Actinide Removal Process Modified Flowsheet Demonstration: Filter Only Operation – 17415

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ABSTRACT

January 2016 marked the demonstration of the Actinide Removal Process (ARP) Filter-Only Flowsheet at the Savannah River Site's Liquid Waste Organization operated by Savannah River Remediation, LLC. This ongoing flowsheet demonstration has resulted in a marked increase in throughput over the historical Monosodium Titanate (MST) flowsheet through both increased facility availability and production rate. Not only has the Interim Salt Disposition Program been able to process salt waste more quickly, there has been more processing time between cleaning of the filter elements, which has the added benefit of reducing cesium-137 (Cs-137) loading to the Salt Disposal Facility (SDF). The new flowsheet is a promising improvement to salt waste processing, enhancing the mission of closing Waste Tanks at the Savannah River Site in Aiken, South Carolina. The demonstration of Filter-Only flowsheet has increased salt waste throughput, reduced Cs-137 load to the SDF, and may increase equipment longevity compared to the historical MST flowsheet. The gains in salt volume dispositioned through ARP/MCU benefits the safe, timely, and cost effective closure of legacy waste tanks at the Savannah River Site, reducing the most significant environmental risk in the State of South Carolina.

INTRODUCTION

The ARP and Modular Caustic Side Solvent Extraction Unit (MCU), collectively referred to as the Interim Salt Disposition Program or ARP/MCU, were developed to remove strontium, actinides, and cesium from alkaline salt waste in the interim period before startup of the Salt Waste Processing Facility (SWPF). In the MST flowsheet, salt waste is assembled and qualified in Tank 21 before being decanted to Tank 49, the feed tank for ARP. The salt solution is fed to the ARP in small 14000–14500 L batches where it is contacted with MST for a specified time for actinide adsorption. The MST/salt solution is then transferred to the 512-S building for filtration before the clarified salt solution is sent to MCU. Under the MST flowsheet, filtrate flowrate could only be maintained above 30 L/min for little over three or four batches before being reduced by 60% after only about 40 batches or processing ~575000 L of salt waste. To recover filter performance, the primary filter, a crossflow filter, would be chemically cleaned. Every two cleaning cycles, the dead end secondary filter, downstream of the crossflow filter, would require replacement. Each of these filter cleaning evolutions would require batch washing of the concentrated MST/sludge solids, sending wash water containing unprocessed Cs-137 directly to the SDF.

Since the ARP/MCU startup in 2008, the soluble strontium and actinides of the salt feed to the ARP have been below the Saltstone Waste Acceptance Criteria (WAC) limits meaning, that even without the MST treatment, the MCU Decontaminated Salt Solution (DSS) is qualified to feed the SPF. Salt batches could be processed in the ARP in filter-only operation, bypassing the MST Strike tanks entirely with no MST addition. Provided the salt batch qualification sample results show that the Salt Batch supernate meets the SPF WAC (except for cesium), the salt solution can be sent directly for filtration, and the remainder of the ARP (i.e. cross-flow filtration process) would continue to operate in the current configuration. No changes would be made to the MCU process.

ARP was modified so that the operation could be switched back and forth between the MST flowsheet and ARP filter-only operation, when applicable. The first of an anticipated two demonstration cycles of the Filter-Only flowsheet has shown an outstanding improvement in salt throughput. Average cycle batch wise filtrate flowrate increased to 32 L/min over 209 batches, more than double the number of batches of any other cycle. While the first 59 batches were intentionally restricted to 30 L/min, filtrate flowrates of over 38 L/min were observed after stepwise increase of flow set point to 38 L/min thereafter. Only after 135 batches did filtrate flowrate began to steadily decline, until the termination of the cycle with the completion of batch 209 after processing approximately 3078000 L of salt waste. Processing to 209 batches before batch washing and filter cleaning has the potential to reduce the Cs-137 load to the SDF by as much as 5 times over the average cycle length of ~40 batches. Finally, the maximum average Transmembrane Pressure (TMP), the driving force of crossflow filtration, was 213,737 Pa during the Filter-Only cycle compared to 241,317 Pa for the MST flowsheet cycles producing only 70% of the Filter-Only cycle flowrate. At lower TMP, the Filter-Only flowsheet may aid in extending the life of the crossflow filter while maintaining elevated filtrate flow to MCU.

Baseline ARP / MCU Flowsheet

The (Baseline) ARP facilities consists of two monosodium titanate (MST) Strike Tanks located in the 241- 96H Tank Farm facility and the 512-S facility. In the MST Strike Tanks, MST is added to the salt solution, followed by reaction time to allow some portions of soluble strontium and actinides to sorb onto the MST. The MST/salt solution is then transferred to the Late Wash Precipitate Tank (LWPT) in the 512-S facility for filtration. The products of this filtration are MST/sludge slurry and clarified salt solution (CSS). The MST/sludge solids slurry is accumulated and concentrated for multiple batches. The concentrated solids slurry is then washed to lower the soluble sodium concentration and transferred (along with spent filter cleaning solution) via the Low Point Pump Pit (LPPP) to the Precipitate Reactor Feed Tank (PRFT) in the Defense Waste Processing Facility (DWPF) to be vitrified. Slurry wash water is sent directly to Tank 50 for treatment in the Saltstone Production Facility (SPF).

The CSS is collected in the Late Wash Hold Tank (LWHT) until it is transferred to the MCU where most of the cesium is removed through a solvent extraction process. The products of the MCU process are the concentrated cesium solution stream, called strip effluent (SE), and a decontaminated salt solution (DSS) stream. The SE is transferred to the Strip Effluent Feed Tank (SEFT) in DWPF to be vitrified.

The DSS is transferred to Tank 50 to feed the SPF for final disposition.
Figure 1 shows the simplified diagram for the Baseline Salt Waste Treatment flowsheet. The ARP decontaminates low-curie salt solution via adsorption of strontium-90 (Sr-90), actinide radionuclides, and entrained sludge solids in the salt solution onto MST followed by filtration. The actinide, Sr-90, and MST laden sludge waste stream are transferred to DWPF for vitrification and the remaining clarified salt solution is transferred to the MCU process. The MCU process extracts Cs from the clarified salt solution using caustic side solvent extraction (CSSX) chemistry. The low Cs-137/low actinide DSS is subsequently transferred to Tank 50 for feed to the SPF, and the strip effluent (SE) solution of cesium nitrate from the CSSX process is transferred to DWPF for vitrification.

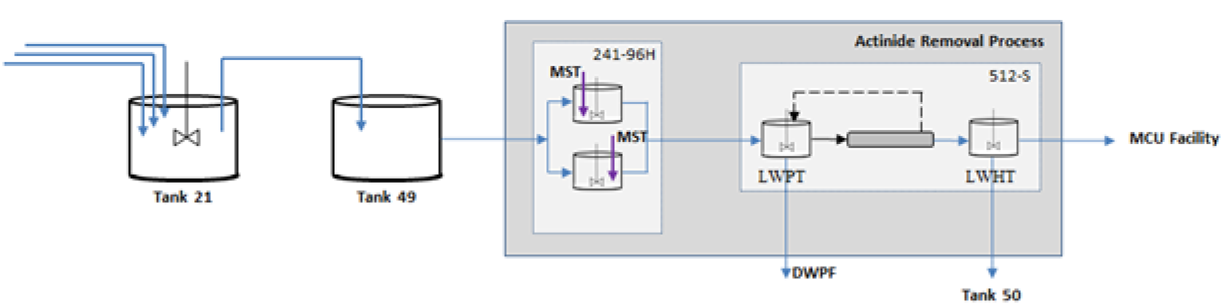

Fig 1. Schematic of the ARP/MCU Process

ARP FILTER-ONLY FLOWSHEET

Since the ARP/MCU startup in 2008, the soluble strontium and actinides of the salt feed to the ARP has been below the Saltstone Waste Acceptance Criteria (WAC) limits, which means even without the MST treatment, the DSS is qualified to feed the SPF. In fact, since Salt Batch 1, the salt batches have been qualified without crediting the effect of MST on soluble strontium and actinides. These batches could be processed in the ARP in filter-only operation. In filter-only ARP operation, the only difference in the ARP is that the salt solution does not receive an MST strike prior to filtration (i.e., soluble strontium and actinides are not removed from the salt waste).

If the salt batch qualification sample results show that the Salt Batch supernate meets the SPF WAC (except for cesium), the salt solution would be sent directly to the LWPT, and the remainder of the ARP (i.e. cross-flow filtration process) would continue to operate in the current configuration in building 512-S. No change would be made to the MCU process under ARP filter-only operations. Figure 2 shows the simplified diagram for Filter-Only ARP Salt Waste Treatment Flow Sheet.

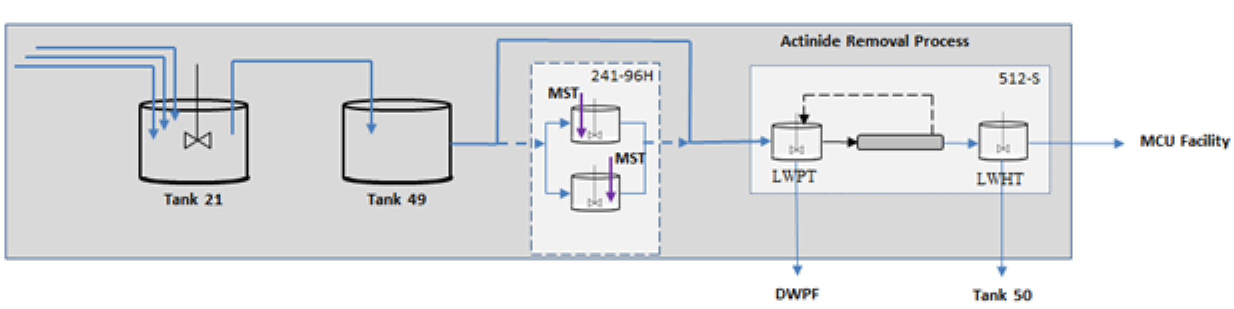

Fig 2. Filter Only (No MST Strikes) Salt Waste Treatment Flow Sheet

It was planned that the ARP would be modified so that the operation can be switched back and forth between the baseline ARP operation and ARP filter-only operation as required.

Flushing the Late Wash Precipitate Tank

Salt solution treated with MST/Sludge solids is transferred to 512-S from two Strike Tanks at 241-96H. The material is processed through a cross flow filter to concentrate the solids in the LWPT. Batches of the MST-treated salt are filtered until a desired weight percent MST/Sludge solids is reached in the LWPT heel. The solids in the LWPT are then washed, and a chemical cleaning of the cross flow filter is performed. DWPF operations tracks the mass and weight percent solids through the filtration cycle only. Operations requests from engineering the mass of solids in the LWPT at the beginning of a cycle. Once that number is obtained, operations tracks the mass and weight percent solids in the LWPT procedurally for the cycle.

Flushing of LWPT is done to prepare the process for transitioning into a no-MST flowsheet. Under the no-MST flowsheet, the ARP operations is modified to include a “Filter Only” (i.e., no MST strike in 241-96H) option when the actinide and strontium loading in the salt solution batch in Tank 49 is acceptable for transfer to Saltstone. The Nuclear Criticality Safety Evaluation specifies that the LWPT to be inventoried to less than 8490 grams of MST prior to entering filter-only operations. This ensures that the MST left in the LWPT will not adsorb enough fissile material to result in a criticality. Flushing the LWPT also helps ensure that the Filter-Only operation starts with trivial amount of solid in the LWPT (feed tank).

Demonstrated Performance

Direct transfer from Tank 49 to ARP LWPT without the addition of MST began in January 2016 and thus far has had a very positive change in flow performance as compared to previous cycles. The first no-MST Filter Only cycle, designated as SB8BCY2 (Salt Batch 8B Cycle 2) in Figure 3, exhibited very different performance indicators compared to MST laden cycles SB7BCY3 and SB7BCY4. SB7BCY3 and SB7BCY4 are also shown in Figure 3.

The ARP facility successfully demonstrated increasing the filtrate flowrate target by 25% from 30.3 L/min to 37.8 L/min and has sustained the average filtrate flowrate within 10% of this filtrate flow rate for over 100 batches. To protect the crossflow filter, care was taken to ensure that transmembrane pressure (TMP) would not increase beyond 275.8 kPa. The increase in filtrate flow rate was performed in 1.9

L/min increments over 3-5 batches in length. Transmembrane pressure required to achieve 30.3 L/min filtrate flowrate during Filter-Only operation was significantly lower, 83-96.5 kPa compared to 138-207 kPa for MST operation. After secondary filter replacement, SB7BCY3 TMP increased 20% over the initial three batches after batch 5. SB7BCY4 experienced an even larger, 75%, increase in TMP over the first three batches of cycle startup using the same secondary filter. Startup of the filter-only cycle experienced only an 8% increase in TMP over the first three batches, again, using the same secondary filter.

Normalizing transmembrane pressure to filtrate flowrate is useful for comparison and gives an indication of the required driving force necessary (TMP) per L/min filtrate. More efficient crossflow filtration is indicted by lower requisite normalized TMP, TMP divided by filtrate flowrate. Normalized TMP during Filter-Only operation was less than half that required for SB7BCY4 indicating filtration of the LWPT is progressing more efficiently with fewer solids requiring half the driving force per unit of filtrate flow. Lower TMP allows extending the crossflow filter cycle while maintaining elevated filtrate flow to MCU.

A Filter cleaning evolution has been performed and crossflow filter performance did recover. The first batch of the first Filter-Only cycle completed with 2.893 KPa/L/min normalized TMP, and the final batch of the cycle completed with 8.924 KPa/L/min showing clear crossflow filter fouling as a result of processing. Post crossflow filter cleaning, the first batch completed with a normalized TMP of 2.627 KPa/L/min, demonstrating the cleaning cycle successfully restored filter performance. Over the first 52 batches of SB9CY1 the filter has maintained an average normalized TMP of 3.534 KPa/L/min, which is slightly higher than the previous Filter-Only average at this point in the cycle, but it is still significantly better than historical performance with MST. The secondary filter did not exhibit the fouling characteristics typically observed after a cleaning evolution. Filtrate pressure to the secondary filter did increase over per-cleaning values, but it was slowly over the course of 10 batches. There was an insignificant change in filtrate pressure at the start of SB9CY1. Pressure rise reached a plateau after the first 17 batches of SB9CY1 and has remained steady though batch 52, about 10% higher than the start of the cycle. The cleaning evolution between Salt Batch 7B Cycle 2 and cycle 3 doubled the filtrate pressure immediately.

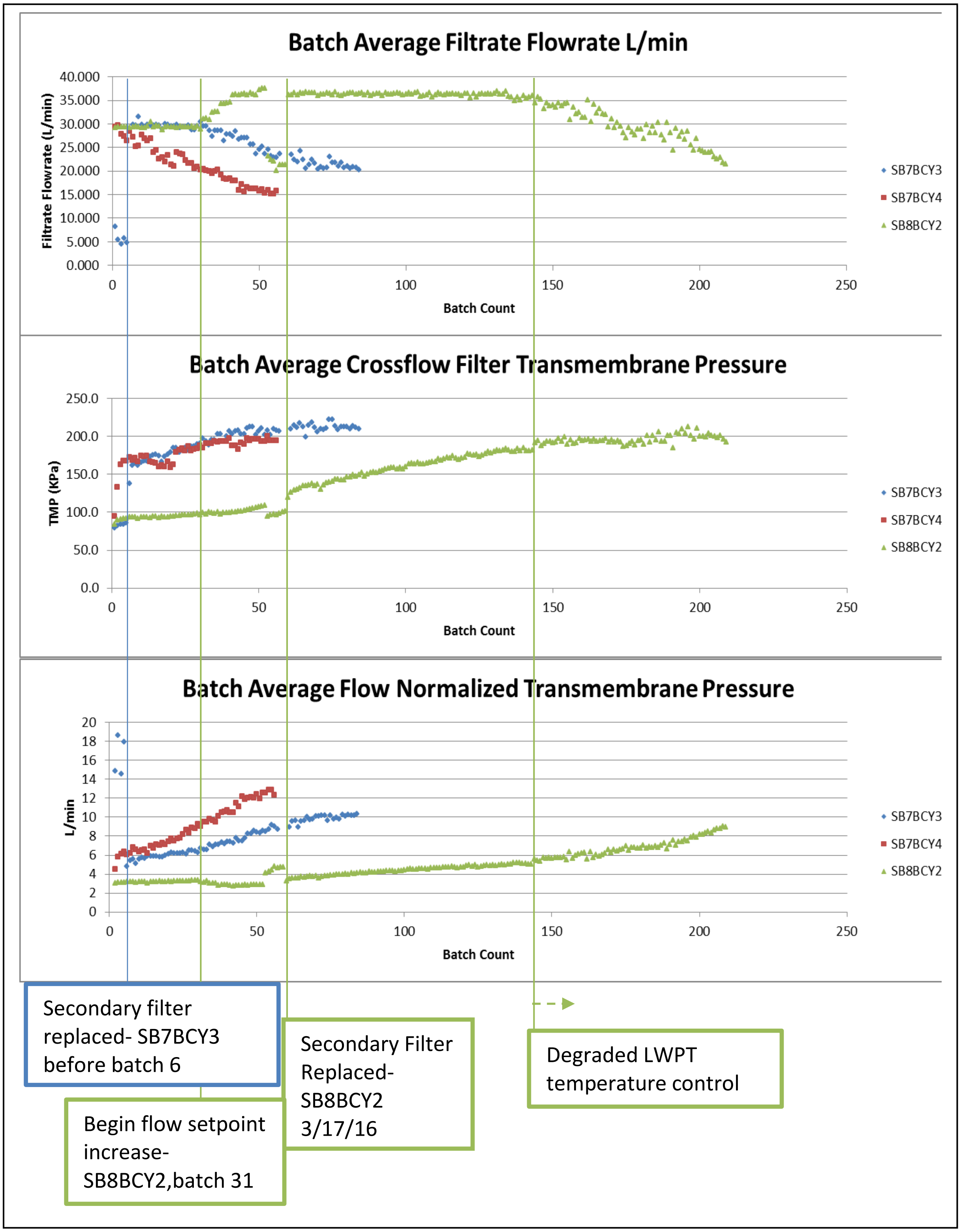

Fig 3. Filter-Only Demonstration Results Comparison

CONCLUSION

This paper presented a comparison of the MST and No-MST, or Filter-Only, Flowsheets currently being demonstrated at the Savannah River Site. Eliminating the addition of MST has resulted in significant increases in filtrate production. More than twice the volume of filtrate can be processed between filter cleanings and filtration is more efficient.