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Implementation of Increased Salt & Decreased Sludge Volumes in the Defense Waste Processing Facility -19597

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ABSTRACT

The Savannah River Site (SRS) Liquid Waste System (LWS) safely stores and treats high-level radioactive waste. The LWS consists of 51 waste storage tanks (eight of which are operationally closed and filled with grout), waste evaporators, treatment facilities, and solidification facilities such as the Defense Waste Processing Facility (DWPF) and Saltstone Production Facility (SPF). The disposition of high-level waste (HLW) into a glass waste form poured into canisters at the DWPF began in 1996. DWPF processed a sludge only flowsheet until 2008 when the Actinide Removal Process (ARP) and Modular Caustic Side Solvent Extraction Unit (MCU) began treating the salt waste from the underground liquid storage tanks by striking with monosodium titanate (MST) to remove actinides, when necessary to meet downstream acceptance criteria, and removing the MST and entrained sludge solids (SS) by filtration before using an organic solvent to strip the cesium from the salt, creating two new concentrated HLW streams. This change caused the DWPF to begin processing under both a sludge-only and a coupled operations flowsheet where salt streams would only be added when available. This strategy allows for continuous glass canister production at DWPF.

Recently, DWPF completed a 10-month melter replacement in December 2017 and the Concentrate, Storage, and Transfer Facility (CSTF) has completed repairs to the 3H Evaporator system. These facility outages have caused delays in preparing the next batch of sludge feed for DWPF. Concurrent with these facility outages, the Salt Waste Processing Facility (SWPF) has been undergoing system testing and commissioning, working toward startup. SWPF is designed to process salt waste in the same manner as ARP/MCU, but with much higher throughput volumes produced per unit time. In order to process the SWPF salt streams efficiently, DWPF will implement a coupled operation only flowsheet.

Based on the facility outages mentioned above, efforts have been made to identify strategies to minimize sludge volumes and maximize salt volumes in the DWPF until the next sludge batch is ready for processing in DWPF. Savannah River Remediation (SRR) recently performed an evaluation that examines the effects of reducing the volume of sludge and maximizing the addition of the cesium-rich concentrated salt solution in each Sludge Receipt and Adjustment Tank (SRAT) batch in order to extend the existing sludge batch as long as possible until the next sludge batch is ready. These effects include a reduction of weight percent solids in the DWPF processing vessels, an increase in cycle time, a new canister heat generation value that remains within regulatory limits, and higher gamma source that remains within bulk facility gamma shielding. Balancing the above parameters resulted in a small reduction of sludge volume per SRAT batch under SWPF operation and maximizing the salt volumes for both ARP/MCU and SWPF operation. This slight reduction in sludge volume and increase in salt volumes allows SRR to mitigate some of the schedule impact incurred by the facility outages. This strategy was evaluated for both ARP/MCU and SWPF operation. This strategy has been successfully implemented under ARP/MCU operation using small step changes in the current process.

This paper provides an overview of the evaluation performed for DWPF with ARP/MCU and DWPF with SWPF operations.

INTRODUCTION

DWPF processes HLW waste received from the CSTF. CSTF sends three streams to DWPF: a washed sludge slurry stream and two separate salt streams that are by-product streams from processing of salt solution. The salt streams are a MST/SS stream and a strip effluent (SE) stream. Salt solution is sent from Tank 49 to the ARP facilities. At the ARP facilities, the soluble actinides and strontium present in the salt solution may be reduced by striking the salt solution with MST, followed by a filtration step to remove the MST and SS contained in the salt solution. The resulting MST/SS stream is sent to the Precipitate

Reactor Feed Tank (PRFT) in DWPF. The clarified salt solution (CSS) from ARP is sent to MCU to remove the cesium using banks of centrifugal contactors. The CSS is contacted with a solvent in the extraction bank to extract the cesium (Cs) from the salt solution into the solvent. The solvent is then sent to the strip bank of contactors to remove Cs from the solvent by contacting it with dilute acid. This acidic cesium-laden stream is called SE and is sent to the Strip Effluent Feed Tank (SEFT) in DWPF. The decontaminated salt solution (DSS) is sent to the Saltstone Production Facility (SPF) to be disposed as low-level waste. ARP/MCU is anticipated to be replaced by SWPF. SWPF will produce similar MST/SS and SE streams in larger quantities [1].

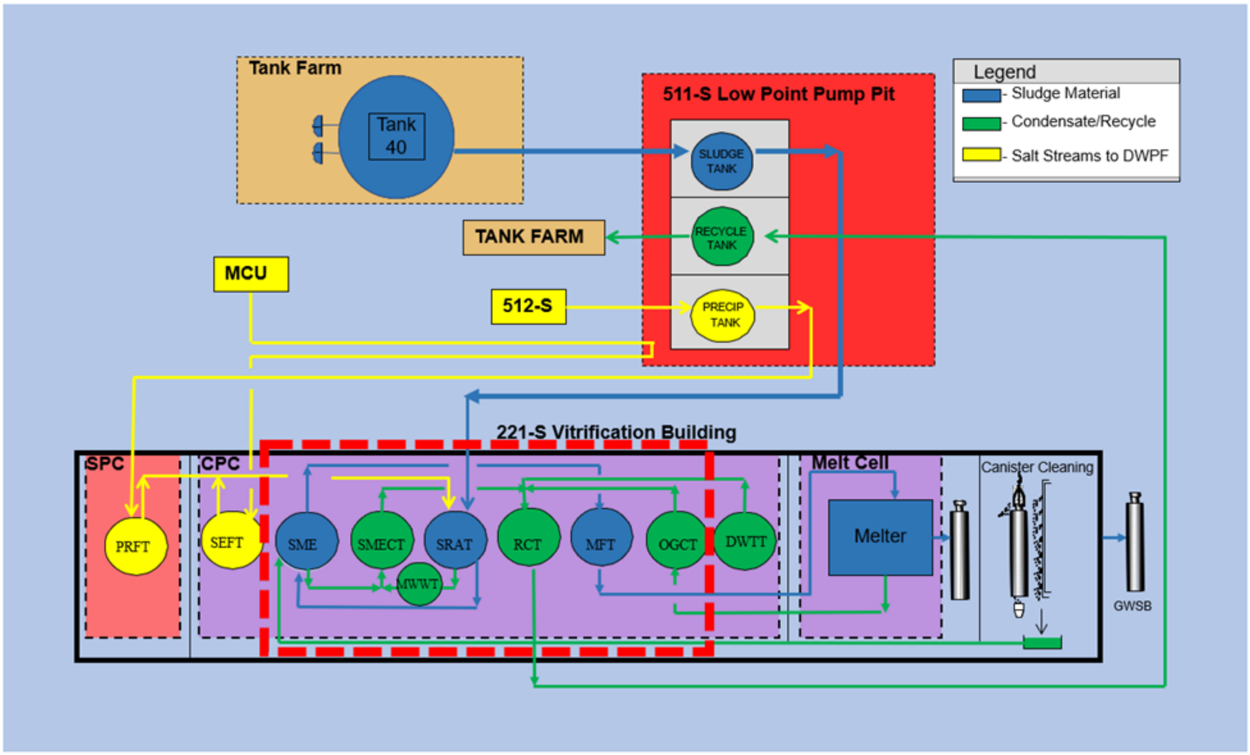

Figure 1. Flow path for sludge slurry, salt streams, and recycle streams for DWPF. The CSTF is referred to as Tank Farm in this figure.

The washed sludge slurry is brought to the SRAT through the Low Point Pump Pit (LPPP) – Sludge Pump Tank (SPT). Because the SPT is smaller than the SRAT, sludge is brought up in two transfers from Tank 40. After sludge is received, the MST/SS are then added to the SRAT while it is boiling. A SRAT receipt sample is taken after the desired volume of MST/SS addition is completed and analyzed to determine the acid requirement for the batch. Nitric and formic acids are added to perform acid-base neutralizations, adjust the rheological properties of the sludge, reduce mercury to its elemental state for steam stripping and balance redox state of the glass produced from the melter. The SRAT is heated to boiling and maintained for a designated length of time to remove most of the mercury. While the SRAT is boiling, SE can be added. SE must be added under boiling conditions and it is convenient to boil for SE additions and mercury stripping simultaneously. Once the steam stripping, SE additions, and any necessary concentration are complete, the SRAT is cooled and a product sample is taken. The resulting slurry is transferred to the SME to be further concentrated and combined with a frit to make a suitable glass for long-term stable storage of the radioactive isotopes. The SME is sampled after processing is complete and the results are compared in the Product Composition Control System (PCCS) to determine whether the resulting glass will meet requirements for both processability and waste form performance. If the batch passes, it is transferred to the Melter Feed Tank (MFT) which provides feed to the melter [2].

Recently, DWPF completed a 10-month melter replacement in December 2017 and the CSTF has completed repairs to the 3H Evaporator system. These facility outages have caused delays in preparing the next batch of sludge feed for DWPF. Concurrent with these facility outages, SWPF has been undergoing system testing in order to start in November of 2019. SWPF is designed to process salt waste in the same manner as ARP/MCU, but with much higher throughput volumes produced per unit time. In order to process the SWPF salt streams efficiently, DWPF will implement a coupled operation only flowsheet.

Based on the facility outages mentioned above, efforts have been made to identify strategies to minimize sludge volumes and maximize salt volumes in the DWPF until the next sludge batch is ready for processing in DWPF. An evaluation was performed to identify processing and regulatory impacts of reducing volumes of sludge and increasing volumes of salt streams to an individual SRAT batch for both ARP/MCU and SWPF operation. Items evaluated are:

1) Processing impacts of lowering the volume of sludge. Typically, ~22,712 liters of sludge are processed in one batch of feed at DWPF. Sludge volumes were lowered to 20,250, 18,900, and 17,700 liters and evaluated for their impact on Low Point Pump Pit (LPPP) management and weight percent total solids across the DWPF processing vessels. LPPP is a pump pit halfway through a transfer that is used to complete a transfer to DWPF. The tanks in LPPP hold a smaller volume than the tanks at DWPF and contain self-priming pumps. Heel levels need to be managed such that sludge can still be pumped from the SPT to the SRAT while decreasing the total volume of sludge entering the SRAT per batch for each targeted sludge volume evaluated. Weight percent total solids are an indicator of rheology and are important when products are sampled and transferred from vessel to vessel in DWPF. The weight percent total solids were predicted and compared to the DWPF design basis for total weight percent solids.
2) Increasing the nominal addition volume of salt product streams to a SRAT batch from approximately 13,500 liters to 48,450 liters. This increase mainly impacts the cycle time and waste water volumes. DWPF is a batch process and requires balanced cycle times between processing vessels in order to operate efficiently. The new cycle time was predicted and compared to the processing rates of ARP/MCU and SWPF respectively to determine if DWPF could meet the required processing speeds. DWPF creates a waste water stream that is sent back to CSTF. This stream is mostly condensate from the SRAT and the SME. Any change in salt stream addition volumes will impact the volume of waste water as most of those streams are boiled off. Increased waste water volumes will increase the load on the 2H evaporator in CSTF and increase the sampling demand on the DWPF laboratory. The expected waste water volumes were evaluated and compared to the current waste water strategy to determine the impact.
3) Regulatory impacts of both lowering the volume of sludge and increasing the addition volume of salt product streams. These mainly impact canister heat generation and facility bulk gamma shielding. The maximum power of a canister is set forth in the DWPF waste acceptance criteria (WAC) to maintain structural integrity of the temporary storage vaults by protecting the maximum surface temperature of the vault ceiling. New canister heat generation values were calculated and compared against the limit set forth in the DWPF WAC to ensure continued compliance. Increasing the salt product stream will increase the cesium loading throughout the facility. Predicted curie contents of vessels were compared to the DWPF design basis for gamma shielding under MCU operation.

APPROACH

DWPF will experience a processing change when SWPF comes online. Currently ARP/MCU provides the salt feeds to DWPF. ARP is operating without an MST strike and MCU is operating with the Next Generation Solvent. This results in approximately 1,890 liters of SE per day when MCU is processing and 15,100 liters of MST/SS from ARP every 6 months. New processing goals under ARP/MCU operation require maximization of salt in a SRAT batch. Moving forward, the maximum SE will be added to each SRAT batch while MST/SS will be added when available. Nominal volumes of SE per batch under ARP/MCU operations will be 40,100 liters at Salt Batch 10 concentrations of Cs-137. When processing impacts are evaluated, a nominal value of 0 liters MST/SS and 40,100 liters SE concentrations will be added to each SRAT batch. The maximum volume of SE currently allowed by the safety basis is 40,300 liters of SE at 3.96 Ci/L. Regulatory impacts will be evaluated with 20,100 liters MST/SS and 56,800 liters SE at 4.36 Ci/L Cs-137.

SWPF has similar unit operations as ARP/MCU, but on a larger scale. It will produce similar product streams at larger volumes and potentially higher activity. It is expected that the processing goals of maximizing salt per SRAT batch will remain the same when SWPF-DWPF coupled operations begin. A combination of a MST strike and filtration will be used at SWPF to remove actinides and sludge solids. The Bobcalix solvent will be used in contactors to remove the cesium from the salt stream. SWPF has the capability to perform a double MST strike, but it is not expected in the near term due to projected salt batch compositions. This evaluation will assume only single strike operation. SWPF throughput is expected to be 48,450 liters of SE every 6 days and 16,600 liters of MST/SS every 7 days.

In order for DWPF to manage the volume of the streams coming from SWPF on a weekly basis, it will be necessary to add both the MST/SS and SE streams to each SRAT batch. The maximum volume of MST/SS per SRAT batch is expected to be limited due to glass quality impacts. These glass limitations will be determined from the PCCS Assessment prior to processing but are assumed to be consistent with ARP/MCU operation. Impacts to processing were evaluated using a nominal value of 16,600 liters MST/SS and 48,450 liters SE per SRAT batch. Regulatory impacts were evaluated using maximum values of 20,100 liters MST/SS and 85,900 liters SE per SRAT batch.

Two proposed changes to processing were evaluated: lowering the volume of sludge and increasing the addition volume of salt product streams, mainly SE, per SRAT batch. Nine criteria were selected for evaluation because of one or both processing changes for both ARP/MCU and SWPF operation. These criteria are shown in Table I. Those criteria not evaluated for ARP/MCU operation had a minimal impact compared to current operation. The criterion not evaluated for SWPF operation was already evaluated and the proposed changes do not challenge the conclusions of the previous evaluation. The main contributor to selecting each criterion for evaluation is also shown in Table I.

TABLE I. Summary of the criteria evaluated and the proposed change which caused the criteria to be considered. The exclusion of some criteria for being evaluated within this document for both ARP/MCU and SWPF are explained in their respective section.

Focus Area	Criteria	ARP/MCU Operation	SWPF Operation	Main Contributor
LPPP Management	*SPT Management*	✓	✓	Sludge
	PPT Management		✓	MST/SS
Processing Impacts	*Wt.% Solids Content*	✓	✓	Sludge
	SE Additions	✓	✓	SE
	Boiling Time	✓	✓	SE
	Cycle Time		✓	SE
	Waste Water	✓	✓	SE and solids
Regulatory Impacts	*Canister Heat Generation*	✓	✓	SE and Sludge
	Gamma Shielding	✓		SE

Presented below is a description of the criteria in Table 1.

LPPP Management

SPT Management

Sludge will be brought to DWPF through two transfers from the SPT for both ARP/MCU and SWPF operation. A water flush of 5,300 liters is included in the second SPT transfer. The transfer pump is not self-priming, so the liquid level must be at least 15,100 liters to start the pump. To lower the volume of sludge brought from Tank 40 for each SRAT batch and to ensure operation of the SPT transfer pump, the normal heel of 4,200 liters in the SPT will need to be raised from current levels. The heel levels were calculated to meet the physical constraints of the SPT and the targeted sludge volumes.

PPT Management

MST/SS are brought to the PRFT through the LPPP – Precipitate Pump Tank (PPT). This tank will be used to transfer MST/SS from both ARP and SWPF. There will be no change to PPT management during ARP/MCU operation as the frequency of transfers is low and allows time for DWPF to add MST/SS over several SRAT batches. During SWPF operation, PPT transfers will need to occur every week instead of every 6 months to transfer the 10,600 liters of MST/SS produced weekly to DWPF. This transfer pump is also not self-priming and the PPT must have a liquid level of at least 15,100 liters to transfer out of the PPT. These criteria were evaluated against current PPT heel levels to determine if new heel levels are required.

SE is brought to DWPF via a pass-through jumper in the LPPP that lies full. SE is added to the transfer line when MCU or SWPF completes a batch and an equivalent volume of SE already in the transfer line is pushed into the SEFT. There is no LPPP pump tank for SE that needs to be managed with the increased production rates of SWPF.

Processing Impacts

Wt.% Solids Content

Most of the solids content in the SRAT comes from the sludge. Decreasing the volume of sludge without any mitigative strategy will decrease the solids content of the SRAT. The design basis wt% solids for DWPF are 18-25 wt% in the SRAT product and 40-50 wt% in the SME product. The rheological properties of yield stress and consistency associated with these design basis solids ranges were based on simulant material which can differ from the properties of real waste. Throughout the different sludge macrobatches processed at DWPF, very different rheological properties have been seen. These rheological differences have resulted in processing adjustments to vary the wt% solids in order to process the batch in the facility with the capabilities of the installed equipment. Current processing of SB9 has not displayed any rheological issues with a SRAT solids range of 18-25 wt% and a SME solids range of 27-41 wt%. However, SB9 is still a relatively new batch and has not yet been consistently processed at the extremes of these ranges.

A prediction of wt% solids throughout the Chemical Process Cell (CPC) at 34% waste loading (WL), grams of waste oxides per grams of glass oxides, was conducted using a spreadsheet with the same methodology as the SME Blend application currently in use by DWPF to provide the frit requirement and concentration endpoint for each SME batch. The spreadsheet was re-run using the results of the previous cycle until a steady state was reached. This prediction was compared to DWPF design basis and SB9 processing history for total weight percent solids content. No MST/SS addition was considered for ARP/MCU operation. DWPF receives a MST/SS transfer approximately once a month during ARP/MCU operation and it is not available for addition to most SRAT batches. For SWPF operation, an MST/SS addition was considered for every SRAT batch as SWPF plans to transfer one batch per week to DWPF.

SE Additions

This section will evaluate changes to the current processing strategy. Maximizing salt volumes in each SRAT batch will be felt mainly in the increase of SE additions. Future SRAT batches will always contain SE and contain MST/SS when it is available. The maximum volume of SE that can be added under the ARP/MCU Safety Basis is 40,300 liters at 3.96 Ci/L. A volume of 40,100 liters will be used as the nominal SE addition for ARP/MCU operation.

SWPF will produce SE at a much higher rate than ARP/MCU. It will produce 48,450 liters of SE approximately every 6 days. A new Safety Basis limit will be established under SWPF operation to allow for increased volumes of SE per SRAT batch. The new limit will be based on a maximum curie concentration in the SRAT. This corresponds to a maximum of 85,900 liters of SE at 17.4 Ci/L Cs-137 when the contributions from the SRAT heel and sludge are not included. If they are included, this volume would decrease. A consistent volume of SE can be added to each SRAT batch when the SRAT heel and sludge volumes are uniform from batch to batch.

Boiling Time

Increasing the SE volume per SRAT batch will increase the SRAT boiling time. Currently, 75,000 pounds of steam, or 25 hours at nominal steam rates, are required to strip the mercury in the SRAT. The maximum SE addition rate is 37.9 liters per minute and is limited by a safety orifice in the line. The orifice protects against creating a flammable atmosphere in the SRAT by restricting the rate at which the flammable solvent constituent, Isopar L, releases into the vessel headspace when it is introduced to the SRAT. SE is currently added at approximately 19 liters per minute so that the contents added match the rate contents are being boiled off to maintain a consistent level. During the 25 hours of boiling required to strip the mercury, approximately 28,400 liters of SE can be added. Additional SE will increase the overall boiling time. The additional boiling time was calculated and used to determine cycle time.

Formate destruction over time increases during boiling and causes the pH of the SRAT to increase, resulting in the precipitation of soluble species from solution. The precipitation of the soluble solids can influence the rheological behavior of the SRAT product and potentially cause issues with the sample or transfer pumps in the vessel. Significant formate destruction during the SRAT cycle can change the redox state of the slurry and potentially impact Melter operation. Nitric and formic acids are used to adjust the redox of the slurry in the SRAT to be within a range of 0.09-0.33 for Melter operation. Formic acid acts as the reductant while nitric acid serves as the source of the oxidant. If the feed is too oxidized, it can cause operational issues like foaming in the melter. If the feed is too reducing, it can cause unwanted precipitation and accumulation of metals in the melter. The precipitated metals can form a conductive layer and shorten the operating life of the melter. Destruction of the reductant causes the feed to become more oxidizing which shifts the redox toward 0.09. The impact of formate destruction was evaluated using recent process history.

Cycle Time

CPC processing occurs in batches: one batch of waste is treated with acid, stripped of mercury, and sent to the SME to be mixed with frit. Cycle times, the length of time to process a vessel, should be balanced between the vessels and short enough to meet the production rates of the upstream salt facilities. The SRAT is the only CPC vessel that currently receives SE. Therefore, the increase of SE volumes will only impact SRAT cycle times.

The increase of MCU SE volumes and occasional caustic boiling to add ARP MST/SS are not expected to increase the CPC cycle times such that DWPF cannot match the pace of ARP/MCU upstream and were not further evaluated.

The DWPF CPC cycle times during SWPF operation was the only case analyzed. A prediction of the SRAT and SME cycle time was performed and compared to the upstream throughput rates to determine if DWPF could match the required processing speeds. A MST/SS addition will occur every SRAT batch and increase the average caustic boiling time. A SE addition will also occur every SRAT batch after acid addition and require more boiling time than necessary to strip the mercury from the SRAT. The SME cycle time will not be impacted by an increased volume of SE. There are no changes to analytical requirements for SWPF processing at this time that would increase the cycle time. The nominal SWPF MST/SS addition of 10,600 liters and SE addition of 48,450 liters was used to determine the cycle time. Activity durations were based on times seen at peak canister production and engineering judgment.

Waste Water

The waste water tanks in the CPC will be affected by the reduction of solids in the SRAT and SME as well as the increased volume of SE in each SRAT batch. The reduction of solids in the SME directly effects the volume of condensate sent to the Off-gas Condensate Tank (OGCT) per MFT batch. The lower the solids content, the more water is evaporated in the melter, and the faster the OGCT fills. An increase in SE additions to the SRAT will cause an increase in condensate sent to the Slurry Mix Evaporator Condensate Tank (SMECT) as the concentration endpoint in the SRAT remains the same even with larger volumes of SE added to the SRAT. The SMECT collects the condensate from concentration in the SRAT and the SME. Including PRFT material additions to every SRAT batch under SWPF operation will also increase the volume from the SRAT to the SMECT. The addition of increased volumes of salt streams for both ARP/MCU and SWPF processing causes more frequent SMECT transfers to the RCT than current operation. The expected waste water volumes were evaluated and compared to current waste water transfers to determine the impact.

Regulatory Impacts

Canister Heat Generation

The projected canister heat generation of combined incoming streams is a criterion set forth by DWPF in its WAC before it will accept waste from another facility. DWPF proves this criterion is met during qualification of a new sludge macrobatch. This value is calculated via an equation given in the DWPF WAC for ARP/MCU transfers and SWPF transfers. This equation is based on the concentration and pre-determined coefficient of each reportable radionuclide. This equation is then used to calculate the maximum contribution from the sludge, MST/SS, and SE separately. The three contributors to canister heat generation are then added together to calculate the total canister heat generation. Most of these reportable radionuclides exist in the sludge. If the volume of sludge per SRAT batch is decreased, then the concentrations of many of these isotopes will decrease for the sludge portion of the canister heat contribution. The cesium concentration will increase because of the increased SE addition. Concentrations of isotopes in the MST/SS stream will remain similar to or lower than current processing levels.

The canister heat generation equation provided in the WAC assumes 1,996 kg of glass at 50% WL. This is more conservative than reducing the volume of sludge used, so the volume of sludge was not varied for the sludge component. The maximum allowable volume of 20,100 liters MST/SS was used for both ARP/MCU and SWPF operation. The maximum allowable volumes of 56,800 and 85,900 liters SE were used for ARP/MCU and SWPF operation, respectively. The canister heat generation value was calculated using the equations given in the WAC and compared against the limits also given in the WAC.

Gamma Shielding

Reducing the volume of sludge per SRAT batch will slightly change the concentration of the radionuclides from the sludge within a SRAT batch. The soluble radionuclide concentration may increase because of MST/SS additions. However, bringing in lower volumes of sludge and concentrating the SRAT to the same volumetric endpoint of 22,700 liters would result in a lower overall concentration. The increased SE addition volumes to a SRAT batch will increase the total Cs-137 concentration in the SRAT product stream.

The impact of increased cesium from salt processing on the shielding above transfer lines, the LPPP, and in the DWPF was evaluated during the design of MCU up to a maximum of 12.2 Ci/L in the SRAT product and deemed acceptable. Using the new lower volumes of sludge and maximum volumes of MST/SS and SE, the curie content per liter of Cs-137 in the SRAT product stream was calculated and compared against the acceptable range.

The SE from SWPF operations is expected to be 17.4 Ci/L and will exceed the previously performed analyses. New Radiological Engineering and Health Physics evaluations on the radiological impact of the SWPF feed to DWPF conclude the facilities bulk shielding is adequate to maintain personnel exposure below administrative limits when 37,900 liters of sludge per SRAT batch and 17.4 Ci/L SE from SWPF are considered. Decreasing the sludge volume from 37,900 liters while keeping the SE addition constant will decrease the Cs-137 concentration in the SRAT product stream from the design values as the design values account for a higher volume of sludge. This decrease in Cs-137 from the sludge is negligible when compared to the Cs-137 contribution from the anticipated SE and is not further evaluated in this paper.

RESULTS

This section provides the results for LPPP management, processing considerations, and regulatory limitations. Each section discusses the subject for both ARP/MCU and SWPF operation, if necessary. See Table I for a summary of criteria evaluated. Table II shows a summary of the results.

TABLE II. Summary of the criteria evaluated and the results.

Focus Area	Criteria	Current Operation	ARP/MCU Operation	SWPF Operation
LPPP Management	*SPT Management*	Heel volume: 4,200 liters	Heel volumes will increase	Heel volumes will increase
	PPT Management	Heel volume: 4,200 liters	Not evaluated	No heel volume adjustment
Processing Impacts	*Wt.% Solids Content*	SRAT: 18-25 SME: 27-41	SRAT: 17 SME: 33 Facility monitoring of process parameters to identify rheological deterioration	SRAT: 20 SME: 36 Facility monitoring of process parameters to identify rheological deterioration
	SE Additions	Once available, manageable impact to processing speed	Every batch, manageable impact to processing speed	Every batch, significant impact to processing speed
	Boiling Time	25 hours	35 hours	43 hours
	CPC Cycle Time		Not evaluated in this paper.	6.0 days at 100% attainment
	Waste Water	3.3 RCT transfers	3.6 RCT transfers, significant increase in volume to the SMECT, slight increase to OGCT	4.3 RCT transfers, significant increase in volume to the SMECT, slight increase to OGCT
Regulatory Impacts	*Canister Heat Generation*	N/A	Limit: 792 W/can Projected: 335 W/can	Limit: 792 W/can Projected: 325 W/can
	Gamma Shielding	N/A	Limit: 12.2 Ci/L Projected: 4.91 Ci/L	Not evaluated in this paper.

LPPP Management

SPT Management

The minimum SPT heel levels were calculated to meet the constraints of lowering the volume of sludge per SRAT batch while also achieving the minimum level for transfer pump suction. These new levels are shown in Table III.

Table III. Volumes in the SPT after each step required to bring the targeted volume of sludge to the SRAT. The volumes shown include any drain-back that occurs after the pump is stopped. All values are given in liters.

Total Sludge Volume	After Sludge Transfer #1	Heel #1	After Sludge Transfer #2	After Flush Water	Heel #2
20,250	17,000	4,350	2,600	17,000	4,200
18,900	17,000	4,350	2,600	17,000	4,900
17,700	17,000	4,350	2,600	17,000	5,700

PPT Management

The normal heel in the PPT is 4,900 liters. This transfer pump is also not self-priming and requires a minimum liquid level of 15,100 liters to transfer out of the PPT. With SWPF producing 10,600 liters of MST/SS per week that will pass through the PPT, this volume requirement will be met, and heel volumes will not need to be adjusted.

Processing Impacts

Wt.% Solids Content

Figure 2 depicts the predicted wt% solids in both the SRAT and the SME under ARP/MCU operation for each sludge volume. Table IV shows the stabilized wt% solids prediction and the expected frit demand for each scenario.

The wt% solids in the SRAT during ARP/MCU operation will decrease slightly if the sludge per SRAT batch is decreased. The SRAT is predicted to stabilize at 16.38 wt% or 17.13 wt% if the lowest or the highest sludge volume is processed, respectively. This is ~1.0 wt% lower than both design basis and SB9 processing so far.

The wt% solids in the SME during ARP/MCU operation will decrease significantly if the volume of sludge per SRAT batch is decreased. At the lowest sludge volume of 17,700 liters, the SME wt% solids stabilize to 29.6 wt%. This is lower than the design basis range, but within the observed range of wt% solids for SB9 that has not yet produced any processing difficulties. The highest sludge volume of 20,250 liters stabilizes to 33.3 wt%.

Figure 3 depicts the predicted wt% solids in both the SRAT and the SME under SWPF operation for each sludge volume. Table V shows the stabilized wt% solids prediction and the expected frit demand for each sludge volume.

The wt% solids in the SRAT and the SME during SWPF operation are higher than those projected for ARP/MCU operation. This increase is due to the addition of the 6 wt% dried solids SWPF MST/SS stream to every SRAT batch. The wt% solids in the SRAT will stabilize to 19.93-19.45 wt% and is within both the design basis and solids range already seen during SB9 processing. The wt% solids in the SME during SWPF operation will be below design basis but remain within the wt% solids window for SB9. The highest sludge volume of 20,250 liters causes the SME solids to stabilize at a higher value of approximately 37 wt%.

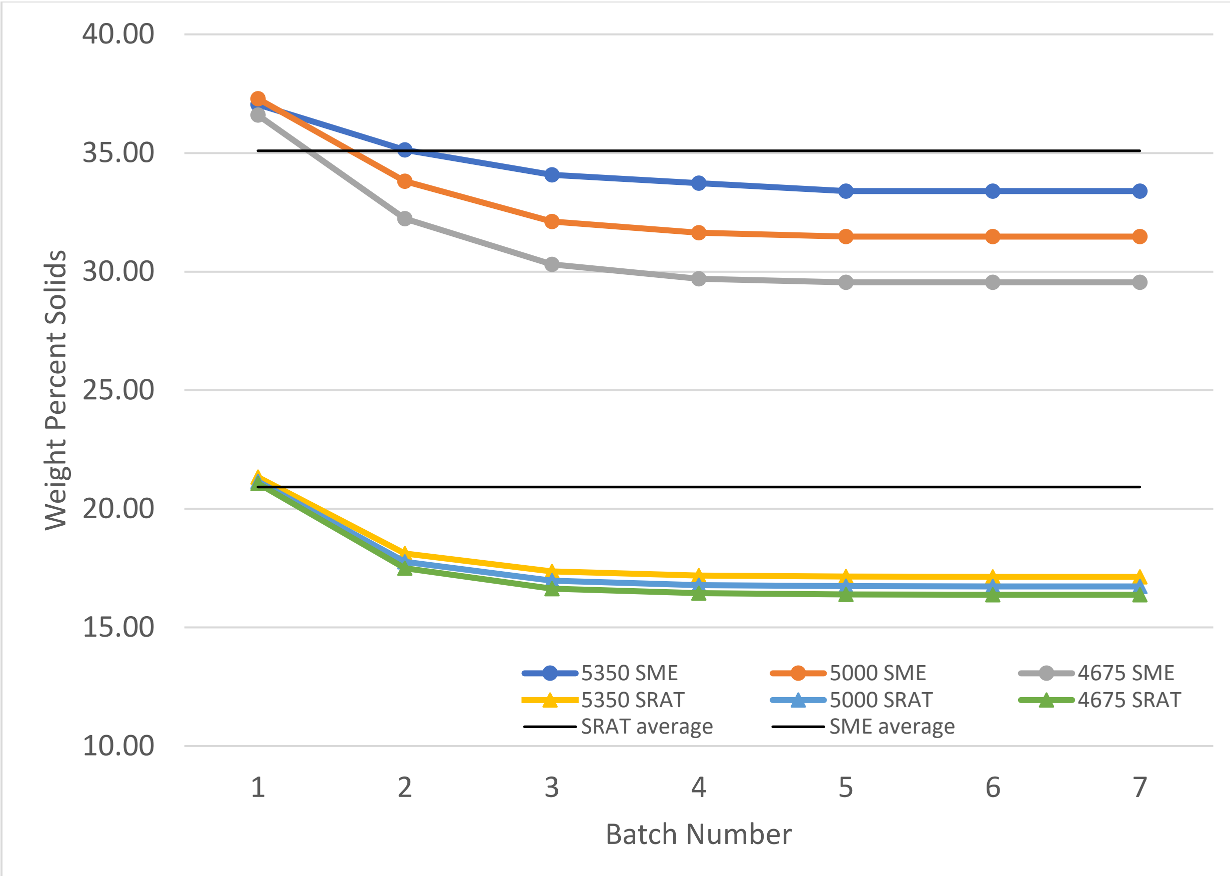

Figure 2. Weight percent solids at the end of SRAT and SME processing during ARP/MCU operation for the first 7 batches at 34% WL. Each line represents a different volume of sludge from Tank 40 in either the SRAT or the SME.

TABLE IV. Stabilized SRAT and SME wt% solids and frit demand for each sludge volume under ARP/MCU operation.

Volume of sludge to the SRAT [L]	Stabilized wt.% solids in the SRAT	Stabilized wt% solids in the SME	Frit demand [kg]
20,250	17.13	33.39	4,041
18,900	16.73	31.48	3,832
17,700	16.38	29.55	3,650

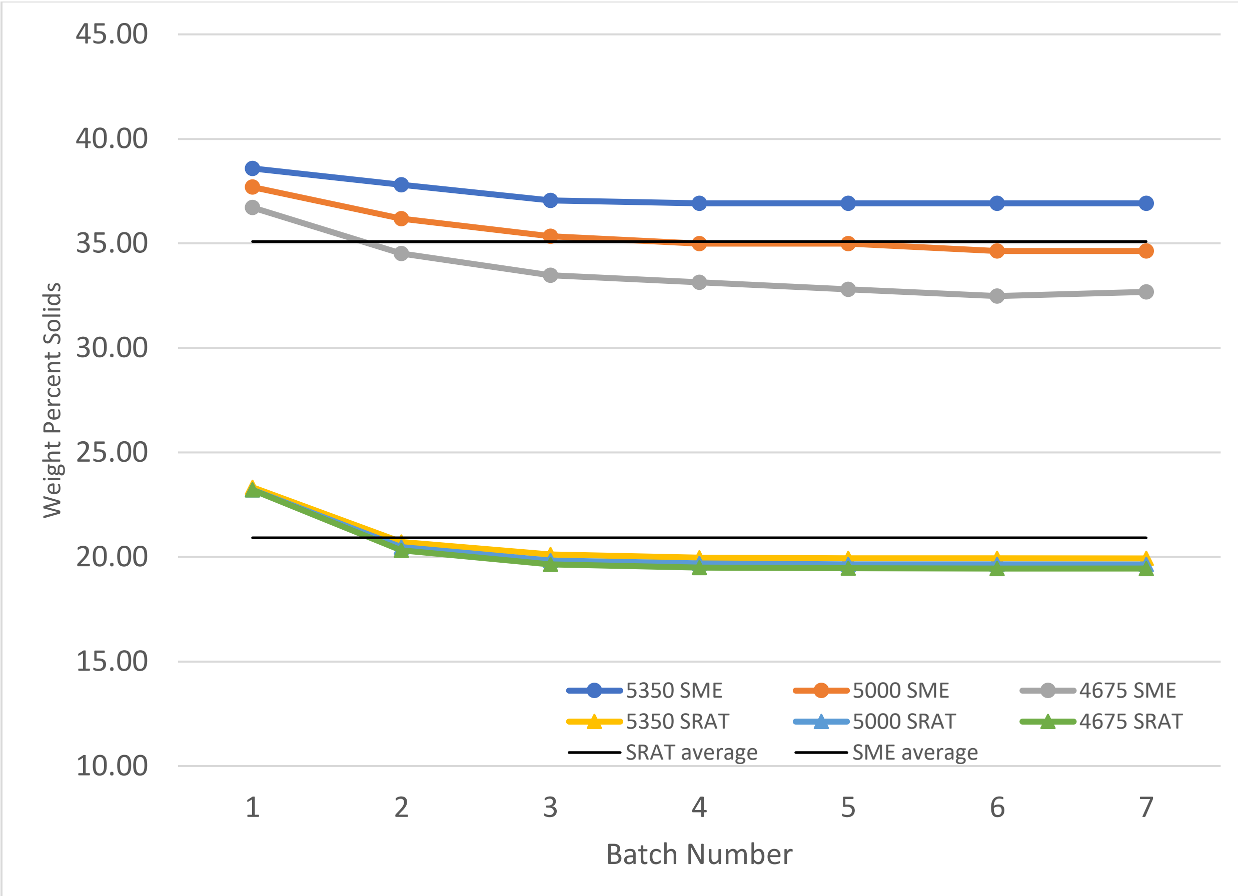

Figure 3. Weight percent solids at the end of SRAT and SME processing during SWPF operation for the first 7 batches at 34% WL. Each line represents a different volume of sludge from Tank 40 in either the SRAT or the SME.

TABLE V. Stabilized SRAT and SME wt% solids and frit demand for each sludge volume under SWPF operation.

Volume of sludge [L]	Stabilized wt.% solids in the SRAT	Stabilized wt% solids in the SME	Frit demand [kg]
20,250	19.93	36.92	4,005
18,900	19.64	34.64	3,793
17,700	19.45	32.68	3,612

SE Additions

A SE addition volume of 40,100 liters for ARP/MCU operation requires multiple transfers from the SEFT to the SRAT, with a refill of the SEFT in between transfers to the SRAT. The working volume of the SEFT is 29,100 liters. Multiple SE additions to the SRAT have never been needed prior to the new processing goal of maximizing salt volumes. This will require procedure revisions to control the volume of SE added to a SRAT batch such that safety basis limits are not exceeded.

SWPF will produce SE at a much higher rate than ARP/MCU. It will produce 48,450 liters of SE approximately every 6 days with a new Safety Basis limit of 85,900 liters of SE at 17.4 Ci/L Cs-137 when the contributions from the SRAT heel and sludge are not included. If they are included, this volume would decrease. A minimum of 45,450 liters of SE need to be added to a SRAT batch and the SRAT cycle time must be less than approximately 6 days to match the pace of SWPF.

Increased Boiling Time

Boiling the SRAT for the 25 hours required for mercury stripping allows for the addition of approximately 28,400 liters of SE without impacting the cycle time. Any increase in the SE addition volume past 28,400 liters will increase the SRAT cycle time. An additional 10 hours is required to boil 40,100 liters of SE during ARP/MCU operation and 18 additional hours are required to add the nominal 48,450 liters of SE during SWPF operation.

Three SB9 SRAT batches received over 100,000 pounds of steam. There were no abnormal conditions observed during processing of those batches. Adding the targeted 40,100 liters of SE per SRAT batch under ARP/MCU operation requires an extra 10 hours of boiling, or a total of 105,000 pounds of steam. Adding the targeted 48,450 liters of SE per SRAT batch under SWPF operation requires an extra 18 hours of boiling, or a total of 129,000 pounds of steam. It is not expected that this increase will cause a dramatic difference in processing. However, formate destruction and processing abnormalities will be monitored during implementation of higher volumes of SE.

Cycle Time

The cycle time in the SRAT is 144 hours, or 6.0 days, under SWPF operation. This value represents DWPF production at 100% attainment, MST/SS always being available, and SE being available in 24,225 liter batches every 3 days. This cycle time of 6.0 days allows DWPF to keep up with the SWPF throughputs of 10,600 liters MST/SS every 7 days and 48,450 liters SE every 6 days.

The cycle time in the SME is 3.5 days. The extra 2.5 days between SRAT and SME cycle times would allow for any remediation of a SME batch with water or nitric acid without impacting overall cycle time. If remediation of a SME batch required more sludge, overall cycle time would be impacted as SRAT processing would need to be completed before a partial transfer to the SME for remediation. It is difficult to predict the duration of a sludge remediation.

Outages in DWPF occur and prohibit always processing one SRAT batch per week. Assuming 75% attainment, DWPF would produce 39 SRAT batches in 1 year. There will be periods where processing stops completely for maintenance and other times where processing will take longer than anticipated. An estimated 39 SRAT batches per year is an attempt to account for both types of increased cycle time.

If DWPF cannot process at least 10,600 liters of MST/SS and 48,450 liters of SE per SRAT batch in under approximately 6 days, SWPF throughput could be affected. There is little lag storage between the two facilities. This will cause DWPF and SWPF to be tightly coupled. There is a maximum of 29,100 liters SE storage in the SEFT and 39,200 liters MST/SS storage between the PPT and the PRFT. These values are the working volumes of the tanks. The maximum lag storage available is equivalent to approximately 25 days of MST/SS production and 3.6 days of SE production. A shutdown at DWPF could impact SWPF throughput, up to and including a shutdown of SWPF. This would be dependent upon the storage capacity of both facilities, the current processing status of both facilities, and the duration of the DWPF outage.

Waste Water

Approximately 3.3 RCT batches are required to process one CPC batch with the current volume of ARP/MCU salt streams. This will increase to ~3.6 RCT batches with 40,100 liters ARP/MCU SE per SRAT batch. This slight increase will have a minimal impact on the laboratory. Under SWPF operation, the number of RCT batches will increase to ~4.3 batches per CPC batch because of MST/SS additions to every SRAT batch and increased volumes of SE. This increase is more significant, resulting in one additional RCT transfer per CPC batch. This will increase the demand on the laboratory to analyze RCT samples to determine the volume of sludge sent back to Tank 22 and increase the volume of recycle waste water sent to CSTF resulting in a larger load on the 2H evaporator.

Decreasing the solids in a batch will slightly decrease the volume of water sent to the SMECT by the SME and increase the volume of water sent to the OGCT. Increasing the water sent to the melter could cause pressure spikes in the melter vessel as the water flashes to steam and the melter pressure control system works to balance it. It will also likely increase the load on the steam atomized scrubbers and the condenser in the Melter Offgas System. Increasing the number of RCT batches sent to CSTF will increase the number of samples performed by the DWPF laboratory personnel.

Regulatory Impacts

Canister Heat Generation

The projected canister heat generation was calculated using the equations given in the DWPF WAC for ARP/MCU and SWPF operation. This equation is based on the concentration and pre-determined coefficient of each reportable radionuclide. The results for the total heat generation values for ARP/MCU and SWPF operation are shown in Table VI.

TABLE VI. Total canister heat generation values for ARP/MCU and SWPF operation at varying volumes of sludge.

	ARP/MCU		SWPF	
Sludge only [W]	52.44		52.53	
MST/SS [W]	30.95		21.38	
Volume sludge [L]	SE contribution [W]	Total canister wattage [W]	SE contribution [W]	Total canister wattage [W]
20,250	140.2	**223.6**	219.6	**293.5**
18,900	150.0	**233.4**	234.9	**308.8**
17,700	251.3	**334.7**	251.3	**325.2**

During ARP/MCU operation, adding 20,100 liters MST/SS and 56,800 liters of SE to each SRAT batch with lower volumes of sludge remains within the WAC limit for canister heat generation of 792 W/canister over all examined sludge volumes. During SWPF operation, adding 20,100 liters MST/SS and 85,900 liters of SE to each SRAT batch with lower volumes of sludge remains within the WAC limit of 834 W/canister over all examined sludge volumes. All examined scenarios are within WAC limits for canister heat generation.

Gamma Shielding

The impact of increased cesium from salt processing on the shielding above transfer lines, the LPPP, and in the DWPF was evaluated during the design of MCU up to a maximum of 12.2 Ci/L in the SRAT product and deemed acceptable. Using the new lower volumes of sludge and maximum volumes of MST/SS and SE, the curie content per liter of Cs-137 in the SRAT product stream was calculated to be 3.59 – 4.91 Ci/L, depending up on the sludge volume used. This range is bounded by the evaluation showing 12.2 Ci/L is acceptable.

DISCUSSION

Table II shows the focus areas evaluated and the results of each area. Most focus areas require acceptable processing changes for both ARP/MCU and SWPF operation. The weight percent solids warrant further discussion, shown below. The increase of waste water transfers will increase the number of samples performed by the DWPF laboratory and may affect personnel dose rates. This discussion is also shown below.

Weight Percent Solids and Rheology

The design basis wt% solids for DWPF are 18-25 wt% in the SRAT product and 40-50 wt% in the SME product. The rheological properties associated with these numbers are based on simulant material which has been shown to behave differently than real waste. Over the past five years, DWPF has been operating with the SRAT solids within design basis, at 21 wt%, and SME solids below design basis, at 35 wt%. During the brief history of SB9 processing, SRAT solids have been seen between 18-25 wt% and SME solids between 27-41 wt%. However, SB9 is still a relatively new batch and has not yet been consistently processed at the extremes of these ranges.

The highest sludge volume of 20,250 liters stabilizes to 33.3 wt% in the SME during ARP/MCU operation. This value is close to the current processing average of 35 wt%, but still below the design basis range of 40-50 wt%. SB9 can produce SME batches at the lower end of the design basis operating range, where the system was designed to perform. However, solids as low as 27 wt% have been successfully processed during SB9.

The highest sludge volume of 20,250 liters stabilizes to 37 wt% in the SME during SWPF operation. This value is lower than design basis, but within the range of solids seen during SB9 processing.

The sludge volumes can be lowered for both ARP/MCU and SWPF operation. Lowering the sludge volumes per SRAT batch will cause consistent operation at the low end of the ranges seen in SB9 processing so far and SB9 has not yet been consistently processed at the extremes of the wt% solids ranges. To lower the sludge volumes on a consistent basis, the facility will have to monitor for rheological deterioration through process indications. If this were to occur, it could be corrected by selecting a higher volume of sludge to process.

DWPF Laboratory

The increase in waste water transfers to CSTF due to increased SE will increase the number of samples the DWPF laboratory has to perform. This may cause a backup of samples for analysis within the lab as well as increase personnel exposure due to increased numbers of samples.

The increase in SE volumes per SRAT batch under both ARP/MCU and SWPF operation will cause dose rates to rise. It has been shown the dose rate will stay within facility shielding design limits. However, lab personnel will experience an increase in dose from current levels. Procedures and/or staffing may need to be adjusted accordingly.

During SWPF operation, some activities that require hands-on work will need to be performed differently, or not at all. For example, some equipment will need to be replaced instead of performing maintenance, and the laboratory will require a modified lab waste handling system. The lower volumes of sludge per SRAT batch will have a negligible effect on the on-going projects to maintain dose as low as reasonably achievable. The increased concentration of Cs-137 in the SE is being examined outside the scope of this study by Radiological Engineering and Health Physics.

CONCLUSIONS

The processing and regulatory impacts of lowering the volume of sludge while maximizing the volume of salt product streams were evaluated. Implementing these changes allows SRR to mitigate some of the schedule impacts caused by the DWPF Melter replacement and CSTF 3H evaporator system repairs. The impacts are:

<u>DWPF-ARP/MCU Operation</u>

1) A decrease in weight percent solids throughout CPC vessels. The volume of sludge per SRAT batch should be lowered step-wise. This will allow for consistent operation at lower wt% solids levels. The facility should monitor process indications for any rheological degradation. If this were to occur, it can be corrected by increasing the volume of sludge processed per SRAT batch.
2) No impact to SPT heel levels as the sludge volume will not be changed. Impact to PPT heel levels was not evaluated as the frequency of transfers is low under ARP operation and allows DWPF ample time to DWPF to add MST/SS over several SRAT batches.
3) There will be a slight increase in waste water volumes transferred to CSTF. The required number of RCT batches per SRAT will increase from 3.3 to 3.6 transfers.
4) The SRAT boiling time will be increased by 10 hours to add 40,100 liters SE to each SRAT batch. This will increase the total steam applied to a SRAT to approximately 105,000 pounds.

5) The addition of 20,100 liters MST/SS and 56,800 liters of SE to each SRAT batch with lower volumes of sludge remains within the WAC limit for canister heat generation of 792 W/canister over all examined sludge volumes.
6) The calculated curie content per liter of Cs-137 in the SRAT product stream is 3.59 – 4.91 Ci/L, depending upon the sludge volume used. This range is bounded by the evaluation showing 12.2 Ci/L is acceptable.

DWPF-SWPF Operation

1) A change in weight percent total solids in the CPC vessels. A sludge volume of 20,250 liters stabilizes to 37 wt% total solids at 34% WL.
2) The SPT heel will need to be raised to a minimum of 4,200 liters when the sludge volume is reduced to 20,250 liters from 22,700 liters. There is no impact to the PPT heel levels as the expected throughput of SWPF will meet the minimum levels required by the vessel.
3) The SRAT cycle time is 6.0 days at 100% attainment when 16,600 liters MST/SS and 48,450 liters SE are added to each SRAT batch. This cycle time matches the throughput of SWPF and any downtime experienced by DWPF may slow or stop SWPF production.
4) There will be a significant increase in waste water volumes transferred to CSTF. The required number of RCT batches per SRAT will increase from 3.3 to 4.3 transfers.
5) The SRAT boiling time will be increased by 18 hours to add 48,450 liters SE to each SRAT batch. This will increase the total steam applied to a SRAT to approximately 129,000 pounds.
6) The addition of 20,100 liters MST/SS and 85,900 liters of SE to each SRAT batch with lower volumes of sludge remains within the WAC limit of 834 W/canister over all examined sludge volumes.
7) The calculated curie content per liter of Cs-137 in the SRAT product stream is 3.59 – 4.91 Ci/L, depending upon the sludge volume used. This range is bounded by the evaluation showing 12.2 Ci/L is acceptable.

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