptable distribution values.

#### 3.6.2 Air Emissions Evaluation

The air emissions calculation for MCU was revised based on the Salt Batch 1 data (Ref. 52). 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.

A 40 CFR 61, Appendix D evaluation was performed using data from Reference 7 (Ref. 53). The initial evaluation showed the potential effective dose to be greater than 0.1 mrem/year (PIC Level 1 source). Using the approved alternative calculation methodology that is documented in Reference 54 and the Level II radionuclide emissions calculated for Salt Batch 1, the calculated Level II dose found in Table 4 of Reference 52 was increased by 1777%. The resultant potential effective dose equivalent (PEDE) is 2.39E-04 mrem/year and the effective dose equivalent (EDE) is 1.12E-05 mrem/year using the methodology described. This estimate would make this activity a Potential Impact Category (PIC) Level 4, which is the lowest classification under the Savannah River Site (SRS) Radionuclide National Emissions Standards for Hazardous Air Pollutants (NESHAP) Program and does not require periodic sampling (Reference 54). A PIC Level 4 source requires an annual administrative review of facility uses to confirm absence of radioactive materials in forms and quantities not conforming to prescribed specification and/or limits. This administrative action is consistent with that performed for Salt Batch 4 and will be performed for Salt Batch 5.

### 3.6.3 Radiological Design Calculations

The radiological source term for Salt Batch 5 is less than the MCU Design Basis (Ref. 49). Therefore, the Design Basis is still considered the bounding case, and the new salt batch is not expected to impact the radiological design of the ARP/MCU facilities (Ref. 55).

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 Cs-137 limit (Ref. 56). However, there are gaps that exist between the process cell covers where elevated dose rates could exist. Lead wool snakes and steel plates are used to provide equivalent shielding in and above the cell cover gaps. At feed concentrations of 0.4 Ci/gal Cs-137, Reference 56 determined only lead wool snakes need to be used to fill the gaps between the cell covers to meet the design basis. At feed concentrations greater than 0.4 Ci/gal Cs-137, Reference 57 requires steel plates in addition to the lead wool snakes to meet the design basis. Salt Batch 5 is below 0.4 Ci/gal Cs-137 (Ref. 7).

### 3.6.4 Requirements for 241-96H

The feed stream to 241-96H shall be less than or equal to 1.4E+06 rem/gal as documented in Chapter 3 (Section 3.3.3.3) of the DSA (Ref. 36) and protected by the Inhalation Dose Potential Specific Administrative Control (SAC) (5.5.4.2.48) (Ref. 58). The calculated IDP for Salt Batch 5 feed is 1.59E+04 rem/gal (see Attachment 1).

Reference 18 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 Salt Batch 5 feed is 5.64E-05 Ci/gal (Ref. 7). Therefore, additional calculations need not be performed.

### 3.6.5 Hydrogen Generation

The bounding calculated hydrogen generation rate for ARP is 3.19E-06 $ft^3$ $H_2$/hr/gal (Ref. 59), and for MCU feed the rate is 6.29E-07 $ft^3$ $H_2$/hr/gal (Ref. 60). The calculated hydrogen generation rate for Salt Batch 5 material is 1.37E-09 $ft^3$ $H_2$/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 Caustic Additions at 512-S

This study is based on the results of Tank 21 material that has been prepared as Salt Batch 5 and the heel in Tank 49. This evaluation is conducted to ensure the hydroxide concentration will protect solids formation, particularly sodium oxalate ($Na_2C_2O_4$) and aluminum hydroxide ($Al(OH)_3$). Attachment 18 discusses the use of OLI Stream Analyzer 3.2 to evaluate the free hydroxide ($OH^{-1}$) concentration needed for Tank 49 to support ISDP Salt Batch 5 operations, in particular, to prevent filter fouling issues at 512-S. The free hydroxide concentration recommendation to prevent filter flouling at 512-S is to remain greater than or equal to 2.22 M (the normal feed concentration at 512-S with dilution experienced at 241-96H—2.36 M * (1-5.81%) = 2.22 (Ref. 9)) and less than or equal to 3.0, as seen in Attachment 18.

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**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 | 7.47E+03 | 2.83E-05 | 1.70E+08 | 4.81E+03 |
| Sr-90 | 2.58E+05 | 9.77E-04 | 8.90E+04 | 8.69E+01 |
| | | | | |
| **Total Dose (rem/gal)** | | | | **4.89E+03** |
| **512-S WAC limit (rem/gal)** | | | | **3.00E+06** |
| **% of WAC limit** | | | | **0.16%** |

**Method 2**

| Radionuclide | Concentration (pCi/mL) | Concentration (Ci/gal) | Dose Potential CEDE DCF (rem/Ci) | IDP (rem/gal) |
|---|---|---|---|---|
| Sr-90 | 2.58E+05 | 9.77E-04 | 8.90E+04 | 8.69E+01 |
| Ru-106 | 8.19E+01 | 3.10E-07 | 2.40E+05 | 7.44E-02 |
| Cs-137 | 5.90E+07 | 2.23E-01 | 1.90E+04 | 4.24E+03 |
| Ce-144 | 7.70E+01 | 2.91E-07 | 2.00E+05 | 5.83E-02 |
| Pm-147 | 1.80E+02 | 6.81E-07 | 1.90E+04 | 1.29E-02 |
| Pu-238 | 1.46E+04 | 5.53E-05 | 1.70E+08 | 9.39E+03 |
| Pu-239 | 1.49E+03 | 5.64E-06 | 1.90E+08 | 1.07E+03 |
| Pu-240 | 1.49E+03 | 5.64E-06 | 1.90E+08 | 1.07E+03 |
| Pu-241 | 5.22E+03 | 1.98E-05 | 3.30E+06 | 6.52E+01 |
| Am-241 | 7.60E+00 | 2.88E-08 | 1.60E+08 | 4.60E+00 |
| Cm-244 | 1.05E+01 | 3.97E-08 | 1.00E+08 | 3.97E+00 |
| | | | | |
| **Total Dose (rem/gal)** | | | | **1.59E+04** |
| **512-S WAC limit (rem/gal)** | | | | **3.00E+06** |
| **% of WAC limit** | | | | **0.53%** |

Data from Reference 7.
Dose Potential committed effective does equivalent (CEDE) DCF references are defined in the DWPF WAC (Ref. 2).

**Attachment 2: Hydrogen Generation Rate from Salt Batch 5 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 | 5.63E+00 | 2.13E-08 | 1.54E-02 | 48.36 | 3.28E-10 | 5.42E-14 |
| Y-90 | 2.58E+05 | 9.77E-04 | 5.54E-03 | 48.36 | 5.41E-06 | 8.93E-10 |
| Sr-90 | 2.58E+05 | 9.77E-04 | 1.16E-03 | 48.36 | 1.13E-06 | 1.87E-10 |
| Ru-106 | 8.19E+01 | 3.10E-07 | 5.95E-04 | 48.36 | 1.84E-10 | 3.04E-14 |
| Rh-106 | 8.19E+01 | 3.10E-07 | 1.89E-02 | 48.36 | 5.87E-09 | 9.69E-13 |
| Sb-125 | 5.99E+01 | 2.27E-07 | 3.37E-03 | 48.36 | 7.64E-10 | 1.26E-13 |
| Cs-134 | 5.54E+03 | 2.10E-05 | 1.02E-02 | 48.36 | 2.14E-07 | 3.53E-11 |
| Cs-137 | 5.90E+07 | 2.23E-01 | 1.01E-03 | 48.36 | 2.26E-04 | 3.72E-08 |
| Ba-137m | 5.59E+07 | 2.12E-01 | 3.94E-03 | 48.36 | 8.34E-04 | 1.38E-07 |
| Ce-144 | 7.70E+01 | 2.91E-07 | 6.58E-04 | 48.36 | 1.92E-10 | 3.17E-14 |
| Pr-144 | 7.70E+01 | 2.91E-07 | 7.33E-03 | 48.36 | 2.14E-09 | 3.53E-13 |
| Pm-147 | 1.80E+02 | 6.81E-07 | 3.67E-04 | 48.36 | 2.50E-10 | 4.13E-14 |
| Eu-154 | 1.53E+01 | 5.79E-08 | 9.08E-03 | 48.36 | 5.26E-10 | 8.68E-14 |
| Pu-238 | 1.49E+04 | 5.64E-05 | 3.26E-02 | 134.7 | 1.84E-06 | 8.45E-10 |
| Pu-239 | 1.49E+03 | 5.64E-06 | 3.02E-02 | 134.7 | 1.70E-07 | 7.83E-11 |
| Pu-240 | 1.49E+03 | 5.64E-06 | 3.06E-02 | 134.7 | 1.72E-07 | 7.92E-11 |
| Am-241 | 7.60E+00 | 2.88E-08 | 3.28E-02 | 134.7 | 9.44E-10 | 4.34E-13 |
| Cm-244 | 1.05E+01 | 3.97E-08 | 3.44E-02 | 134.7 | 1.37E-09 | 6.28E-13 |
| | | | | | | |
| **Total ($ft^3$ $H_2$/hr/gal)** | | | | | | **1.77E-07** |
| **512-S WAC limit ($ft^3$ $H_2$/hr/gal)** | | | | | | **1.64E-06** |
| **% of WAC limit** | | | | | | **10.79%** |

Data from Reference 7.
R values are defined in the DWPF WAC (Ref. 2).
Q values are defined in Reference 61.

**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. 2).

$NO_x$ 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 | 2.23E-01 | 0.70 | 1.56E-01 |
| Carbonate | 9.60E-02 | 1.40 | 1.34E-01 |
| Nitrite | 2.47E-01 | 1.86 | 4.59E-01 |
| Nitrate | 1.11E-01 | 1.00 | 1.11E-01 |
| Manganese ion* | 1.22E-01 | 0.84 | 1.03E-01 |
| Mercury ion* | 1.51E-02 | 0.70 | 1.06E-02 |
| **$NO_x$ emission** | | | 9.74E-01 |
| | | | |
| **$NO_x$ Total (tons/yr)** ($NO_x$ total = 19.1 * $NO_x$ emission) | | | **18.61** |
| **DWPF WAC Limit (tons/yr)** | | | **103.52** |
| **Percent of Limit** | | | **17.98%** |

Data from Reference 16.

* Manganese and mercury ion were determined using elemental data.

Data from Reference 16.
Mn = 3.45wt% dry solids    TS = 17.08 wt%
Hg = 1.56 wt% dry solids    SG = 1.14 kg/L

Converting wt% dry solids to Molarity in slurry
M slurry = wt% dry solids/100*wt% total solids/100*SpG slurry*1000/MW

| **Sludge Only $NO_x$ Emission** | |
|---|---|
| **DWPF** | **18.61 tons/year** |
| **WAC LIMIT** | **103.52 tons/year** |
| **Percent of Limit** | **17.98%** |

**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. 10). 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.

The soluble species in the Salt Batch 5material sent to DWPF will experience dilution effects due to normal processing and the washing of the MST/sludge solids before transferring to the PRFT via the LPPP. The soluble species in $NO_X$ emissions are nitrite and nitrate. Hydroxide does largely partition to Saltstone but is added as a part of the salt batch preparation; therefore, the feed concentration is used for $NO_x$ determination. A partition amount was determined to be 0.001339 to the LPPP and 0.998554 to CSS (Ref. 62). The amount of nitrite and nitrate can be determined by multiplying the Salt Batch 4 value by the partition to the LPPP.

| | Result | Result (M) | Factor | $NO_x$ Contribution (M) |
|---|---|---|---|---|
| Hydroxide | 2.36E+00 M | 2.36E+00 | 0.70 | 1.65E+00 |
| Carbonate | 2.34E-01 M | 2.34E-01 | 1.40 | 3.28E-01 |
| Nitrite | 7.38E-04 M | 7.38E-04 | 1.86 | 1.37E-03 |
| Nitrate | 3.72E-03 M | 3.72E-03 | 1.00 | 3.72E-03 |
| Manganese ion* | 5.30E-01 mg/L | 9.65E-06 | 0.84 | 8.10E-06 |
| Mercury ion* | 8.82E+01 mg/L | 4.40E-04 | 0.70 | 3.08E-04 |
| **Total $NO_x$ contribution (M)** | | | | **1.99E+00** |
| **Total $NO_x$ contribution (g/L)** | | | | **9.13E+01** |

Data from Table 1.
*Data from Reference 7.

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

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

$NO_x$ = 9.13E+01 g/L * 3.00E+05 L/yr / 453.6 g/lb /2000 lb/ton

The total $NO_x$ contribution by ARP is 3.02E+01 tons/year.

| **Total $NO_x$ Emission** | |
|---|---|
| **DWPF** | **18.61 tons/year** |
| **ARP** | **30.24 tons/year** |
| **TOTAL** | **48.25 tons/year** |
| **WAC LIMIT** | **103.52 tons/year** |
| **Percent of Limit** | **47.19%** |

**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. 2).

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

| **Species** | **Ci/g dried sludge slurry** | **Ci/lb calcined sludge solids** | **Canister Heat Generation factors (W/Ci)** | **Species Contribution to Canister Heat Generation (W/lb)** |
|---|---|---|---|---|
| Sr-90 | 1.51E-02 | 8.84E+00 | 6.70E-03 | 5.92E-02 |
| Ru-106 | 6.29E-07 | 3.68E-04 | 1.95E-02 | 7.18E-06 |
| Cs-137 | 6.32E-04 | 3.70E-01 | 4.74E-03 | 1.75E-03 |
| Ce-144 | 1.21E-06 | 7.08E-04 | 8.00E-03 | 5.67E-06 |
| U-233 | 1.20E-07 | 7.02E-05 | 2.86E-02 | 2.01E-06 |
| Pu-238 | 1.45E-04 | 8.49E-02 | 3.26E-02 | 2.77E-03 |
| Pu-239 | 1.10E-05 | 6.44E-03 | 3.02E-02 | 1.94E-04 |
| Pu-240 | 3.70E-06 | 2.17E-03 | 3.06E-02 | 6.63E-05 |
| Am-241 | 4.21E-05 | 2.46E-02 | 3.28E-02 | 8.08E-04 |
| Cm-244 | 2.04E-05 | 1.19E-02 | 3.44E-02 | 4.11E-04 |
| **Total Species Contribution (W/canister in lbs)** | | | | 6.52E-02 |
| **Canister Heat Generation (W/canister in tons)** | | | | 143.49 |
| | | | | |
| **WAC Limit (W/canister)** | | | | 437 |
| **Percent of Limit** | | | | 32.83% |

Data from Reference 16.

Ci/lb calcined sludge solids
= Ci/g dried sludge slurry * (454 g/lb) * Dried to Calcine Factor
Dried to Calcine Factor = 17.08 / 13.25 = 1.29 (Ref. 16)

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. 10). 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 | 2.58E+05 | 9.77E-04 | 6.70E-03 | 6.54E-06 |
| Ru-106 | 8.19E+01 | 3.10E-07 | 1.95E-02 | 6.04E-09 |
| Cs-137 | 5.90E+07 | 2.23E-01 | 4.74E-03 | 1.06E-03 |
| Ce-144 | 7.70E+01 | 2.91E-07 | 8.00E-03 | 2.33E-09 |
| U-233 | 9.68E+01 | 3.66E-07 | 2.86E-02 | 1.05E-08 |
| Pu-238 | 1.46E+04 | 5.53E-05 | 3.26E-02 | 1.80E-06 |
| Pu-239 | 1.49E+03 | 5.64E-06 | 3.02E-02 | 1.70E-07 |
| Pu-240 | 1.49E+03 | 5.64E-06 | 3.06E-02 | 1.73E-07 |
| Am-241 | 7.60E+00 | 2.88E-08 | 3.28E-02 | 9.44E-10 |
| Cm-244 | 1.05E+01 | 3.97E-08 | 3.44E-02 | 1.37E-09 |
| | | | | |
| **Heat Generation (W/gallon)** | | | | **1.07E-03** |
| **Heat Generation per canister (W/canister)** | | | | **7.23E+00** |

Data from Reference 7.
Heat Generation factors are defined in Reference 61.

ARP contribution = 1.07E-03 W/gallon * 3.39E+04 gallon/week / 5 canister/week
= 7.23 W/canister

MCU will feed SE to DWPF at a rate of 0.52 gpm or 5242 gallons/week (Ref. 63). The contribution from Cs-137 is the value of the Salt Batch 5 material (0.223 Ci/gallon) multiplied by a concentration factor of 15 (Ref. 2). MCU contribution is 3.35 Ci/gallon. DWPF nominally produces 5 canisters a week.

MCU contribution = 3.35 Ci/gallon * 4.74E-03 W/Ci * 5242 gallon/week /
5 canister/week = 16.64 W/canister

**Total Canister Heat Generation**

| | |
|---|---|
| **DWPF** | **143.49W/canister** |
| **ARP** | **7.23 W/canister** |
| **MCU** | **16.64 W/canister** |
| **TOTAL** | **167.36 W/canister** |
| | |
| **WAC LIMIT** | **437 W/canister** |
| **Percent of Limit** | **38.30%** |

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

| Species | µCi/g dried sludge | Gamma Dose Constant (mR/hr/µCi) | Gamma Source Strength (mR/hr/g) | Gamma Source Strength (mR/hr/gal) |
|---|---|---|---|---|
| Co-60 | 3.18E+00 | 1.37E-03 | 4.36E-03 | 3.21E+00 |
| Ru-106 | 6.29E-01 | 1.38E-04 | 8.68E-05 | 6.40E-02 |
| Sb-125 | 2.46E-01 | 3.80E-04 | 9.35E-05 | 6.89E-02 |
| Cs-134 | 2.27E+00 | 9.99E-04 | 2.27E-03 | 1.67E+00 |
| Cs-137 | 6.32E+02 | 3.82E-04 | 2.41E-01 | 1.78E+02 |
| Ce-144 | 1.21E+00 | 2.33E-05 | 2.82E-05 | 2.08E-02 |
| Eu-154 | 1.67E+01 | 7.56E-04 | 1.26E-02 | 9.30E+00 |
| Eu-155 | 3.59E+00 | 6.67E-05 | 2.39E-04 | 1.76E-01 |
| Pu-238 | 1.45E-04 | 7.90E-05 | 1.15E-08 | 8.44E-06 |
| | | | | |
| **Gamma Source Strength (mR/hr/g)** | | | | **2.61E-01** |
| **Gamma Source Strength (mR/hr/gal)** | | | | **1.92E+02** |

Data from Reference 16.

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)
= 1.14 * 1000 * 3.785 * (17.08 /100) = 736.98
SG and wt% total solids are found in Reference 16.

The total Gamma Source Strength for insoluble solids is determined by the addition of Gamma Source Strength in Ci/g dried sludge multiplied by the ratio of total solids to insoluble solids (17.08 / 12.02) (Ref. 16).

Gamma Source Strength = 2.61E-01 * (1.42) = 3.71E-01 mR/hr/g insoluble solids

**Gamma Source Strength** **1.92E+02 mR/hr/gallon**
**WAC LIMIT** **4070 mR/hr/gallon**
**Percent of Limit** **4.73%**

**Gamma Source Strength** **3.71E-01 mR/hr/g insoluble solids**
**WAC LIMIT** **3.7 mR/hr/g insoluble solids**
**Percent of Limit** **10.03%**

**Attachment 6: Neutron Shielding** (DWPF WAC 5.4.4)

The total alpha concentration is determined by added the concentration of the individual alpha contributors from Reference 16.

| Radionuclides | Ci/g TS | Ci/gal |
|---|---|---|
| U-233 | 1.20E-07 | 9.53E-05 |
| U-234 | 4.94E-08 | 3.89E-05 |
| U-235 | 6.18E-10 | 4.74E-07 |
| U-236 | 1.05E-09 | 8.11E-07 |
| U-238 | 1.61E-08 | 1.24E-05 |
| Pu-238 | 1.45E-04 | 1.11E-01 |
| Pu-239 | 1.10E-05 | 8.34E-03 |
| Pu-240 | 3.70E-06 | 2.95E-03 |
| Am-241 | 4.21E-05 | 3.33E-02 |
| Cm-244 | 2.04E-05 | 1.66E-02 |
| Cm-245 | 1.48E-07 | 1.10E-04 |
| **Total Alpha** | **2.23E-04** | **1.72E-01** |

The contribution from the sludge is the following:
Total Alpha 2.23E-04 Ci/g TS

Total Solids (TS) = 17.08 wt% (Ref. 16)
Insoluble Solids (IS) = 12.02 wt% (Ref. 16)

Ci/g insoluble solids
= 2.23E-04 Ci/g TS * (17.08 TS/ 12.02 IS)
= 3.16E-04 Ci/g insoluble solids

**Neutron Shielding 3.16E-04 Ci/g insoluble solids**
**WAC LIMIT 1.50E-03 Ci/g insoluble solids**
**Percent of Limit 21.08%**

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

The Sludge Batch 7b contribution to the IDP WAC limit.

**Method 1**

| Radionuclide | Concentration (Ci/gal) | Dose Potential CEDE DCF (rem/Ci) | IDP (rem/gal) |
|---|---|---|---|
| Alpha* | 1.72E-01 | 1.70E+08 | 2.93E+07 |
| Sr-90 | 1.16E+01 | 8.90E+04 | 1.03E+06 |
| | | | |
| **Total Dose (rem/gal)** | | | **3.03E+07** |
| **DWPF WAC limit (rem/gal)** | | | **2.47E+08** |
| **% of WAC limit** | | | **12.29%** |

* As seen in Attchment 6.

**Method 2**

| Radionuclide | Concentration (Ci/gal) | Dose Potential CEDE DCF (rem/Ci) | IDP (rem/gal) |
|---|---|---|---|
| Sr-90 | 1.16E+01 | 8.90E+04 | 1.03E+06 |
| Ru-106 | 4.99E-04 | 2.40E+05 | 1.20E+02 |
| Cs-137 | 4.95E-01 | 1.90E+04 | 9.41E+03 |
| Ce-144 | 9.34E-04 | 2.00E+05 | 1.87E+02 |
| Pm-147 | 1.62E-01 | 1.90E+04 | 3.08E+03 |
| Pu-238 | 1.11E-01 | 1.70E+08 | 1.89E+07 |
| Pu-239 | 8.34E-03 | 1.90E+08 | 1.58E+06 |
| Pu-240 | 2.95E-03 | 1.90E+08 | 5.61E+05 |
| Pu-241 | 3.66E-02 | 3.30E+06 | 1.21E+05 |
| Am-241 | 3.33E-02 | 1.60E+08 | 5.33E+06 |
| Cm-244 | 1.66E-02 | 1.00E+08 | 1.66E+06 |
| | | | |
| **Total Dose (rem/gal)** | | | **2.92E+07** |
| **DWPF WAC limit (rem/gal)** | | | **2.47E+08** |
| **% of WAC limit** | | | **11.81%** |

Data from Reference 16.
Dose Potential CEDE DCF references are defined in the DWPF WAC (Ref. 2).

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

| Radionuclide | Ci/g total dried (Ref. 16) | Specific Activity (Ci/g) | g/g total solids | wt% dried sludge slurry |
|---|---|---|---|---|
| U-233 | 1.20E-07 | 9.68E-03 | 1.24E-05 | 1.24E-03 |
| U-235 | 6.18E-10 | 2.16E-06 | 2.86E-04 | 2.86E-02 |
| Pu-239 | 1.10E-05 | 6.22E-02 | 1.77E-04 | 1.77E-02 |
| Pu-240 | 3.70E-06 | 2.28E-01 | 1.62E-05 | 1.62E-03 |
| Pu-241 | 4.61E-05 | 1.03E+02 | 4.48E-07 | 4.48E-05 |
| Am-242m | 3.89E-08 | 9.72E+00 | 4.00E-09 | 4.00E-07 |
| Cm-244 | 2.04E-05 | 8.09E+01 | 2.52E-07 | 2.52E-05 |
| Cm-245 | 1.48E-07 | 1.72E-01 | 8.62E-07 | 8.62E-05 |

Specific Activity is found in Reference 61.

| Species | wt% total dried |
|---|---|
| Fe | 1.47E+01 |
| U | 5.02E+00 |

Data from Reference 16.

Eq. Pu-239 = Pu-239 + Pu-241 + Cm-244 + 15(Cm-245) + 35(Am-242m)
= (1.77E-02 + 4.48E-05 + 2.52E-05 + 15 * 8.62E-05 +
35 * 4.00E-07) wt% dried solids
= 1.91E-02 wt% dried solids

Eq. U-235 = U-235 + 1.4 * U-233 = (2.86E-02 + 1.4 * 1.24E-03) wt% dried solids
= 3.03E-02 wt% dried solids

Criteria #1
Pu-240 to Pu-241: 1.62E-03 / 4.48E-05
= 36.27:1

Criteria #2
Fe/Eq. Pu-239 = 1.47E+01 / 1.91E-02 = 7.72E+02:1

Sludge Batch 7b consist of material from Tank 51 and a large heel of Sludge Batch 7a. Sludge Batch 7a contains a plutonium drop from H Canyon; therefore, the Eq. Pu-239 concentration of ≤0.59 g/gallon requirement does apply.

Criteria #3
To determine the concentration Eq. Pu-239
= (wt.% Eq. Pu-239 / 100) * SpG slurry * 1000* 3.785 * (wt% total solids / 100)
= (1.91E-02 / 100) * 1.14 * 1000 * 3.785 * (17.08 / 100)
= 1.41E-01 g/gallon

0.141 g/gallon is less than 0.59 g/gallon

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

Criteria #4
To calculate % Eq. U-235 Enrichment, divide Eq. U-235 by the U concentration to calculate Eq. U-235 Enrichment:

% U-235 Enrichment = (Eq. U-235/U)*100 = (3.03E-02 / 5.02E+00) * 100 = 0.648%

% U-235 Enrichment is 0.604%.
WAC Enrichment LIMIT is 0.93%.
Percent of Limit is 64.97%.

**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 4,000 pounds. This produces 20,000 pounds of glass a week or 9.07E+06 g/week. This mass is used to calculate weight percent for some of the insoluble species.

<u>Determine the mass of the elementals in Sludge Batch 7b</u>
The volume of the in the sludge slurry is 739,487gallons with a specific gravity of 1.14 kg/L and total solids weight percent of 17.08 % (Ref. 16).

The mass of the sludge slurry
= Volume of sludge slurry * (3.785 L / 1 gal) * SpG
= 7.39E+05 gal * 3.785 L / 1 gal * 1.14 kg/L = 3.19E+06 kg

The mass of the total solids (TS) in the sludge slurry
= Mass of sludge slurry * (wt% TS / 100)
= 3.19E+06 kg * (17.08 / 100) = 5.45E+05 kg

The mass of the elemental
= Mass of TS * wt. % elemental

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

| Sludge Species | Wt% TS Basis | Elemental Mass (kg) | Gravimetric Factor | Mass of Oxide (kg) | Percent of glass |
|---|---|---|---|---|---|
| Al | 8.93E+00 | 4.87E+04 | 1.8895 | 9.20E+04 | 8.829% |
| Ba | 1.00E-01 | 5.45E+02 | 1.1165 | 6.08E+02 | 0.058% |
| Ca | 6.90E-01 | 3.76E+03 | 1.3992 | 5.26E+03 | 0.505% |
| Ce | 1.30E-01 | 7.08E+02 | 1.1713 | 8.30E+02 | 0.080% |
| Cr | 5.00E-02 | 2.72E+02 | 1.4616 | 3.98E+02 | 0.038% |
| Cu | 1.10E-01 | 5.99E+02 | 1.2518 | 7.50E+02 | 0.072% |
| Fe | 1.47E+01 | 8.03E+04 | 1.4297 | 1.15E+05 | 11.019% |
| K | 2.00E-02 | 1.09E+02 | 1.2046 | 1.31E+02 | 0.013% |
| La | 3.00E-02 | 1.63E+02 | 1.1728 | 1.92E+02 | 0.018% |
| Mg | 3.20E-01 | 1.74E+03 | 1.6583 | 2.89E+03 | 0.278% |
| Mn | 3.45E+00 | 1.88E+04 | 1.2912 | 2.43E+04 | 2.331% |
| Na | 1.36E+01 | 7.40E+04 | 1.348 | 9.98E+04 | 9.578% |
| Ni | 2.91E+00 | 1.59E+04 | 1.2726 | 2.02E+04 | 1.938% |
| Pb | 1.00E-02 | 5.45E+01 | 1.0772 | 5.87E+01 | 0.006% |
| Si | 1.17E+00 | 6.38E+03 | 2.1393 | 1.36E+04 | 1.310% |
| Th | 1.23E+00 | 6.70E+03 | 1.1379 | 7.63E+03 | 0.732% |
| Ti | 0.00E+00 | 0.00E+00 | 1.6685 | 0.00E+00 | 0.000% |
| U | 5.02E+00 | 2.74E+04 | 1.1792 | 3.23E+04 | 3.097% |
| Zn | 1.00E-02 | 5.45E+01 | 1.2447 | 6.78E+01 | 0.007% |
| Zr | 1.30E-01 | 7.08E+02 | 1.3508 | 9.57E+02 | 0.092% |
| | | | | | |
| **Total Mass of Oxide Elementals (kg)** | | | | | **4.17E+05** |
| **Total Mass of Glass at 40 Weight Percent Sludge Oxide Loading (kg)** | | | | | **1.04E+06** |

Data from Reference 16.

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

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

4.17+05 / 0.40 = 1.04E+06 kg

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

**The concentration of $TiO_2$**

The sludge $TiO_2$ contribution is 0.000% as seen above in the table.

The ARP/MCU Contribution:
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. 10). The feed concentration of 0.395 g MST/L is adjusted to a design basis at 0.6 g MST/L (Ref. 10).

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 of glass are 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:
0.000% + 0.790% = 0.790%

| | |
|---|---|
| **$TiO_2$** | **0.790%** |
| **DWPF WAC Limit** | **2.000%** |
| **Percent of the Limit** | **39.51%** |

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

**The concentration of $Cr_2O_3$**

The $Cr_2O_3$ sludge contribution is 0.038% as seen above in the table.

The ARP/MCU contribution:
Using a feed rate of 1.68 gpm for each MST strike tank (Ref. 10):

Feed Rate = 2 * 1.68 gpm * 60 min/hr * 24 hr/day * 7 day/wk * 3.785 L/gal
= 1.28E+05 L/wk (or 1.77E+06 gal/yr)

The Salt Batch 5 material has 4.10E+01 mg/L (Ref. 7) or 5.26E+03 g/week.

$Cr_2O_3$ = 5.26E+03 g/week Cr / 52 g/mol Cr / 2 mol $Cr_2O_3$/ mol Cr * (152 g/mol Cr2O3)
= 7.68E+03 g/wk

Percent of $Cr_2O_3$ in glass
= 7.68E+03 g/wk / 9.07E+06 g/wk *100 = 0.085%

Sludge plus ARP/MCU contribution:
0.038% + 0.085% = 0.123%

| | |
|---|---|
| **$Cr_2O_3$** | **0.123%** |
| **DWPF WAC Limit** | **0.300%** |
| **Percent of the Limit** | **40.97%** |

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

| | |
|---|---|
| $Cr_2O_3$ | 0.038% |
| DWPF WAC Limit | 0.300% |
| Percent of the Limit | 12.75% |

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

**The concentration of $PO_4$**

The $PO_4$ sludge contribution:
$PO_4^{2-}$ is measured in the sludge slurry by the phosphorus amount. Phosphorus measured 2.00E-02 wt% (Ref. 16).

The mass of P
= 5.45E+05 kg * (2.00E-02 / 100) = 1.09E+02 kg P

$PO_4^{2-}$ = 1.09E+02 kg P / 30.97 kg/kmol P * 1 kmol $PO_4$/kmol P * 94.97 kg/kmol $PO_4$
= 3.34E+02 kg $PO_4$

Percent of $PO_4^{2-}$ in glass:
= 3.34E+02 kg / 1.04E+06 kg * 100 = 0.0321%

The ARP/MCU contribution:
Using a feed rate of 1.68 gpm for each MST strike tank (Ref. 10):

Feed Rate = 2 * 1.68 gpm * 60 min/hr * 24 hr/day * 7 day/wk * 3.785 L/gal
= 1.28E+05 L/wk (or 1.77E+06 gal/yr)

The Salt Batch 5 material has 5.02E-03 M (Table 1) or 4.77E-01 g/L or 6.11E+04 g/week of phosphate.

Phosphate 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. The phospate will be washed as well; therefore, the majority of the phosphate in the Salt Batch feed will partition to the CSS stream. The partition is 0.001339 (shown in Attachment 3).

The $PO_4$ coming to DWPF
6.11E+04 g/week * 0.001339 = 8.18E+01 g/wk

Percent of $PO_4$ in glass
= 8.18E+01 g/wk / 9.07E+06 g/wk *100 = 0.00090%

Sludge plus ARP/MCU contribution:
0.0321% + 0.00090% = 0.033%

**$PO_4$ 0.033%**
**DWPF WAC Limit 3.000%**
**Percent of the Limit 1.10%**

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

**The concentration of NaF**

The NaF sludge contribution:
The Molarity of $F^-$ (Ref. 16) = 0.0009 M

Determine mass of NaF
= 0.0009 mol/L F * 1 mol/L NaF / 1 mol/L F * 739,487 gal * 3.785 L/gal * 41.98 g/mol NaF / 1000 g/kg
= 1.06E+02 kg NaF

Percent of NaF in glass
= 1.06E+02 kg / 1.04E+06 kg * 100 = 0.0102%

The ARP/MCU contribution:
The $F^-$ in the ARP/MCU feed is 9.08E+00 mg/L (Table 1) or 1.26E+03 g/wk.

Determine rate of NaF
= 1.26E+03 g/wk / 18.99 g/mol * 1 mol/L NaF / 1 mol/L F * 41.98 g/mol NaF
= 2.79E+03 g/wk

Sodium fluoride 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. The sodium fluoride will be washed as well; therefore, the majority of the sodium fluoride in the Salt Batch feed will partition to the CSS stream. The partition is 0.001339 (shown in Attachment 3).

The NaF coming to DWPF
2.79E+03 g/week * 0.001339 = 3.73E+00 g/wk

Percent of NaF in glass
= 3.73E+00 g/wk / 9.07E+06 g/wk *100 = 0.00004%

Sludge plus ARP/MCU contribution:
0.010% + 0.00004% = 0.012%

| | |
|---|---|
| **NaF** | **0.0102%** |
| **DWPF WAC Limit** | **1.000%** |
| **Percent of the Limit** | **1.02%** |

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

**The concentration of NaCl**

The NaCl sludge contribution:
The Molarity of $Cl^-$ (Ref. 16) = 1.30E-03 M

The mass of NaCl
= 1.30E-03 mol/L Cl 1 mol/L NaCl / 1 mol/L Cl * 767,637 gal * 3.785 L/gal * 58.45 NaCl / 1000 g/kg
= 1.06E+02 kg NaCl

Percent of NaCl in glass
= 1.06E+02 kg / 1.04E+06 kg * 100 = 0.020%

The ARP/MCU contribution:
The $Cl^-$ in the ARP/MCU feed is 1.369E-02 M (Table 1) or 4.93E+02 mg/L or 6.32E+04 g/wk.

Determine rate of NaCl
= 6.32E+04 g/wk / 35.453 g/mol * 1 mol/L NaCl / 1 mol/L Cl * 58.44 g/mol NaCl = 1.04E+05 g/wk

Sodium chloride 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. The sodium chloride will be washed as well; therefore, the majority of the sodium chloirde in the Salt Batch feed will partition to the CSS stream. The partition is 0.001339 (shown in Attachment 3).

The NaCl coming to DWPF
1.04E+05 g/week * 0.001339 = 1.39E+02 g/wk

Percent of NaCl in glass
= 1.39E+02 g/wk / 9.07E+06 g/wk *100 = 0.00154%

Sludge plus ARP/MCU contribution:
0.020% + 0.00154% = 0.022%

| | |
|---|---|
| **NaCl** | **0.022%** |
| **DWPF WAC Limit** | **1.000%** |
| **Percent of Limit** | **2.20%** |

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

**The concentration of Cu**

The Cu sludge contribution:
The percent in glass located in the table is in the form of CuO. Therefore the percent of Cu in glass must be determined. Percent of CuO in glass from the table is 0.072%. The percentage of Cu can be determine by dividing by the gravimetric factor for copper.

Percent of Cu in glass
0.072% / 1.2518 = 0.0576%

The ARP/MCU contribution:

The Cu in the ARP/MCU feed is 1.29 mg/L (Ref. 7) or 1.65E+02 g/week.

Percent of Cu in glass
= 1.65E+02 g/wk Cu / 9.07E+06 g/wk *100
= 0.0018%

Sludge plus ARP/MCU contribution:
0.0576% + 0.0018% = 0.059%

| | |
|---|---|
| **Cu** | **0.059%** |
| **DWPF WAC Limit** | **0.500%** |
| **Percent of the Limit** | **11.88%** |

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

**The concentration of $SO_4$**

The $SO_4$ sludge contribution:
$SO_4$ is measured in the sludge slurry by the sulfur amount. Sulfur measured 3.70E-1 wt% (Ref. 16). The same steps that were used for the tables above are applied to sulfate.
The mass of the S in the sludge slurry is 2.02E+03 kg.

$SO_4$ = 2.02E+03 kg S / 32 kg/kmol S * 1 kmol $SO_4$/kmol S * 96 kg/kmol $SO_4$
= 6.05E+03 kg $SO_4$

Percent of $SO_4$ in glass:
= 6.05E+03 kg / 1.04E+06 kg * 100 = 0.5808%

The ARP/MCU contribution:

The $SO_4$ in the ARP/MCU feed is 7.48E-02 M (Table 1) or 7.18E+00 g/L or 9.21E+05 g/week.

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. The sulfate will be washed as well; therefore, the majority of the sulfate in the Salt Batch feed will partition to the CSS stream. The partition is 0.001339 to LPPP (shown in Attachment 3).

The $SO_4$ coming to DWPF
9.21E+05 g/week * 0.001339 = 1.23E+03 g/wk

Percent of $SO_4$ in glass
= 1.23E+03 g/wk / 9.07E+06 g/wk *100 = 0.014%

Sludge plus ARP/MCU contribution:
0. 5808% + 0.014% = 0.5944%

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

**The concentration of $SO_4$ (continued)**

While this qualification effort uses 40 wt% waste loading to determine solubilities of the glass, the DWPF is actually processing at a target of 36 wt% waste loading (Ref. 17). The below calcuations show what the sulfate solubility is estimated at target processing conditions.

To determine the mass of glass, assume a waste loading of 36 percent.

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

4.17+05 / 0.36 = 1.16E+06 kg

As seen above the amount of sulfate in the sludge is 6.05E+03 kg.

Percent of $SO_4$ in glass:

= 6.05E+03 kg / 1.16E+06 kg * 100 = 0.523%

Sludge plus ARP/MCU contribution at 36 wt% WL:

0. 523% + 0.014% = 0.5363%

| | |
|---|---|
| $SO_4$ | 0.536% |
| DWPF WAC Limit | 0.6000% |
| Percent of the Limit | 89.38% |

**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 | 0.790% | 39.51% |
| $Cr_2O_3$ | 0.3 | 0.123% | 40.97% |
| $PO_4$ | 3 | 0.0330% | 1.10% |
| NaF | 1 | 0.010% | 1.02% |
| NaCl | 1 | 0.022% | 2.20% |
| Cu | 0.5 | 0.0594% | 11.88% |
| $SO_4^{-2}$<br>$Na_2SO_4$ | 0.6<br>(0.88) | 0.5944% | 99.06% |

**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. 16):
Weight Percent total solids: 17.08 %
Density of slurry: 1.14
Volume of slurry: 739,487 gallons

**Sulfate Concentration**

Sludge contribution:
Amount in sludge: 6.05E+03 kg $SO_4^{2-}$ (as seen in Attachment 9)

Molarity of Sulfate
= (6.05E+03 kg) * (1000 g/kg) / 96 g/mol / (7.39E+05 gal * 3.785 L/gal)
= 0.0225 M

The total sulfate concentration Sludge Batch 7b is 0.0225 M or 38.79% of DWPF WAC limit.

ARP/MCU contribution: 1.23E+03 g/wk (as seen in Attachment 9)

Using a feed rate of 1.68 gpm for each MST strike tank (Ref. 10):

Feed Rate = 2 * 1.68 gpm * 60 min/hr * 24 hr/day * 7 day/wk * 3.785 L/gal
= 1.28E+05 L/wk (or 3.40E+04 gal/wk)

The volume of Salt Batch 5 is 7.27E+05 gallons.

The time to process Salt Batch 5
= 7.27E+05 gal / 3.40E+04 gal/wk = 21.4 wk

Sulfate in ARP/MCU:
= 1.23E+03 g/wk * 21.4 wk / 1000 g/kg
= 2.64E+01 kg

Molarity of Sulfate
= (6.05E+03 kg + 2.64E+01 kg) * (1000 g/kg) / 96 g/mol /
(739,487 gal * 3.785 L/gal)
= 0.0226 M

The total sulfate concentration (SB7b with Salt Batch 5) is 0.0226 M or 38.96 % of DWPF WAC limit.

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

**Mercury Concentration**

Sludge contribution:

Amount in sludge: 1.56 wt% TS (Ref. 16)

Concentration in slurry
= wt% dry solids / 100 * wt% total solids / 100 * SpG slurry * 1000
= (1.56 / 100) * (17.08 /100) * 1.14 * 1000
= 3.04 g/L

The total mercury concentration (Sludge Batch 7b only) is 3.04 g/L or 14.46 % of DWPF WAC limit.

The Salt Batch 5 contribution is 88.2 mg/L or 0.0882 g/L (Ref. 7).

The total mercury concentration (Sludge Batch 7b with Salt Batch 5) is 3.12 g/L or 14.88 % 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 at DWPF.

See Attachment 9 for methodology to determine the mass of each elemental.

| Species | wt % Total Solids | Elemental Mass (kg) | Gravimetric Factor | Mass of Oxide (kg) |
|---|---|---|---|---|
| Al | 8.93E+00 | 4.87E+04 | 1.8895 | 9.20E+04 |
| B | 0.00E+00 | 0.00E+00 | 3.2199 | 0.00E+00 |
| Ba | 1.00E-01 | 5.45E+02 | 1.1165 | 6.08E+02 |
| Ca | 6.90E-01 | 3.76E+03 | 1.3992 | 5.26E+03 |
| Ce | 1.30E-01 | 7.08E+02 | 1.1713 | 8.30E+02 |
| Cr | 5.00E-02 | 2.72E+02 | 1.4616 | 3.98E+02 |
| Cu | 5.00E-02 | 2.72E+02 | 1.2518 | 3.41E+02 |
| Fe | 1.47E+01 | 8.03E+04 | 1.4297 | 1.15E+05 |
| K | 2.00E-02 | 1.09E+02 | 1.2046 | 1.31E+02 |
| La | 3.00E-02 | 1.63E+02 | 1.1728 | 1.92E+02 |
| Li | 1.00E-02 | 5.45E+01 | 2.15253 | 1.17E+02 |
| Mg | 3.20E-01 | 1.74E+03 | 1.6583 | 2.89E+03 |
| Mn | 3.45E+00 | 1.88E+04 | 1.2912 | 2.43E+04 |
| Na | 1.36E+01 | 7.40E+04 | 1.348 | 9.98E+04 |
| Ni | 2.91E+00 | 1.59E+04 | 1.2726 | 2.02E+04 |
| Pb | 1.00E-02 | 5.45E+01 | 1.0772 | 5.87E+01 |
| Si | 1.17E+00 | 6.38E+03 | 2.1393 | 1.36E+04 |
| Ti | 0.00E+00 | 0.00E+00 | 1.6685 | 0.00E+00 |
| Th | 1.23E+00 | 6.70E+03 | 1.1379 | 7.63E+03 |
| U | 5.02E+00 | 2.74E+04 | 1.1792 | 3.23E+04 |
| Zn | 1.00E-02 | 5.45E+01 | 1.2447 | 6.78E+01 |
| Zr | 1.30E-01 | 7.08E+02 | 1.3508 | 9.57E+02 |
| | | | | |
| **Total Mass of Oxide Elementals (kg)** | | | | **4.16E+05** |
| **Total Mass of Glass at 40 Weight Percent Sludge Oxide Loading (kg)** | | | | **1.04E+06** |

Data from Reference 16.

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

4.16E+05 kg / 0.40 = 1.04E+06 kg

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

Determine the mass of Glass in pounds:

1.04E+06 kg * 1 lb / 0.454 kg = 2.29E+06 lbs

Amount of Time needed to process entire batch:

2.29E+06 lbs / 20,000 lbs/wk = 114.7 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. 10). The feed concentration of 0.395 g MST/L is adjusted to a design basis of 0.6 g MST/L (Ref. 10).

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 * 114.7 wk = 1.81E+04 lbs or 8.23E+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:

4.16E+05 kg elemental oxide in sludge + 8.23E+03 kg $TiO_2$ = 4.25E+05 kg

At 40 weight percent sludge oxide loading, the mass is 1.06E+06 kg. The amount of frit needed is determined by subtracting the amount of elemental oxides by the total mass at 40 weight percent.

1.06E+06 kg – 4.25E+05 kg = 6.37E+05 kg of Frit

The nominal Frit 418 compositions are listed below (Ref. 64). 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 | 5.09E+04 |
| $Li_2O$ | 8 | 5.09E+04 |
| MgO | 0 | 0.00E+00 |
| $Na_2O$ | 8 | 5.09E+04 |
| $SiO_2$ | 76 | 4.84E+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 7b Mass of Oxide (kg) | Mass of Oxide w/ ARP addition (kg) | Mass of Oxide w/ Frit addition (kg) | Mass of Elemental (kg) | Elemental weight % in glass |
|---|---|---|---|---|---|---|
| Al | 1.8895 | 9.20E+04 | 9.196E+04 | 9.20E+04 | 4.87E+04 | 4.59% |
| B | 3.2199 | 0.00E+00 | 0.000E+00 | 5.09E+04 | 1.58E+04 | 1.49% |
| Ba | 1.1165 | 6.08E+02 | 6.085E+02 | 6.08E+02 | 5.45E+02 | 0.05% |
| Ca | 1.3992 | 5.26E+03 | 5.262E+03 | 5.26E+03 | 3.76E+03 | 0.35% |
| Ce | 1.1713 | 8.30E+02 | 8.299E+02 | 8.30E+02 | 7.08E+02 | 0.07% |
| Cr | 1.4616 | 3.98E+02 | 3.983E+02 | 3.98E+02 | 2.72E+02 | 0.03% |
| Cu | 1.2518 | 3.41E+02 | 3.411E+02 | 3.41E+02 | 2.72E+02 | 0.03% |
| Fe | 1.4297 | 1.15E+05 | 1.148E+05 | 1.15E+05 | 8.03E+04 | 7.56% |
| K | 1.2046 | 1.31E+02 | 1.313E+02 | 1.31E+02 | 1.09E+02 | 0.01% |
| La | 1.1728 | 1.92E+02 | 1.917E+02 | 1.92E+02 | 1.63E+02 | 0.02% |
| Li | 2.15253 | 1.17E+02 | 1.173E+02 | 5.11E+04 | 2.37E+04 | 2.24% |
| Mg | 1.6583 | 2.89E+03 | 2.892E+03 | 2.89E+03 | 1.74E+03 | 0.16% |
| Mn | 1.2912 | 2.43E+04 | 2.428E+04 | 2.43E+04 | 1.88E+04 | 1.77% |
| Na | 1.348 | 9.98E+04 | 9.977E+04 | 1.51E+05 | 1.12E+05 | 10.53% |
| Ni | 1.2726 | 2.02E+04 | 2.018E+04 | 2.02E+04 | 1.59E+04 | 1.49% |
| Pb | 1.0772 | 5.87E+01 | 5.871E+01 | 5.87E+01 | 5.45E+01 | 0.01% |
| Si | 2.1393 | 1.36E+04 | 1.364E+04 | 4.98E+05 | 2.33E+05 | 21.92% |
| Ti | 1.6685 | 0.00E+00 | 8.233E+03 | 8.23E+03 | 4.93E+03 | 0.46% |
| Th | 1.1379 | 7.63E+03 | 7.628E+03 | 7.63E+03 | 6.70E+03 | 0.63% |
| U | 1.1792 | 3.23E+04 | 3.226E+04 | 3.23E+04 | 2.74E+04 | 2.58% |
| Zn | 1.2447 | 6.78E+01 | 6.784E+01 | 6.78E+01 | 5.45E+01 | 0.01% |
| Zr | 1.3508 | 9.57E+02 | 9.570E+02 | 9.57E+02 | 7.08E+02 | 0.07% |
| | | | | | | |
| **Total Mass of Oxide Elementals (kg) (sludge)** | | | | | | **4.16E+05** |
| **Total Mass of Oxide Elementals sludge w/ ARP addition (kg)** | | | | | | **4.25E+05** |
| **Total Mass of Oxide Elementals sludge + ARP w/ Frit addition (kg)** | | | | | | **1.06E+06** |

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 40 weight percent, 33 weight percent, and 1.30 specific gravity, respectively, for Sludge Batch 7b. The results of the April 24, 2012, run of PCCS with the elemental weight percents of Sludge Batch 7b coupled processing are listed below:

| | |
|---|---|
| B Leaching: | 0.893 g/L |
| Li Leaching: | 0.901 g/L |
| Na Leaching: | 0.885 g/L |
| Liquidus: | 979.231 ºC |
| Viscosity: | 38.718 poise |
| Homogeneity: | 226.180 wt% oxide |
| $Al_2O_3$: | 8.664 wt% oxide |
| Conserv: | 99.833 wt% oxide |
| Frit: | 70.709 wt% oxide |
| $R_2O$: | 19.023 wt% oxide |
| Nepheline: | 0.672 ratio |

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

The sludge only contribution:

| **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 | 2.47E-03 | 1.54E-02 | 48.36 | 3.81E-05 | 6.28E-09 |
| Y-90 | 1.16E+01 | 5.54E-03 | 48.36 | 6.43E-02 | 1.06E-05 |
| Sr-90 | 1.16E+01 | 1.16E-03 | 48.36 | 1.35E-02 | 2.22E-06 |
| Ru-106 | 4.99E-04 | 5.951E-04 | 48.36 | 2.97E-07 | 4.90E-11 |
| Rh-106 | 4.99E-04 | 1.894E-02 | 48.36 | 9.45E-06 | 1.56E-09 |
| Sb-125 | 1.94E-04 | 3.37E-03 | 49.36 | 6.54E-07 | 1.10E-10 |
| Cs-134 | 1.87E-03 | 1.02E-02 | 48.36 | 1.91E-05 | 3.15E-09 |
| Cs-137 | 4.95E-01 | 1.01E-03 | 48.36 | 5.00E-04 | 8.25E-08 |
| Ba-137m | 4.63E-01 | 3.94E-03 | 48.36 | 1.82E-03 | 3.01E-07 |
| Ce-144 | 9.34E-04 | 6.580E-04 | 48.36 | 6.15E-07 | 1.01E-10 |
| Pr-144 | 9.34E-04 | 7.338E-03 | 48.36 | 6.85E-06 | 1.13E-09 |
| Pm-147 | 1.62E-01 | 3.67E-04 | 48.36 | 5.95E-05 | 9.81E-09 |
| Eu-154 | 1.34E-02 | 9.08E-03 | 48.36 | 1.22E-04 | 2.01E-08 |
| Pu-238 | 1.11E-01 | 3.26E-02 | 134.7 | 3.62E-03 | 1.66E-06 |
| Pu-239 | 8.34E-03 | 3.02E-02 | 134.7 | 2.52E-04 | 1.16E-07 |
| Pu-240 | 2.95E-03 | 3.06E-02 | 134.7 | 9.02E-05 | 4.14E-08 |
| Am-241 | 3.33E-02 | 3.28E-02 | 134.7 | 1.09E-03 | 5.03E-07 |
| Cm-244 | 1.66E-02 | 3.44E-02 | 134.7 | 5.71E-04 | 2.62E-07 |
| | | | | | |
| **Total ($ft^3$ $H_2$/hr/gal)** | | | | | **1.58E-05** |
| **DWPF WAC limit ($ft^3$ $H_2$/hr/gal)** | | | | | **8.95E-05** |
| **% of WAC limit** | | | | | **17.70 %** |

Data from Reference 16.
R values are defined in the DWPF WAC (Ref. 2).
Heat Generation Factor values are defined in Reference 61.

To determine the total hydrogen generation rate for DWPF coupled operations:

DWPF operates in batches to produce nominally 186 canisters a year (it is conservative to use this value with production rate expected to increase to 293 canisters per year for Sludge Batch 7b). Nominally 5 canisters are produced in each 6,000 gallon batch. Therefore, DWPF processes 223,200 gallons a year. ARP/MCU contribution is additive to the sludge contribution. The ARP/MCU contribution is determined by finding the amount of time to process the salt batch compared to the gallons of sludge DWPF processes in a year. From Reference 10, salt is fed to the MST strike tanks at 1.29E+05 L/wk (or 3.40E+04 gal/wk).

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

Determine the time to process Salt Batch 5:
Volume of Salt Batch 5 is 7.27E+05 gallons. This is based on the amount in the qualification tank, Tank 21.

Time
= 7.27E+05 gallons / 3.40E+04 gallons/week / 52 weeks/year
= 4.11E-01 yr

Amount for Sludge Batch 7b
223,200 gallon / yr * 4.11E-01 yr = 9.18E+04 gallons

The Hydrogen Generation rate can be determined for coupled operations using the same method as sludge only. Following the addition of the all the radionuclies to determine the hydrogen generation ($ft^3/hr$), divide the total by the amount of Salt Batch 5 for Sludge Batch 7b.

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

| Radionuclide | Results (pCi/mL) | Results (pCi/ batch) | "Q" Value (W/Ci) | R ($ft^3$ $H_2$/ $10^6$ BTU) | Heat Generation (W/gal) | Hydrogen Generation ($ft^3$ $H_2$/hr ) |
|---|---|---|---|---|---|---|
| Co-60 | 5.63E+00 | 1.55E-02 | 1.54E-02 | 48.36 | 2.38E-04 | 3.93E-08 |
| Y-90 | 2.58E+05 | 7.09E+02 | 5.54E-03 | 48.36 | 3.93E+00 | 6.49E-04 |
| Sr-90 | 2.58E+05 | 7.09E+02 | 1.16E-03 | 48.36 | 8.23E-01 | 1.36E-04 |
| Ru-106 | 8.19E+01 | 2.25E-01 | 5.95E-04 | 48.36 | 1.34E-04 | 2.21E-08 |
| Rh-106 | 8.19E+01 | 2.25E-01 | 1.89E-02 | 48.36 | 4.26E-03 | 7.03E-07 |
| Sb-125 | 5.99E+01 | 1.65E-01 | 3.37E-03 | 48.36 | 5.55E-04 | 9.16E-08 |
| Cs-134 | 5.54E+03 | 1.52E+01 | 1.02E-02 | 48.36 | 1.55E-01 | 2.56E-05 |
| Cs-137 | 5.90E+07 | 1.62E+05 | 1.01E-03 | 48.36 | 1.64E+02 | 2.70E-02 |
| Ba-137m | 5.59E+07 | 1.54E+05 | 3.94E-03 | 48.36 | 6.06E+02 | 1.00E-01 |
| Ce-144 | 7.70E+01 | 2.12E-01 | 6.58E-04 | 48.36 | 1.39E-04 | 2.30E-08 |
| Pr-144 | 7.70E+01 | 2.12E-01 | 7.34E-03 | 48.36 | 1.55E-03 | 2.57E-07 |
| Pm-147 | 1.80E+02 | 4.95E-01 | 3.67E-04 | 48.36 | 1.82E-04 | 3.00E-08 |
| Eu-154 | 1.53E+01 | 4.21E-02 | 9.08E-03 | 48.36 | 3.82E-04 | 6.31E-08 |
| Pu-238 | 1.46E+04 | 4.01E+01 | 3.26E-02 | 134.7 | 1.31E+00 | 6.02E-04 |
| Pu-239 | 1.49E+03 | 4.10E+00 | 3.02E-02 | 134.7 | 1.24E-01 | 5.69E-05 |
| Pu-240 | 1.49E+03 | 4.10E+00 | 3.06E-02 | 134.7 | 1.25E-01 | 5.76E-05 |
| Am-241 | 7.60E+00 | 2.09E-02 | 3.28E-02 | 134.7 | 6.85E-04 | 3.15E-07 |
| Cm-244 | 1.05E+01 | 2.89E-02 | 3.44E-02 | 134.7 | 9.93E-04 | 4.57E-07 |
| **Total ($ft^3$ $H_2$/hr)** | | | | | | **1.29E-01** |
| | | | | | | |
| **Total ($ft^3$ $H_2$/hr/gal )** | | | | | | **1.40E-06** |
| **DWPF WAC limit ($ft^3$ $H_2$/hr/gal)** | | | | | | **8.95E-05** |
| **% of WAC limit** | | | | | | **1.56%** |

Data from Reference 7.
Q values are defined in Reference 61.

| | |
|---|---|
| **DWPF** | **1.58E-05 $ft^3$ $H_2$/hr/gal** |
| **ARP/MCU** | **1.40E-06 $ft^3$ $H_2$/hr/gal** |
| **Total** | **1.72E-05 $ft^3$ $H_2$/hr/gal** |
| **WAC LIMIT** | **8.95E-05 $ft^3$ $H_2$/hr/gal** |
| **Percent of Limit** | **19.26%** |

**Attachment 13-A: Hydrogen Generation Rate from Salt Batch 5 Material for Tank 50** (Tank Farm WAC 11.2.2)

The hydrogen generation rate shall be calculated using the following formulas (Ref. 40):

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.

$NO_{eff}$ = 2.78 M + 0.5 (0.551 M) = 3.06 M

$R\alpha = 134.7 - 82.3 * [3.06M]^{1/3} - 13.6 * [3.06M]^{2/3} + 11.8 * [3.06M]$ = 2.27E+01

$R_{\beta/\gamma} = 48.36 - 52.78 * [3.06M]^{1/3} + 14.1 * [3.06M]^{2/3} + 0.572 * [3.06M]$ = 3.21E+00

Q values are the Heat Generation factors and are defined in Reference 61.

Radionuclide concentrations in the following tables are from Table 1. Cesium isotopes and Ba-137m have a DF of 12 applied to the feed value.

See Table below:

| | |
|---|---|
| **Hydrogen Generation** | **1.37E-09 $ft^3$ $H_2$/hour/gallon @ 43ºC** |
| **Tank 50 WAC Limit** | **2.90E-08 $ft^3$ $H_2$/hour/gallon @ 43ºC** |
| **Percent of Limit** | **4.72%** |

**Attachment 13-A: Hydrogen Generation Rate from Salt Batch 5 Material for Tank 50** (Tank Farm WAC 11.2.2)

| **Radionuclide** | **Results (pCi/ml)** | **Results (Ci/gal)** | **"Q" Value (W/Ci)** | **$R_\alpha$ (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 | 9.46E+02 | 3.58E-06 | 3.37E-05 | | 3.21E+00 | 1.21E-10 | 1.32E-15 |
| C-14 | 7.20E+02 | 2.73E-06 | 2.93E-04 | | 3.21E+00 | 7.98E-10 | 8.75E-15 |
| Co-60 | 5.63E+00 | 2.13E-08 | 1.54E-02 | | 3.21E+00 | 3.28E-10 | 3.60E-15 |
| Ni-63 | 4.06E+02 | 1.54E-06 | 1.01E-04 | | 3.21E+00 | 1.55E-10 | 1.70E-15 |
| Sr-90 | 1.93E+05 | 7.31E-04 | 1.16E-03 | | 3.21E+00 | 8.47E-07 | 9.28E-12 |
| Y-90 | 1.93E+05 | 7.31E-04 | 5.54E-03 | | 3.21E+00 | 4.05E-06 | 4.43E-11 |
| Tc-99 | 2.28E+04 | 8.63E-05 | 5.01E-04 | | 3.21E+00 | 4.32E-08 | 4.74E-13 |
| Sb-125 | 5.99E+01 | 2.27E-07 | 3.37E-03 | | 3.21E+00 | 7.64E-10 | 8.37E-15 |
| Sn-126 | 1.93E+02 | 7.31E-07 | 1.08E-03 | | 3.21E+00 | 7.89E-10 | 8.64E-15 |
| I-129 | 1.30E+01 | 4.92E-08 | 4.77E-04 | | 3.21E+00 | 2.35E-11 | 2.57E-16 |
| Cs-134 | 4.62E+02 | 1.75E-06 | 1.02E-02 | | 3.21E+00 | 1.78E-08 | 1.95E-13 |
| Cs-135 | 2.34E+01 | 1.23E-06 | 3.32E-04 | | 3.21E+00 | 4.09E-10 | 4.48E-15 |
| Cs-137 | 4.92E+06 | 1.86E-02 | 1.01E-03 | | 3.21E+00 | 1.88E-05 | 2.06E-10 |
| Ba-137m | 4.66E+06 | 1.76E-02 | 3.94E-03 | | 3.21E+00 | 6.95E-05 | 7.61E-10 |
| Pm-147 | 1.80E+02 | 6.81E-07 | 3.67E-04 | | 3.21E+00 | 2.50E-10 | 2.74E-15 |
| Eu-154 | 1.53E+01 | 5.79E-08 | 9.08E-03 | | 3.21E+00 | 5.26E-10 | 5.76E-15 |
| U-233 | 9.68E+01 | 3.66E-07 | 2.86E-02 | 2.27E+01 | | 1.05E-08 | 8.11E-13 |
| U-234 | 9.00E+01 | 3.41E-07 | 2.83E-02 | 2.27E+01 | | 9.64E-09 | 7.46E-13 |
| U-236 | 1.08E+00 | 4.09E-09 | 2.66E-02 | 2.27E+01 | | 1.09E-10 | 8.43E-15 |
| U-238 | 3.70E+00 | 1.40E-08 | 2.49E-02 | 2.27E+01 | | 3.49E-10 | 2.70E-14 |
| Np-237 | 3.39E+00 | 1.28E-08 | 2.88E-02 | 2.27E+01 | | 3.69E-10 | 2.86E-14 |
| Pu-238 | 1.49E+04 | 5.64E-05 | 3.26E-02 | 2.27E+01 | | 1.84E-06 | 1.42E-10 |
| Pu-239/240 | 1.49E+03 | 5.64E-06 | 3.02E-02 | 2.27E+01 | | 1.71E-07 | 1.32E-11 |
| Pu-241 | 5.22E+03 | 1.98E-05 | 3.20E-05 | | 3.21E+00 | 6.32E-10 | 6.92E-15 |
| Pu-242 | 3.82E+01 | 1.45E-07 | 2.90E-02 | 2.27E+01 | | 4.20E-09 | 3.25E-13 |
| Am-241 | 7.60E+00 | 2.88E-08 | 3.28E-02 | 2.27E+01 | | 9.44E-10 | 7.31E-14 |
| Cm-244 | 1.05E+01 | 3.97E-08 | 3.44E-02 | 2.27E+01 | | 1.37E-09 | 1.06E-13 |
| Ra-226 | 3.12E+02 | 1.18E-06 | 2.84E-02 | 2.27E+01 | | 3.35E-08 | 2.59E-12 |
| Eu-155 | 3.62E+01 | 1.37E-07 | 7.59E-04 | | 3.21E+00 | 1.04E-10 | 1.14E-15 |
| Pu-244 | 1.77E-01 | 6.70E-10 | 2.71E-02 | 2.27E+01 | | 1.82E-11 | 1.41E-15 |
| Ru-106 | 8.19E+01 | 3.10E-07 | 5.95E-04 | | 3.21E+00 | 1.84E-10 | 2.02E-15 |
| Am-243 | 3.98E+00 | 1.51E-08 | 3.15E-02 | 2.27E+01 | | 4.74E-10 | 3.67E-14 |
| | | | | | **Total** | **at 0°C** | **1.18E-09** |
| | | | | | | **at 43°C** | **1.37E-09** |
| | | | | | | **at 25°C** | **1.29E-09** |

Data from Reference 7.

**Attachment 13-B: Hydrogen Generation Rate from Diluted Salt Batch 5 Feed Material for Tank 50** (Tank Farm WAC 11.2.2)

With the 28.5% dilution rate expected with the ARP/MCU process, the following apply:

$NO_{eff}$ = 1.99 M + 0.5 (0.394 M) = 2.18 M
Rα = 3.08E+01
$R_{\beta/\gamma}$ = 4.77E+00

| | |
|---|---|
| **Hydrogen Generation** | **2.00E-09 $ft^3$ $H_2$/hour/gallon @ 43ºC** |
| **Tank 50 WAC Limit** | **2.90E-08 $ft^3$ $H_2$/hour/gallon @ 43ºC** |
| **Percent of Limit** | **6.91%** |

With the 32.5% dilution rate expected as the bounding condition for the ARP/MCU process, the following apply:

$NO_{eff}$ = 1.88 M + 0.5 (0.372 M) = 2.06 M
Rα = 3.22E+01
$R_{\beta/\gamma}$ = 5.11E+00

| | |
|---|---|
| **Hydrogen Generation** | **2.14E-09 $ft^3$ $H_2$/hour/gallon @ 43ºC** |
| **Tank 50 WAC Limit** | **2.90E-08 $ft^3$ $H_2$/hour/gallon @ 43ºC** |
| **Percent of Limit** | **7.39%** |

In the following tables:
Data from Reference 7. Cesium isotopes and Ba-137m have a DF of 12 applied to the feed value.

Q values are the Heat Generation factors and are defined in Reference 61.

## Attachment 13-B (continued): Hydrogen Generation Rate for Tank 50 (28.5% Dilution)

| Radionuclide | Results (pCi/ml) | Results (Ci/gal) | "Q" Value (W/Ci) | $R_{\alpha}$ ($ft^3$ $H_2/10^6$ 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 | 9.46E+02 | 3.58E-06 | 3.37E-05 | | 4.77E+00 | 1.21E-10 | 1.96E-15 |
| C-14 | 7.20E+02 | 2.73E-06 | 2.93E-04 | | 4.77E+00 | 7.98E-10 | 1.30E-14 |
| Co-60 | 5.63E+00 | 2.13E-08 | 1.54E-02 | | 4.77E+00 | 3.28E-10 | 5.34E-15 |
| Ni-63 | 4.06E+02 | 1.54E-06 | 1.01E-04 | | 4.77E+00 | 1.55E-10 | 2.52E-15 |
| Sr-90 | 1.93E+05 | 7.31E-04 | 1.16E-03 | | 4.77E+00 | 8.47E-07 | 1.38E-11 |
| Y-90 | 1.93E+05 | 7.31E-04 | 5.54E-03 | | 4.77E+00 | 4.05E-06 | 6.58E-11 |
| Tc-99 | 2.28E+04 | 8.63E-05 | 5.01E-04 | | 4.77E+00 | 4.32E-08 | 7.03E-13 |
| Sb-125 | 5.99E+01 | 2.27E-07 | 3.37E-03 | | 4.77E+00 | 7.64E-10 | 1.24E-14 |
| Sn-126 | 1.93E+02 | 7.31E-07 | 1.08E-03 | | 4.77E+00 | 7.89E-10 | 1.28E-14 |
| I-129 | 1.30E+01 | 4.92E-08 | 4.77E-04 | | 4.77E+00 | 2.35E-11 | 3.82E-16 |
| Cs-134 | 4.62E+02 | 1.75E-06 | 1.02E-02 | | 4.77E+00 | 1.78E-08 | 2.90E-13 |
| Cs-135 | 2.34E+01 | 1.23E-06 | 3.32E-04 | | 4.77E+00 | 4.09E-10 | 6.65E-15 |
| Cs-137 | 4.92E+06 | 1.86E-02 | 1.01E-03 | | 4.77E+00 | 1.88E-05 | 3.06E-10 |
| Ba-137m | 4.66E+06 | 1.76E-02 | 3.94E-03 | | 4.77E+00 | 6.95E-05 | 1.13E-09 |
| Pm-147 | 1.80E+02 | 6.81E-07 | 3.67E-04 | | 4.77E+00 | 2.50E-10 | 4.07E-15 |
| Eu-154 | 1.53E+01 | 5.79E-08 | 9.08E-03 | | 4.77E+00 | 5.26E-10 | 8.55E-15 |
| U-233 | 9.68E+01 | 3.66E-07 | 2.86E-02 | 3.08E+01 | | 1.05E-08 | 1.10E-12 |
| U-234 | 9.00E+01 | 3.41E-07 | 2.83E-02 | 3.08E+01 | | 9.64E-09 | 1.01E-12 |
| U-236 | 1.08E+00 | 4.09E-09 | 2.66E-02 | 3.08E+01 | | 1.09E-10 | 1.14E-14 |
| U-238 | 3.70E+00 | 1.40E-08 | 2.49E-02 | 3.08E+01 | | 3.49E-10 | 3.67E-14 |
| Np-237 | 3.39E+00 | 1.28E-08 | 2.88E-02 | 3.08E+01 | | 3.69E-10 | 3.88E-14 |
| Pu-238 | 1.49E+04 | 5.64E-05 | 3.26E-02 | 3.08E+01 | | 1.84E-06 | 1.93E-10 |
| Pu-239/240 | 1.49E+03 | 5.64E-06 | 3.02E-02 | 3.08E+01 | | 1.71E-07 | 1.79E-11 |
| Pu-241 | 5.22E+03 | 1.98E-05 | 3.20E-05 | | 4.77E+00 | 6.32E-10 | 1.03E-14 |
| Pu-242 | 3.82E+01 | 1.45E-07 | 2.90E-02 | 3.08E+01 | | 4.20E-09 | 4.41E-13 |
| Am-241 | 7.60E+00 | 2.88E-08 | 3.28E-02 | 3.08E+01 | | 9.44E-10 | 9.92E-14 |
| Cm-244 | 1.05E+01 | 3.97E-08 | 3.44E-02 | 3.08E+01 | | 1.37E-09 | 1.44E-13 |
| Ra-226 | 3.12E+02 | 1.18E-06 | 2.84E-02 | | 4.77E+00 | 3.35E-08 | 5.45E-13 |
| Eu-155 | 3.62E+01 | 1.37E-07 | 7.59E-04 | | 4.77E+00 | 1.04E-10 | 1.69E-15 |
| Pu-244 | 1.77E-01 | 6.70E-10 | 2.71E-02 | 3.08E+01 | | 1.82E-11 | 1.91E-15 |
| Ru-106 | 8.19E+01 | 3.10E-07 | 5.95E-04 | 3.08E+01 | | 1.84E-10 | 1.94E-14 |
| Am-243 | 3.98E+00 | 1.51E-08 | 3.15E-02 | 3.08E+01 | | 4.74E-10 | 4.99E-14 |
| | | | | | **Total** | **at 0°C** | **1.73E-09** |
| | | | | | | **at 43°C** | **2.00E-09** |
| | | | | | | **at 25°C** | **1.89E-09** |

Data from Reference 7.

## Attachment 13-B (continued): Hydrogen Generation Rate for Tank 50 (32.5% Dilution)

| Radionuclide | Results (pCi/ml) | Results (Ci/gal) | "Q" Value (W/Ci) | $R_\alpha$ (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 | 9.46E+02 | 3.58E-06 | 3.37E-05 | | 5.11E+00 | 1.21E-10 | 2.10E-15 |
| C-14 | 7.20E+02 | 2.73E-06 | 2.93E-04 | | 5.11E+00 | 7.98E-10 | 1.39E-14 |
| Co-60 | 5.63E+00 | 2.13E-08 | 1.54E-02 | | 5.11E+00 | 3.28E-10 | 5.73E-15 |
| Ni-63 | 4.06E+02 | 1.54E-06 | 1.01E-04 | | 5.11E+00 | 1.55E-10 | 2.71E-15 |
| Sr-90 | 1.93E+05 | 7.31E-04 | 1.16E-03 | | 5.11E+00 | 8.47E-07 | 1.48E-11 |
| Y-90 | 1.93E+05 | 7.31E-04 | 5.54E-03 | | 5.11E+00 | 4.05E-06 | 7.06E-11 |
| Tc-99 | 2.28E+04 | 8.63E-05 | 5.01E-04 | | 5.11E+00 | 4.32E-08 | 7.54E-13 |
| Sb-125 | 5.99E+01 | 2.27E-07 | 3.37E-03 | | 5.11E+00 | 7.64E-10 | 1.33E-14 |
| Sn-126 | 1.93E+02 | 7.31E-07 | 1.08E-03 | | 5.11E+00 | 7.89E-10 | 1.38E-14 |
| I-129 | 1.30E+01 | 4.92E-08 | 4.77E-04 | | 5.11E+00 | 2.35E-11 | 4.09E-16 |
| Cs-134 | 4.62E+02 | 1.75E-06 | 1.02E-02 | | 5.11E+00 | 1.78E-08 | 3.10E-13 |
| Cs-135 | 2.34E+01 | 1.23E-06 | 3.32E-04 | | 5.11E+00 | 4.09E-10 | 7.13E-15 |
| Cs-137 | 4.92E+06 | 1.86E-02 | 1.01E-03 | | 5.11E+00 | 1.88E-05 | 3.28E-10 |
| Ba-137m | 4.66E+06 | 1.76E-02 | 3.94E-03 | | 5.11E+00 | 6.95E-05 | 1.21E-09 |
| Pm-147 | 1.80E+02 | 6.81E-07 | 3.67E-04 | | 5.11E+00 | 2.50E-10 | 4.36E-15 |
| Eu-154 | 1.53E+01 | 5.79E-08 | 9.08E-03 | | 5.11E+00 | 5.26E-10 | 9.17E-15 |
| U-233 | 9.68E+01 | 3.66E-07 | 2.86E-02 | 3.22E+01 | | 1.05E-08 | 1.15E-12 |
| U-234 | 9.00E+01 | 3.41E-07 | 2.83E-02 | 3.22E+01 | | 9.64E-09 | 1.06E-12 |
| U-236 | 1.08E+00 | 4.09E-09 | 2.66E-02 | 3.22E+01 | | 1.09E-10 | 1.20E-14 |
| U-238 | 3.70E+00 | 1.40E-08 | 2.49E-02 | 3.22E+01 | | 3.49E-10 | 3.84E-14 |
| Np-237 | 3.39E+00 | 1.28E-08 | 2.88E-02 | 3.22E+01 | | 3.69E-10 | 4.06E-14 |
| Pu-238 | 1.49E+04 | 5.64E-05 | 3.26E-02 | 3.22E+01 | | 1.84E-06 | 2.02E-10 |
| Pu-239/40 | 1.49E+03 | 5.64E-06 | 3.02E-02 | 3.22E+01 | | 1.71E-07 | 1.88E-11 |
| Pu-241 | 5.22E+03 | 1.98E-05 | 3.20E-05 | | 5.11E+00 | 6.32E-10 | 1.10E-14 |
| Pu-242 | 3.82E+01 | 1.45E-07 | 2.90E-02 | 3.22E+01 | | 4.20E-09 | 4.62E-13 |
| Am-241 | 7.60E+00 | 2.88E-08 | 3.28E-02 | 3.22E+01 | | 9.44E-10 | 1.04E-13 |
| Cm-244 | 1.05E+01 | 3.97E-08 | 3.44E-02 | 3.22E+01 | | 1.37E-09 | 1.50E-13 |
| Ra-226 | 3.12E+02 | 1.18E-06 | 2.84E-02 | | 5.11E+00 | 3.35E-08 | 5.84E-13 |
| Eu-155 | 3.62E+01 | 1.37E-07 | 7.59E-04 | | 5.11E+00 | 1.04E-10 | 1.81E-15 |
| Pu-244 | 1.77E-01 | 6.70E-10 | 2.71E-02 | 3.22E+01 | | 1.82E-11 | 2.00E-15 |
| Ru-106 | 8.19E+01 | 3.10E-07 | 5.95E-04 | 3.22E+01 | | 1.84E-10 | 2.03E-14 |
| Am-243 | 3.98E+00 | 1.51E-08 | 3.15E-02 | 3.22E+01 | | 4.74E-10 | 5.22E-14 |
| | | | | | **Total** | **at 25°C** | **2.02E-09** |
| | | | | | | **at 0°C** | **1.85E-09** |
| | | | | | | **at 43°C** | **2.14E-09** |

Data from Reference 7.

## Attachment 14: Hazard Categorization Evaluation Salt Batch 5 Feed Qualification

Using the selection of isotopes for Hazard Category determination as defined in References 34 and 42, the Hazard Category for Salt Batch 5 was determined. Total gamma, cesium-removed total alpha, and cesium-removed total beta results were not used in this calculation. Since 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 5. 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 14-1). 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 14-1. 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 14-2, the threshold values are listed for the specific radioisotope. Since Hazard Category 2 threshold values are not available for Cs-135, I-129, and Sb-125, the Hazard Category 3 threshold values (Ref. 66) were applied. The Hazard Category 3 threshold values are more conservative than those for Hazard Category 2. 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. 66). 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. 66). Actinide removal in 241-96H/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 5 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. 66).

The results are presented in Table 14-2. The sum of the ratios is 0.266. This correlates with the expected outcome demonstrated in Reference 67. 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 67, 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 5 Feed Qualification**

**Table 14-1 – Radioisotopic Results**

| **Radionuclides** | **pCi/mL** | **Ci/gal** |
|---|---|---|
| | | |
| **Alpha** | | |
| Pu-238 | 1.49E+04 | 5.64E-05 |
| Pu-239/240 | 1.49E+03 | 5.64E-06 |
| Pu-242 | 3.82E+01 | 1.45E-07 |
| **Sum Pu** | | 6.22E-05 |
| Other α | | 1.55E-05 |
| | | |
| **Gamma** | | |
| Cs-134 | 5.54E+03 | 2.10E-05 |
| Cs-135 | 2.81E+02 | 1.06E-06 |
| Cs-137 | 5.90E+07 | 2.23E-01 |
| Eu-155 | 3.62E+01 | 1.37E-07 |
| Co-60 | 5.63E+00 | 2.13E-08 |
| Eu-154 | 1.53E+01 | 5.79E-08 |
| Sb-125 | 5.99E+01 | 2.27E-07 |
| I-129 | 1.30E+01 | 4.92E-08 |
| **Sum known γ's** | | 2.23E-01 |
| Other γ | | 5.58E-02 |
| | | |
| **Beta** | | |
| Sr-90/Y-90 | 3.86E+05 | 1.46E-03 |
| Pu-241 | 5.22E+03 | 1.98E-05 |
| Tc-99 | 2.28E+04 | 8.63E-05 |
| **Sum known β's** | | 1.57E-03 |
| **Other β** | | 3.92E-04 |

Data from Reference 7.

**Attachment 14 (continued): Hazard Categorization Evaluation Salt Batch 5 Feed Qualification**

**Table 14-2 – Hazard Category Determination for Tank 49**

| Radionuclide | Ci/gal | Vol. overflow (gal) | DSS Ci/gal | DSS vol. (gal) | Strip (Ci/gal) | Strip vol. (gal) | Total Ci | HC2 Threshold (Ci) | Fraction |
|---|---|---|---|---|---|---|---|---|---|
| Cs-134 | 2.10E-05 | 2.45E+04 | 1.75E-06 | 8.23E+03 | 3.15E-04 | 1.33E+03 | 9.45E-01 | 6.00E+04 | 1.58E-05 |
| Cs-135 | 1.06E-06 | 2.45E+04 | 8.86E-08 | 8.23E+03 | 1.60E-05 | 1.33E+03 | 4.79E-02 | 4.20E+02* | 7.55E-08 |
| Cs-137 | 2.23E-01 | 2.45E+04 | 1.86E-02 | 8.23E+03 | 3.35E+00 | 1.33E+03 | 1.01E+04 | 8.90E+04 | 1.13E-01 |
| Pu-238 | 5.64E-05 | 2.45E+04 | 5.64E-05 | 8.23E+03 | 5.64E-05 | 1.33E+03 | 1.92E+00 | 6.20E+01 | 3.10E-02 |
| Pu-239/240 | 5.64E-06 | 2.45E+04 | 5.64E-06 | 8.23E+03 | 5.64E-06 | 1.33E+03 | 1.92E-01 | 5.60E+01 | 3.43E-03 |
| Pu-242 | 1.45E-07 | 2.45E+04 | 1.45E-07 | 8.23E+03 | 1.45E-07 | 1.33E+03 | 4.92E-03 | 5.95E+01 | 8.27E-05 |
| Other α | 1.55E-05 | 2.45E+04 | 1.55E-05 | 8.23E+03 | 1.55E-05 | 1.33E+03 | 5.29E-01 | 1.80E+01 | 2.94E-02 |
| Eu-155 | 1.37E-07 | 2.45E+04 | 1.37E-07 | 8.23E+03 | 1.37E-07 | 1.33E+03 | 4.66E-03 | 7.30E+05 | 6.39E-09 |
| Co-60 | 2.13E-08 | 2.45E+04 | 2.13E-08 | 8.23E+03 | 2.13E-08 | 1.33E+03 | 7.25E-04 | 1.90E+05 | 3.82E-09 |
| Eu-154 | 5.79E-08 | 2.45E+04 | 5.79E-08 | 8.23E+03 | 5.79E-08 | 1.33E+03 | 1.97E-03 | 1.10E+05 | 1.79E-08 |
| Sb-125 | 2.27E-07 | 2.45E+04 | 2.27E-07 | 8.23E+03 | 2.27E-07 | 1.33E+03 | 7.72E-03 | 1.20E+03* | 1.79E-08 |
| I-129 | 4.92E-08 | 2.45E+04 | 4.92E-08 | 8.23E+03 | 4.92E-08 | 1.33E+03 | 1.67E-03 | 6.00E-02* | 5.28E-06 |
| Other γ | 5.58E-02 | 2.45E+04 | 5.58E-02 | 8.23E+03 | 5.58E-02 | 1.33E+03 | 1.90E+03 | 2.20E+04 | 8.64E-02 |
| Sr-90/Y-90 | 1.46E-03 | 2.45E+04 | 1.46E-03 | 8.23E+03 | 1.46E-03 | 1.33E+03 | 4.97E+01 | 2.20E+04 | 2.26E-03 |
| Pu-241 | 1.98E-05 | 2.45E+04 | 1.98E-05 | 8.23E+03 | 1.98E-05 | 1.33E+03 | 6.72E-01 | 2.90E+03 | 2.32E-04 |
| Tc-99 | 8.63E-05 | 2.45E+04 | 8.63E-05 | 8.23E+03 | 8.63E-05 | 1.33E+03 | 2.94E+00 | 3.80E+06 | 7.73E-07 |
| Other β | 3.92E-04 | 2.45E+04 | 3.92E-04 | 8.23E+03 | 3.92E-04 | 1.33E+03 | 1.33E+01 | 2.20E+04 | 6.06E-04 |
| | | | | | | | | **SUM** | **2.66E-01** |

Data from Reference 7. * Hazard Category 3 threshold applied.

**Attachment 15: IDP to Meet MCU, Tank 50, and Saltstone WAC** (Tank Farm WAC 11.4 and Saltstone WAC 5.4.1)

**IDP Based on Salt Batch 5 Feed Material**

| Radionuclide | Concentration (pCi/mL) | Concentration (Ci/gal) | Dose Potential CEDE DCF (rem/Ci) | IDP (rem/gal) |
|---|---|---|---|---|
| Sr-90 | 2.58E+05 | 9.77E-04 | 9.50E+04 | 9.28E+01 |
| Cs-137 | 5.90E+07 | 2.23E-01 | 1.90E+04 | 4.24E+03 |
| Eu-154 | 1.53E+01 | 5.79E-08 | 2.00E+05 | 1.16E-02 |
| Pu-241 | 5.22E+03 | 1.98E-05 | 3.30E+06 | 6.52E+01 |
| Total alpha | 7.47E+03 | 2.83E-05 | 1.90E+08 | 5.37E+03 |
| **Total Dose (rem/gal)** | | | | **9.77E+03** |
| | | | | |
| **MCU WAC limit (rem/gal)** | | | | **1.69E+05** |
| **% of WAC limit** | | | | **5.78%** |
| | | | | |
| **Tank 50 WAC limit (rem/gal)** | | | | **2.09E+05** |
| **% of WAC limit** | | | | **4.68%** |
| | | | | |
| **Saltstone WAC limit (rem/gal)** | | | | **2.09E+05** |
| **% of WAC limit** | | | | **4.68%** |

Data from Reference 7.
The Dose Potential is defined in Reference 3.

**Attachment 16-A: Hydrogen Generation Rate from Salt Batch 5 Feed Material for Saltstone** (Saltstone WAC 5.4.4)

The hydrogen generation rate shall be calculated using the following formulas (Ref. 3):

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.

$NO^{-}_{eff}$= 2.78 M + 0.25 (0.551 M) = 2.92 M

$R_{\alpha} = 134.7 - 82.3 * [2.92M]^{1/3} - 13.6 * [2.92M]^{2/3} + 11.8 * [2.92M]$ = 2.38E+01

$R_{\beta/\gamma} = 48.36 - 52.78 * [2.92M]^{1/3} + 14.1 * [2.92M]^{2/3} + 0.572 * [2.92M]$ = 3.40E+00

See Table below:

| | |
|---|---|
| **Hydrogen Generation** | **1.73E-09 $ft^3$ $H_2$/hour/gallon @ 95ºC** |
| **Saltstone WAC Limit** | **5.59E-08 $ft^3$ $H_2$/hour/gallon @ 95ºC** |
| **Percent of Limit** | **3.09%** |

Q values are the Heat Generation factors and are defined in Reference 61.

In the following tables:
Data from Reference 7. Cesium isotopes and Ba-137m have a DF of 12 applied to the feed value.

**Attachment 16-A (continued): Hydrogen Generation Rate from Salt Batch 5 Feed Material for Saltstone** (Saltstone WAC 5.4.4)

| Radionuclide | Results (pCi/ml) | Results (Ci/gal) | "Q" Value (W/Ci) | $R_{\alpha}$ (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 | 9.46E+02 | 3.58E-06 | 3.37E-05 | | 3.40E+00 | 1.21E-10 | 1.40E-15 |
| C-14 | 7.20E+02 | 2.73E-06 | 2.93E-04 | | 3.40E+00 | 7.98E-10 | 9.26E-15 |
| Co-60 | 5.63E+00 | 2.13E-08 | 1.54E-02 | | 3.40E+00 | 3.28E-10 | 3.81E-15 |
| Ni-59 | 2.00E+01 | 7.57E-08 | 3.98E-05 | | 3.40E+00 | 3.01E-12 | 3.50E-17 |
| Ni-63 | 4.06E+02 | 1.54E-06 | 1.01E-04 | | 3.40E+00 | 1.55E-10 | 1.80E-15 |
| Se-79 | | 0.00E+00 | 3.13E-04 | | 3.40E+00 | 0.00E+00 | 0.00E+00 |
| Sr-90 | 2.58E+05 | 9.77E-04 | 1.16E-03 | | 3.40E+00 | 1.13E-06 | 1.31E-11 |
| Y-90 | 2.58E+05 | 9.77E-04 | 5.54E-03 | | 3.40E+00 | 5.41E-06 | 6.28E-11 |
| Tc-99 | 2.28E+04 | 8.63E-05 | 5.01E-04 | | 3.40E+00 | 4.32E-08 | 5.02E-13 |
| Ru-106 | 8.19E+01 | 3.10E-07 | 5.95E-04 | | 3.40E+00 | 1.84E-10 | 2.14E-15 |
| Rh-106 | 8.19E+01 | 3.10E-07 | 1.89E-02 | | 3.40E+00 | 5.87E-09 | 6.81E-14 |
| Sb-125 | 5.99E+01 | 2.27E-07 | 3.37E-03 | | 3.40E+00 | 7.64E-10 | 8.87E-15 |
| Sn-126 | 1.93E+02 | 7.31E-07 | 1.08E-03 | | 3.40E+00 | 7.89E-10 | 9.15E-15 |
| I-129 | 1.30E+01 | 4.92E-08 | 4.77E-04 | | 3.40E+00 | 2.35E-11 | 2.72E-16 |
| Cs-134 | 4.62E+02 | 1.75E-06 | 1.02E-02 | | 3.40E+00 | 1.78E-08 | 2.07E-13 |
| Cs-135 | 2.34E+01 | 8.86E-08 | 3.32E-04 | | 3.40E+00 | 2.94E-11 | 3.41E-16 |
| Cs-137 | 4.92E+06 | 1.86E-02 | 1.01E-03 | | 3.40E+00 | 1.88E-05 | 2.18E-10 |
| Ba-137m | 4.66E+06 | 1.76E-02 | 3.94E-03 | | 3.40E+00 | 6.95E-05 | 8.06E-10 |
| Ce-144 | 7.70E+01 | 2.91E-07 | 6.58E-04 | | 3.40E+00 | 1.92E-10 | 2.23E-15 |
| Pr-144 | 7.70E+01 | 2.91E-07 | 7.34E-03 | | 3.40E+00 | 2.14E-09 | 2.48E-14 |
| Pm-147 | 1.80E+02 | 6.81E-07 | 3.67E-04 | | 3.40E+00 | 2.50E-10 | 2.90E-15 |
| Eu-154 | 1.53E+01 | 5.79E-08 | 9.08E-03 | | 3.40E+00 | 5.26E-10 | 6.10E-15 |
| Th-232 | 1.10E-03 | 4.16E-12 | 2.38E-02 | 2.38E+01 | | 9.89E-14 | 8.02E-18 |
| U-233 | 9.68E+01 | 3.66E-07 | 2.86E-02 | 2.38E+01 | | 1.05E-08 | 8.49E-13 |
| U-234 | 9.00E+01 | 3.41E-07 | 2.83E-02 | 2.38E+01 | | 9.64E-09 | 7.81E-13 |
| U-235 | 1.94E-01 | 7.34E-10 | 2.71E-02 | 2.38E+01 | | 1.99E-11 | 1.62E-15 |
| U-236 | 1.08E+00 | 4.09E-09 | 2.66E-02 | 2.38E+01 | | 1.09E-10 | 8.82E-15 |
| U-238 | 3.70E+00 | 1.40E-08 | 2.49E-02 | 2.38E+01 | | 3.49E-10 | 2.83E-14 |
| Np-237 | 3.39E+00 | 1.28E-08 | 2.88E-02 | 2.38E+01 | | 3.69E-10 | 3.00E-14 |
| Pu-238 | 1.46E+04 | 5.53E-05 | 3.26E-02 | 2.38E+01 | | 1.80E-06 | 1.46E-10 |
| Pu-239 | 1.49E+03 | 5.64E-06 | 3.02E-02 | 2.38E+01 | | 1.71E-07 | 1.38E-11 |
| Pu-240 | 1.49E+03 | 5.64E-06 | 3.06E-02 | 2.38E+01 | | 1.72E-07 | 1.40E-11 |
| Pu-241 | 5.22E+03 | 1.98E-05 | 3.20E-05 | | 3.40E+00 | 6.32E-10 | 7.34E-15 |
| Pu-242 | 3.82E+01 | 1.45E-07 | 2.90E-02 | 2.38E+01 | | 4.20E-09 | 3.40E-13 |
| Am-241 | 7.60E+00 | 2.88E-08 | 3.28E-02 | 2.38E+01 | | 9.44E-10 | 7.66E-14 |
| Cm-244 | 1.05E+01 | 3.97E-08 | 3.44E-02 | 2.38E+01 | | 1.37E-09 | 1.11E-13 |
| Cm-245 | 1.13E+01 | 4.28E-08 | 3.33E-02 | 2.38E+01 | | 1.42E-09 | 1.15E-13 |
| Sm-151 | 1.53E+02 | 5.79E-07 | 7.41E-04 | 2.38E+01 | | 4.29E-10 | 3.48E-14 |
| Ra-226 | 3.12E+02 | 1.18E-06 | 2.84E-02 | 2.38E+01 | | 3.35E-08 | 2.72E-12 |
| Eu-155 | 3.62E+01 | 1.37E-07 | 7.59E-04 | | 3.40E+00 | 1.04E-10 | 1.21E-15 |
| Th-230 | | 0.00E+00 | 2.77E-02 | 2.38E+01 | | 0.00E+00 | 0.00E+00 |
| Pu-244 | 1.77E-01 | 6.70E-10 | 2.71E-02 | 2.38E+01 | | 1.82E-11 | 1.47E-15 |
| | | | | | | **Total** | **1.28E-09** |
| | | | | | | **at 95°C** | **1.73E-09** |

**Attachment 16-B: Hydrogen Generation Rate from Salt Batch 5 Feed Material for Saltstone** (Saltstone WAC 5.4.4)

With the 28.5% dilution rate expected with the ARP/MCU process, the following apply:

$NO_{eff}$ = 1.99 M + 0.25 (0.394 M) = 2.09 M
$R_{\alpha}$ = 8.24E+01
$R_{\beta/\gamma}$ = 5.13E+00

| | |
|---|---|
| **Hydrogen Generation** | **3.08E-09 $ft^3$ $H_2$/hour/gallon @ 95ºC** |
| **Saltstone WAC Limit** | **5.59E-08 $ft^3$ $H_2$/hour/gallon @ 95ºC** |
| **Percent of Limit** | **5.50%** |

With the 32.5% dilution rate expected as the bounding condition for the ARP/MCU process, the following apply:

$NO_{eff}$ = 1.88 M + 0.25 (0.372 M) = 1.97 M
$R_{\alpha}$ = 8.63E+01
$R_{\beta/\gamma}$ = 5.48E+00

| | |
|---|---|
| **Hydrogen Generation** | **3.27E-09 $ft^3$ $H_2$/hour/gallon @ 95ºC** |
| **Saltstone WAC Limit** | **3.53E-08 $ft^3$ $H_2$/hour/gallon @ 95ºC** |
| **Percent of Limit** | **5.85%** |

Q values are the Heat Generation factors and are defined in Reference 61.

In the following tables:
Data from Reference 7. Cesium isotopes and Ba-137m have a DF of 12 applied to the feed value.

**Attachment 16-B (continued): Hydrogen Generation Rate from Salt Batch 5 Feed Material for Saltstone at 28.5% Dilution** (Saltstone WAC 5.4.4)

| Radionuclide | Results (pCi/ml) | Results (Ci/gal) | "Q" Value (W/Ci) | $R_\alpha$ (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 | 9.46E+02 | 3.58E-06 | 3.37E-05 | | 5.13E+00 | 1.21E-10 | 2.11E-15 |
| C-14 | 7.20E+02 | 2.73E-06 | 2.93E-04 | | 5.13E+00 | 7.98E-10 | 1.40E-14 |
| Co-60 | 5.63E+00 | 2.13E-08 | 1.54E-02 | | 5.13E+00 | 3.28E-10 | 5.75E-15 |
| Ni-59 | 2.00E+01 | 7.57E-08 | 3.98E-05 | | 5.13E+00 | 3.01E-12 | 5.28E-17 |
| Ni-63 | 4.06E+02 | 1.54E-06 | 1.01E-04 | | 5.13E+00 | 1.55E-10 | 2.72E-15 |
| Se-79 | 0.00E+00 | 0.00E+00 | 3.13E-04 | | 5.13E+00 | 0.00E+00 | 0.00E+00 |
| Sr-90 | 2.58E+05 | 9.77E-04 | 1.16E-03 | | 5.13E+00 | 1.13E-06 | 1.98E-11 |
| Y-90 | 2.58E+05 | 9.77E-04 | 5.54E-03 | | 5.13E+00 | 5.41E-06 | 9.48E-11 |
| Tc-99 | 2.28E+04 | 8.63E-05 | 5.01E-04 | | 5.13E+00 | 4.32E-08 | 7.58E-13 |
| Ru-106 | 8.19E+01 | 3.10E-07 | 5.95E-04 | | 5.13E+00 | 1.84E-10 | 3.23E-15 |
| Rh-106 | 8.19E+01 | 3.10E-07 | 1.89E-02 | | 5.13E+00 | 5.87E-09 | 1.03E-13 |
| Sb-125 | 5.99E+01 | 2.27E-07 | 3.37E-03 | | 5.13E+00 | 7.64E-10 | 1.34E-14 |
| Sn-126 | 1.93E+02 | 7.31E-07 | 1.08E-03 | | 5.13E+00 | 7.89E-10 | 1.38E-14 |
| I-129 | 1.30E+01 | 4.92E-08 | 4.77E-04 | | 5.13E+00 | 2.35E-11 | 4.11E-16 |
| Cs-134 | 4.62E+02 | 1.75E-06 | 1.02E-02 | | 5.13E+00 | 1.78E-08 | 3.12E-13 |
| Cs-135 | 2.34E+01 | 8.86E-08 | 3.32E-04 | | 5.13E+00 | 2.94E-11 | 5.16E-16 |
| Cs-137 | 4.92E+06 | 1.86E-02 | 1.01E-03 | | 5.13E+00 | 1.88E-05 | 3.29E-10 |
| Ba-137m | 4.66E+06 | 1.76E-02 | 3.94E-03 | | 5.13E+00 | 6.95E-05 | 1.22E-09 |
| Ce-144 | 7.70E+01 | 2.91E-07 | 6.58E-04 | | 5.13E+00 | 1.92E-10 | 3.36E-15 |
| Pr-144 | 7.70E+01 | 2.91E-07 | 7.34E-03 | | 5.13E+00 | 2.14E-09 | 3.75E-14 |
| Pm-147 | 1.80E+02 | 6.81E-07 | 3.67E-04 | | 5.13E+00 | 2.50E-10 | 4.38E-15 |
| Eu-154 | 1.53E+01 | 5.79E-08 | 9.08E-03 | | 5.13E+00 | 5.26E-10 | 9.21E-15 |
| Th-232 | 1.10E-03 | 4.16E-12 | 2.38E-02 | 8.24E+01 | | 9.89E-14 | 2.78E-17 |
| U-233 | 9.68E+01 | 3.66E-07 | 2.86E-02 | 8.24E+01 | | 1.05E-08 | 2.94E-12 |
| U-234 | 9.00E+01 | 3.41E-07 | 2.83E-02 | 8.24E+01 | | 9.64E-09 | 2.71E-12 |
| U-235 | 1.94E-01 | 7.34E-10 | 2.71E-02 | 8.24E+01 | | 1.99E-11 | 5.60E-15 |
| U-236 | 1.08E+00 | 4.09E-09 | 2.66E-02 | 8.24E+01 | | 1.09E-10 | 3.06E-14 |
| U-238 | 3.70E+00 | 1.40E-08 | 2.49E-02 | 8.24E+01 | | 3.49E-10 | 9.81E-14 |
| Np-237 | 3.39E+00 | 1.28E-08 | 2.88E-02 | 8.24E+01 | | 3.69E-10 | 1.04E-13 |
| Pu-238 | 1.46E+04 | 5.53E-05 | 3.26E-02 | 8.24E+01 | | 1.80E-06 | 5.06E-10 |
| Pu-239 | 1.49E+03 | 5.64E-06 | 3.02E-02 | 8.24E+01 | | 1.71E-07 | 4.79E-11 |
| Pu-240 | 1.49E+03 | 5.64E-06 | 3.06E-02 | 8.24E+01 | | 1.72E-07 | 4.84E-11 |
| Pu-241 | 5.22E+03 | 1.98E-05 | 3.20E-05 | | 5.13E+00 | 6.32E-10 | 1.11E-14 |
| Pu-242 | 3.82E+01 | 1.45E-07 | 2.90E-02 | 8.24E+01 | | 4.20E-09 | 1.18E-12 |
| Am-241 | 7.60E+00 | 2.88E-08 | 3.28E-02 | 8.24E+01 | | 9.44E-10 | 2.65E-13 |
| Cm-244 | 1.05E+01 | 3.97E-08 | 3.44E-02 | 8.24E+01 | | 1.37E-09 | 3.84E-13 |
| Cm-245 | 1.13E+01 | 4.28E-08 | 3.33E-02 | 8.24E+01 | | 1.42E-09 | 4.00E-13 |
| Sm-151 | 1.53E+02 | 5.79E-07 | 7.41E-04 | 8.24E+01 | | 4.29E-10 | 1.21E-13 |
| Ra-226 | 3.12E+02 | 1.18E-06 | 2.84E-02 | 8.24E+01 | | 3.35E-08 | 9.41E-12 |
| Eu-155 | 3.62E+01 | 1.37E-07 | 7.59E-04 | | 5.13E+00 | 1.04E-10 | 1.82E-15 |
| Pu-244 | 1.77E-01 | 6.70E-10 | 2.71E-02 | 8.24E+01 | | 1.82E-11 | 5.11E-15 |
| Am-243 | 3.98E+00 | 1.51E-08 | 3.15E-02 | 8.24E+01 | | 4.74E-10 | 1.33E-13 |
| | | | | | | **Total** | **2.28E-09** |
| | | | | | | **at 95°C** | **3.08E-09** |

**Attachment 16-B (continued): Hydrogen Generation Rate from Salt Batch 5 Feed Material for Saltstone at 32.5% Dilution** (Saltstone WAC 5.4.4)

| Radionuclide | Results (pCi/ml) | Results (Ci/gal) | "Q" Value (W/Ci) | $R_\alpha$ ($ft^3$ $H_2/10^6$ 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 | 9.46E+02 | 3.58E-06 | 3.37E-05 | | 5.48E+00 | 1.21E-10 | 2.26E-15 |
| C-14 | 7.20E+02 | 2.73E-06 | 2.93E-04 | | 5.48E+00 | 7.98E-10 | 1.49E-14 |
| Co-60 | 5.63E+00 | 2.13E-08 | 1.54E-02 | | 5.48E+00 | 3.28E-10 | 6.14E-15 |
| Ni-59 | 2.00E+01 | 7.57E-08 | 3.98E-05 | | 5.48E+00 | 3.01E-12 | 5.64E-17 |
| Ni-63 | 4.06E+02 | 1.54E-06 | 1.01E-04 | | 5.48E+00 | 1.55E-10 | 2.90E-15 |
| Sr-90 | 0.00E+00 | 0.00E+00 | 3.13E-04 | | 5.48E+00 | 0.00E+00 | 0.00E+00 |
| Y-90 | 2.58E+05 | 9.77E-04 | 1.16E-03 | | 5.48E+00 | 1.13E-06 | 2.12E-11 |
| Tc-99 | 2.58E+05 | 9.77E-04 | 5.54E-03 | | 5.48E+00 | 5.41E-06 | 1.01E-10 |
| Ru-106 | 2.28E+04 | 8.63E-05 | 5.01E-04 | | 5.48E+00 | 4.32E-08 | 8.09E-13 |
| Rh-106 | 8.19E+01 | 3.10E-07 | 5.951E-04 | | 5.48E+00 | 1.84E-10 | 3.45E-15 |
| Sb-125 | 8.19E+01 | 3.10E-07 | 1.894E-02 | | 5.48E+00 | 5.87E-09 | 1.10E-13 |
| Sn-126 | 5.99E+01 | 2.27E-07 | 3.37E-03 | | 5.48E+00 | 7.64E-10 | 1.43E-14 |
| I-129 | 1.93E+02 | 7.31E-07 | 1.08E-03 | | 5.48E+00 | 7.89E-10 | 1.48E-14 |
| Cs-134 | 1.30E+01 | 4.92E-08 | 4.77E-04 | | 5.48E+00 | 2.35E-11 | 4.39E-16 |
| Cs-135 | 4.62E+02 | 1.75E-06 | 1.02E-02 | | 5.48E+00 | 1.78E-08 | 3.33E-13 |
| Cs-137 | 2.34E+01 | 8.86E-08 | 3.32E-04 | | 5.48E+00 | 2.94E-11 | 5.51E-16 |
| Ba-137m | 4.92E+06 | 1.86E-02 | 1.01E-03 | | 5.48E+00 | 1.88E-05 | 3.52E-10 |
| Ce-144 | 4.66E+06 | 1.76E-02 | 3.94E-03 | | 5.48E+00 | 6.95E-05 | 1.30E-09 |
| Pr-144 | 7.70E+01 | 2.91E-07 | 6.58E-04 | | 5.48E+00 | 1.92E-10 | 3.59E-15 |
| Pm-147 | 7.70E+01 | 2.91E-07 | 7.34E-03 | | 5.48E+00 | 2.14E-09 | 4.00E-14 |
| Eu-154 | 1.80E+02 | 6.81E-07 | 3.67E-04 | | 5.48E+00 | 2.50E-10 | 4.68E-15 |
| U-233 | 1.53E+01 | 5.79E-08 | 9.08E-03 | | 5.48E+00 | 5.26E-10 | 9.84E-15 |
| U-234 | 1.10E-03 | 4.16E-12 | 2.38E-02 | 8.63E+01 | | 9.89E-14 | 2.91E-17 |
| U-235 | 9.68E+01 | 3.66E-07 | 2.86E-02 | 8.63E+01 | | 1.05E-08 | 3.08E-12 |
| U-236 | 9.00E+01 | 3.41E-07 | 2.83E-02 | 8.63E+01 | | 9.64E-09 | 2.84E-12 |
| U-238 | 1.94E-01 | 7.34E-10 | 2.71E-02 | 8.63E+01 | | 1.99E-11 | 5.87E-15 |
| Np-237 | 1.08E+00 | 4.09E-09 | 2.66E-02 | 8.63E+01 | | 1.09E-10 | 3.21E-14 |
| Pu-238 | 3.70E+00 | 1.40E-08 | 2.49E-02 | 8.63E+01 | | 3.49E-10 | 1.03E-13 |
| Pu-239 | 3.39E+00 | 1.28E-08 | 2.88E-02 | 8.63E+01 | | 3.69E-10 | 1.09E-13 |
| Pu-240 | 1.46E+04 | 5.53E-05 | 3.26E-02 | 8.63E+01 | | 1.80E-06 | 5.31E-10 |
| Pu-241 | 1.49E+03 | 5.64E-06 | 3.02E-02 | 8.63E+01 | | 1.71E-07 | 5.02E-11 |
| Pu-242 | 1.49E+03 | 5.64E-06 | 3.06E-02 | 8.63E+01 | | 1.72E-07 | 5.08E-11 |
| Am-241 | 5.22E+03 | 1.98E-05 | 3.20E-05 | | 5.48E+00 | 6.32E-10 | 1.18E-14 |
| Cm-244 | 3.82E+01 | 1.45E-07 | 2.90E-02 | 8.63E+01 | | 4.20E-09 | 1.24E-12 |
| Cm-245 | 7.60E+00 | 2.88E-08 | 3.28E-02 | 8.63E+01 | | 9.44E-10 | 2.78E-13 |
| Sm-151 | 1.05E+01 | 3.97E-08 | 3.44E-02 | 8.63E+01 | | 1.37E-09 | 4.02E-13 |
| Ra-226 | 1.13E+01 | 4.28E-08 | 3.33E-02 | 8.63E+01 | | 1.42E-09 | 4.19E-13 |
| Eu-155 | 1.53E+02 | 5.79E-07 | 7.41E-04 | 8.63E+01 | | 4.29E-10 | 1.26E-13 |
| Pu-244 | 1.77E-01 | 6.70E-10 | 2.71E-02 | 8.63E+01 | | 1.82E-11 | 5.35E-15 |
| Am-243 | 3.98E+00 | 1.51E-08 | 3.15E-02 | 8.63E+01 | | 4.74E-10 | 1.40E-13 |
| | | | | | | **Total** | **2.43E-09** |
| | | | | | | **at 95°C** | **3.27E-09** |

**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 | 5.63E+00 | 2.13E-08 | 1.37E+03 | 2.92E-05 |
| Sb-125 | 5.99E+01 | 2.27E-07 | 6.08E+02 | 1.38E-04 |
| Cs-134* | 4.62E+02 | 1.46E-07 | 9.99E+02 | 1.45E-04 |
| Cs-137* | 4.92E+06 | 1.55E-03 | 3.82E+02 | 5.92E-01 |
| Eu-154 | 1.53E+01 | 5.79E-08 | 7.56E+02 | 4.38E-05 |
| | | | | |
| **Gamma Source Strength** | **(mrem/hr/gal)** | | | **5.93E-01** |
| **Saltstone WAC limit** | **(mrem/hr/gal)** | | | **9.05E+01** |
| **% of WAC limit** | | | | **0.66%** |

Data from Reference 7.
* 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 | 5.63E+00 | 2.13E-08 | 1.37E+03 | 2.92E-05 |
| Sb-125 | 5.99E+01 | 2.27E-07 | 6.08E+02 | 1.38E-04 |
| Cs-134 | 5.54E+03 | 2.10E-05 | 9.99E+02 | 2.09E-02 |
| Cs-137 | 5.90E+07 | 2.23E-01 | 3.82E+02 | 8.53E+01 |
| Eu-154 | 1.53E+01 | 5.79E-08 | 7.56E+02 | 4.38E-05 |
| | | | | |
| **Gamma Source Strength** | **(mrem/hr/gal)** | | | **8.53E+01** |
| **Saltstone WAC limit** | **(mrem/hr/gal)** | | | **9.05E+01** |
| **% of WAC limit** | | | | **94.28%** |

Data from Reference 7.

**Attachment 18: Maximum Hydroxide Determination for 512-S**

Since there is no mixing in Tank 49, and the Salt Batch 4 heel in Tank 49 has been evaluated for the 512-S maximum hydroxide concentration, Tank 21 analyses (Ref. 7) and the caustic addition blend (Table 1) was used in OLI modeling to determine the maximum hydroxide concentration that may be used at 512-S. Table 18-1 shows the predicted Salt Batch 5 Tank 21 concentrations of cations and anions used in OLI modeling to determine the maximum hydroxide concentration that may be used at 512-S.

**Table 18-1- Predicted Chemistry for Salt Batch 5 Tank 21**

| | **OLI Input Concentration** |
|---|---|
| **Chemical (M)** | |
| Na2CO3 | 2.34E-01 |
| NaOH | 2.36E+00 |
| NaNO3 | 2.78E+00 |
| NaNO2 | 5.51E-01 |
| Na2C2O4 | 2.70E-03 |
| Na2SO4 | 7.48E-02 |
| NaAl(OH)4 | 2.60E-01 |
| SiO2 | 1.64E-03 |

OLI Stream Analyzer 3.2 was used to develop a model to estimate a maximum hydroxide concentration to prevent filter fouling at 512-S. A high hydroxide concentration was predicted to prevent scale formation from sodium oxalate. All calculations in this report were performed under thermodynamic equilibrium condition and adiabatically to predict the temperature change while mixing solutions from one tank to another.

Solids formation is determined based on scaling tendencies. The scaling tendency is defined as the ratio of the real solution solubility product to the thermodynamic limit based on the thermodynamic equilibrium constant. The scaling tendency can be explained as follows:

If Scaling Tendency < 1, then the solid is under-saturated

If Scaling Tendency > 1, then the solid is super-saturated

If Scaling Tendency = 1, then the solid is at saturation

The Salt Batch 5 values shown in Table 18-1 are used as the input and OLI Stream Analyzer reconciled the stream. Table 18-2 shows the scaling tendencies for sodium oxalate and aluminum hydroxide of Salt Batch 5, as well as the scaling tendencies at the maximum allowable hydroxide concentration that will prevent sodium oxalate ($Na_2C_2O_4$) solids formation.

**Table 19-2 – Scaling Tendencies for Salt Batch 5**

| **Constituent** | **Projected Batch 5** | **Batch 5 at 512-S** |
|---|---|---|
| | Hydroxide = 2.36M | Hydroxide = 2.68M |
| $Na_2C_2O_4$ scaling | 0.561 | 0.483 |
| $Al(OH)_3$ scaling | 0.851 | 0.669 |

To prevent filter fouling in 512-S, it is recommended that the free hydroxide concentration remain below 3.0 M. This will keep the scaling tendency of sodium oxalate below 1.

**Attachment 19: Technical Reviews**

| Section | Reviewers | | |
|---|---|---|---|
| 1.0 | E. W. Harrison | C. K. Chiu | |
| 2.0 | E. W. Harrison | C. K. Chiu | |
| 3.0 | E. W. Harrison | C. K. Chiu | |
| 3.1 | H. H. Elder | C. K. Chiu | |
| 3.2 | H. H. Elder | C. K. Chiu | |
| 3.3 | E. W. Harrison | | |
| 3.4 | C. K. Chiu | | |
| 3.5 | E. W. Harrison | C. K. Chiu | |
| 3.6 | E. W. Harrison | S. P. McLeskey | C. K. Chiu |
| 4.0 | E. W. Harrison | C. K. Chiu | |

The reviewers also reviewed the corresponding attachments to the sections.