Evaluation of No-MST Operations in the SRS ARP for Hanford LAWPS

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EXECUTIVE SUMMARY

The Savannah River Site (SRS) Actinide Removal Process has been processing salt waste since 2008. This process includes a filtration step in the 512-S facility. Initial operations included the addition, or strike, of monosodium titanate (MST) to remove soluble actinides and strontium. The added MST and any entrained sludge solids were then separated from the supernate by cross flow filtration. During this time, the filter operations have, on many occasions, been the bottleneck process limiting the rate of salt processing. Recently, 512-S- has started operations utilizing "No-MST" where the MST actinide removal strike was not performed and the supernate was simply pre-filtered prior to Cs removal processing. Direct filtration of decanted tank supernate, as demonstrated in 512-S, is the proposed method of operation for the Hanford Low Activity Waste Pretreatment System (LAWPS) facility. Processing decanted supernate without MST solids has been demonstrated for cross flow filtration to provide a significant improvement in production with the SRS Salt Batches 8 and 9 feed chemistries. The average filtration rate for the first 512-S batch processing cycle using No-MST has increased filtrate production by over 35% of the historical average. The increase was sustained for more than double the amount of filtrate batches processed before cleaning of the filter was necessary. While there are differences in the design of the 512-S and Hanford filter systems, the 512-S system should provide a reasonable indication of LAWPS filter performance with similar feed properties. Based on the data from the 512-S facility and with **favorable feed properties,** the LAWPS filter, as currently sized at over twice the size of the 512-S filter (532 square feet filtration area versus 235 square feet), has the potential to provide sustained filtrate production at the upper range of the planned LAWPS production rate of 17 gpm.

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LIST OF ABBREVIATIONS

ARP	Actinide Removal Process
DWPF	Defense Waste Processing Facility
LAWPS	Low Activity Waste Pretreatment System
LPPPPT	Low Point Pump Pit Precipitate Tank
LWHT	Late Wash Hold Tank
LWPT	Late Wash Precipitate Tank
MCU	Modular Caustic Side Solvent Extraction Unit
MST	Monosodium Titanate
PRFT	Precipitate Feed Tank
SB	Salt Batch
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
TMP	Transmembrane Pressure

1.0 Introduction

The objective of this paper is to review the impact of "No-MST" operations on the Savannah River Site (SRS) 512-S facility and provide a comparison to the proposed filter operation for the Hanford Low Activity Waste Pretreatment System (LAWPS) facility. The intent of the comparison is to show that the filtration step has the potential to not be the rate limiting step in LAWPS operations. The 512-S facility commenced radioactive operations in April of 2008, and has processed approximately 6 million gallons of supernate and dissolved salt. For most of the processing history, the feed to the 512-S facility has contained two levels of monosodium titanate (MST) solids that were added to remove strontium and actinides. Recent operations have filtered the tank supernate without additions of MST. Operating in this manner, filtering decanted supernate, has 512-S utilizing the same strategy as LAWPS. Though there are differences in composition of the waste and the design of the filter systems between the two facilities, 512-S provides the largest set of operational data and lessons learned to gain insight to the filtration step for the LAWPS facility.

2.0 Experimental Procedure

2.1 Process Background
At the SRS there are a set of closely coupled facilities that process salt waste, removing strontium and actinides. The Actinide Removal Process (ARP) is designed to receive salt solution and spike the salt solution with MST. After allowing a reaction time during which sorption occurs, the material is processed through the cross flow filter to separate the MST/sludge solids from the salt solution.

The ARP is housed within two separate facilities, with the MST addition performed in 241-96H and the filtration of MST solids in 512-S. Historically, individual batches of salt waste are transferred to 241-96H where the waste was contacted with MST to sorb strontium and select actinides. The batches of salt solution containing MST sorbent are transferred to the Late Wash Precipitate Tank (LWPT) in 512-S and are concentrated by cross flow filtration, with the filtrate going to the Late Wash Hold Tank (LWHT) and sent to the Modular Caustic Side Solvent Extraction Unit (MCU) for cesium removal for eventual disposal as low level waste immobilized in grout. The concentrated MST slurry remaining in the LWPT is subsequently washed to lower the sodium molarity prior to transferring to the Low Point Pump Pit Precipitate Tank (LPPPPT) and then on to the DWPF Precipitate Feed Tank (PRFT) for vitrification as high level waste. The simplified process diagram is shown as Figure 1.
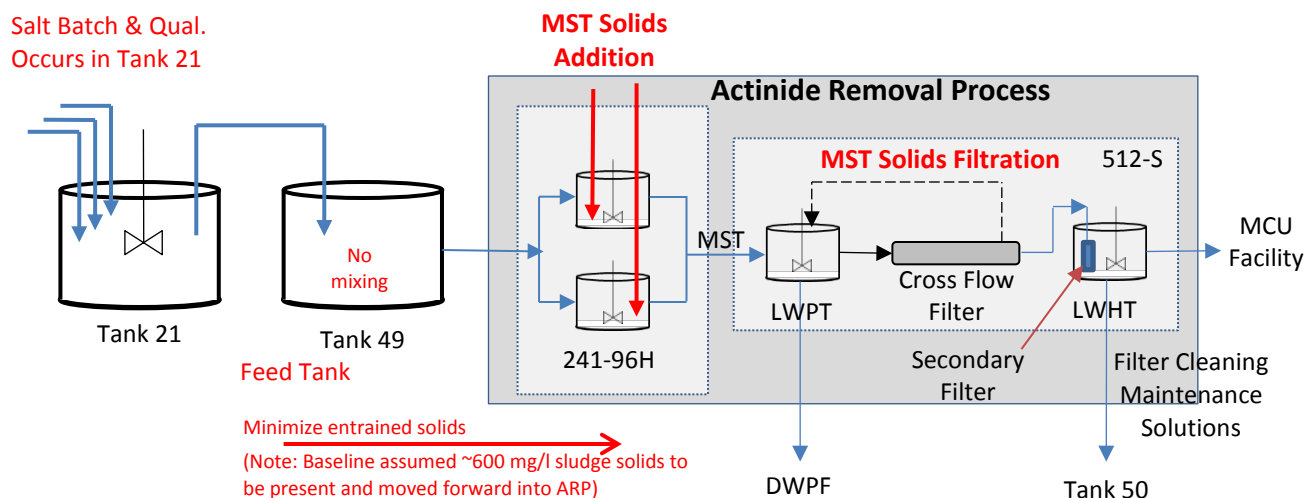
Figure 1. Simplified Diagram of the ARP Process

During cross flow filtration, slurry is recirculated through the tube side of the filter from the LWPT. Filtrate emerges on the shell side of the cross flow filter, is forced through a secondary filter, and enters the LWHT. A separate tank, the surge tank, is utilized during filter cleaning.

The original MST strike process utilized a dose of 0.4 grams MST per liter of waste. In order to improve the overall throughput, the MST addition was reduced to 0.2 grams MST per liter of waste starting with Salt Batch (SB) 5 Cycle 2 (November 2, 2012). An evaluation was performed by SRNL to determine the impact of the MST reduction, including the potential impact to filtration rate.[1] In November of 2015, it was proposed to eliminate the MST strike to increase the number of allowable batches per cycle to reduce the curie loading to Tank 50 and increase the filtration flowrate.[2]

2.2 Terminology

The terminology for the operation of the 512-S filter system is as follows. Each time the feed tank (LWPT) is processed is termed a "batch". Additional batches are run until one of two conditions has been met to interrupt processing. The first condition is that enough MST solids have accumulated that they must be removed to meet the safety basis of control for Pu accumulation (approximately 5 wt % MST). The second condition is that the filtrate production has dropped sufficiently to require cleaning. If either of these conditions is met, feed processing is halted and the contents of the LWPT are washed to lower the sodium molarity and transferred to DWPF for incorporation into glass. The filter is then cleaned. The collection of batches processed before solids are reset is referred to a "cycle". This has coincided with a filter cleaning of the cross flow filter. Therefore, each cycle consists of a series of batches (ranging from 10 to 209) that are accumulating solids in the LWPT.

Mott Corp rates their filter as "Media Grade" and not as an absolute micron rating (media grade 0.1, not 0.1 micron). The rating is based on particle capture efficiency instead of pore size. The capture efficiency per Mott literature is presented later in this report.

2.3 512-S Filter System Description

The original primary filter was a cross flow filter that contained 144 Mott® sintered metal filter tube elements with media grade of 0.1 and a total filter area of 235 ft². The filter tubes are made of 316L

stainless steel with an inner diameter of 0.625" and are 120" long. The filter was replaced in March of 2014 with a filter assembly of the same configuration with the exception of the media grade. The new filter utilized a Mott media grade of 0.5.

Figure 2 contains a drawing and a picture of the cross flow filter installed in 512-S.
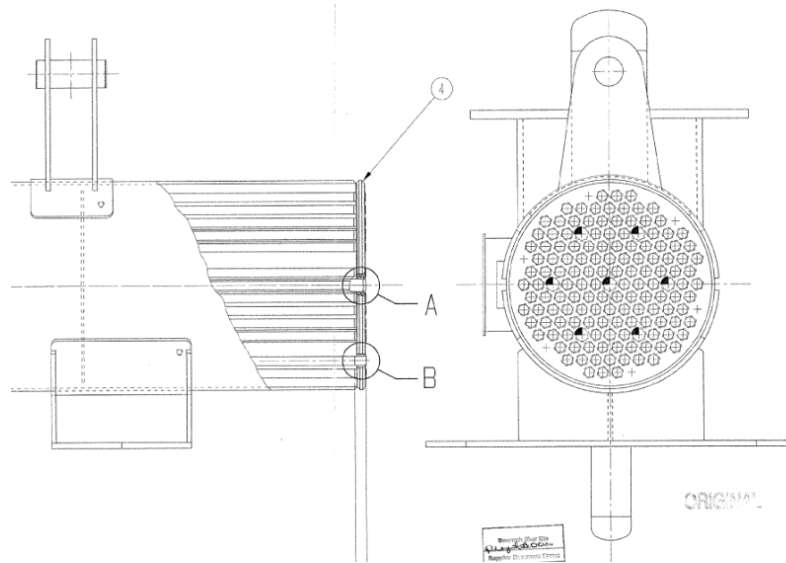
Figure 2. ARP Cross Flow Filter

The particle capture efficiency for the 0.1 and 0.5 Mott® filter media are shown in Table 1. As can be seen in the table; a very small fraction of particles, as large as 0.8 µm, can pass the 0.1 grade media. The fabrication of the porous metal filter media results in a series of interconnected, and sometimes disconnected, passageways of irregular size and shape leading from one surface to another. Some of these passageways, or pores, are relatively large and lead directly from one surface to another in a tortuous path which is continuously interrupted by obstacles of metal particles. Solid material moving through these passageways can get caught by a variety of mechanisms within the pore structure and eventually block or foul the pores. This results in an obstructed fluid movement through the media

reducing the filtration rate. When this happens to an undesirable degree, the media must be cleaned by removing the trapped material. Since the trapped material can occur at or on the media surface and/or within the depth of the media, the method of removal must take into consideration where the fouling material resides and how it is held in place. The fouling mechanism of filters during operation with only entrained solids ("No MST" ARP process and the expected operation of LAWPS) is likely to be different from the fouling during operation with higher levels of solids (initial ARP process and the expected operation of the filters in Waste Treatment and Immobilization Plant Pretreatment Facility). The lack of a known abundant solid particle may result in depth fouling (fouling within the pores) instead of cake fouling (build-up of a layer of solids on the membrane). A new cleaning strategy may be appropriate to optimize the efficiency based on the cause of filter fouling.

Table 1. Filter Particle Capture Efficiency for Mott® Filter Media[3]

Media Grade	Thickness	Particle Size - µm		
		Initial Collection Efficiency		
		90%	99%	99.9%
0.1	0.039"	0.15	0.4	0.8
0.2	0.039"	0.5	0.9	1.4
0.5	0.047"	1	1.7	2.2
1	0.047"	1.5	2.2	3.3
2	0.062"	4	5.5	9
5	0.062"	5	8	13
10	0.062"	10	15	20
20	0.062"	20	25	35
40	0.078"	25	35	45
100	0.093"	50	100	150

Testing performed per ASTM F795
Tested at 1 gpm/ft²
ISO A2 or A3 test dust suspended in water

The system includes an in-line secondary filter on the filtrate stream produced by the cross flow filter. The current secondary filter design is a dead-end filter constructed of 21 sintered metal filter tubes with a 0.5 media grade, with a total surface area of 16.5 ft². The tubes are made from 316L stainless steel and are also manufactured by Mott®. The filter elements sit inside the LWHT. In ARP, the filtrate from the cross flow filter is passed through a secondary filter prior to entering the LWHT. The secondary filter has a history of becoming fouled even though it is located on the filtrate side of the primary filter.[4] Figure 3 contains a drawing of the current secondary filter.
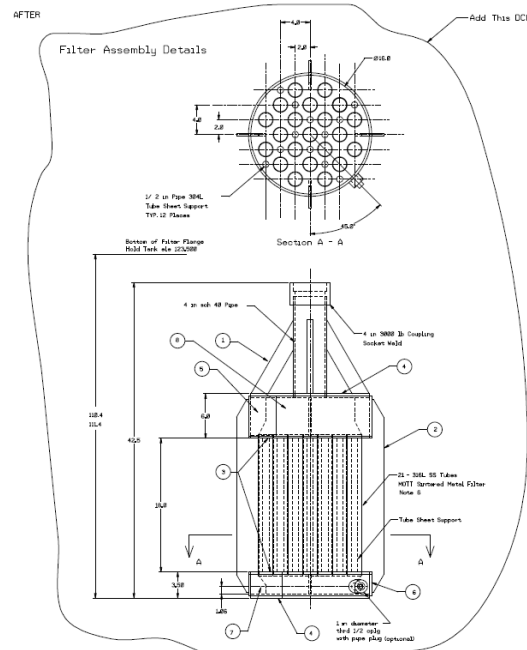
Figure 3. ARP Secondary Filter

2.4 512-S Comparison to LAWPS

2.4.1 Filter Hardware

The 512-S filter and the proposed filter for LAWPS have a couple of commonalities. Both filters are made by the same filter manufacturer, Mott Corp. In addition, the tube lengths are the same at 10 feet.

The LAWPS filter is being designed with an up-and-back flow configuration. In this configuration, the feed will flow up ½ of the filter tubes, collect in a header at the end of the filter bundle and then flow down the remaining tubes. The original and current 512-S filters have been single pass. A spare filter with a very similar up-and-back configuration has been designed and built for 512-S but has yet to be installed. Additional, very relevant data may become available if this filter is installed. The up-and-back flow configuration is designed to keep the axial velocity as high as possible. This is typically intended to minimize the size of the filter cake by imparting maximum shear, thus minimizing the buildup of solids on the filter walls. Because of this impact to the filter cake, a higher axial flow rate is generally expected to minimize performance degradation. However, higher axial flow rates have the most impact with higher insoluble solids feeds. Axial velocity has less impact on systems with low insoluble solids in the feed.[5] The majority of testing with Hanford waste and simulants was done with greater than 2 wt% solids with the exception of a few tests. A test using actual Hanford waste and very low solids (feed concentrated from 0.07 to 0.9 wt % insoluble solids) showed no correlation between axial velocity and filter flux.[6] A second report showed a negative correlation between axial velocity and filtration rate.[7] Therefore, the difference in axial velocity between the two systems is not expected to have a large impact on filter production.

The tube diameter is slightly larger for the 512-S facility. The largest impacts are to the wall shear forces[8], filter surface to feed-volume ratio and axial velocity. The impact on filtrate production between the two systems based on tube diameter is expected to be minor but the additional shear developed for the smaller diameter tubes would be expected to favor the LAWPS filter.

In 512-S the filter is horizontal, while the LAWPS filter orientation is vertical. Filter orientation is typically based on facility layout. Filter tubes are not constructed any differently for horizontal or vertical applications. In terms of filtration production, the difference between filter bundle orientations is minor. Vertical filters have the advantage that particles do not settle on the membrane surface and drain more easily.

Differences in feed flow rate and the number of tubes per bundle will only have a significant impact if flow distribution among the tubes is poor. Assuming each tube is provided sufficient feed, the impact of these parameters to filtrate production will be minor.

The change in media grade from 0.1 to 0.5 was not expected to have a large impact on filter performance. Previous studies with simulants had shown that the 0.1 filter outperformed the 0.5 filter[9] and was recommended for service at 512-S. It should be noted that the testing basis for that decision utilized sludge and MST solids, though testing did include insoluble solids as low as 0.026 wt %. Literature from the manufacturer, Mott, shows liquid flow (no solids) significantly higher for the 0.5 media grade over the 0.1 media grade (2 to 4X) at viscosities of 2 to 5 centipoise,[10] which is the typical range for supernatant viscosity.[11] The 0.5 media grade replacement filter operating at 512-S did not show a significant change in filtrate production over the original 0.1 media grade filter. An increase in performance was observed compared to the previous batches immediately after the filter was changed; however, the performance of the new 0.5 media grade filter was similar to earlier batches processed in the original 0.1 media grade filter.[25]

Both filters are expected to operate at approximately the same nominal temperature. The LAWPS maximum temperature is higher than for 512-S. Higher temperatures tend to increase filtration rate due to lower viscosity.

Both filters will have a component providing a backpressure to the filtrate line.

Table 2 provides a summary comparison of the 512-S and proposed LAWPS filters.

Table 2. Comparison of SRS 512-S Filtration Facility and Proposed LAWPS Filtration System

	SRS 512-S	LAWPS
Manufacturer	Mott	Mott
Tube length (ft)	10	10
Media Grade	0.1 then 0.5[*]	0.1
Number of filter bundles	1	2
Number of tubes per bundle	144	204[**]
Tube Inner Diameter (inches)	0.625	0.5
Total Filter Area (ft^2)	235	534
Axial Velocity (ft/sec)	8-10	14
Feed flow rate (gpm)	1200-1400	900
Orientation	Horizontal	Vertical
Operational Temperature (C)	20-30[***]	20-45
Downstream equipment	Dead end filter	Dual IX columns

[*]*The cross flow filter was replaced in 512-S after approximately 6 years and 4.5M gallons processed due to drop in production. The original filter was a 0.1 media grade, the replacement filter was a 0.5 media grade.*
[**]*2 sets of 102 filter tubes in series for each bundle.*
[***]*Temperature for MST strike*

Note that the proposed cleaning strategy for LAWPS utilized the elution acid from the IX columns to clean the filter. The cleaning acid would be 0.5 M nitric acid. The cleaning solution for 512-S is 0.5 M oxalic acid based on testing that demonstrated oxalic acid worked better than other alternatives, including nitric acid.[12]

2.4.2 Feed Chemistry

Of all differences between the two systems the difference in feeds is expected to be the most dominant. Table 3 gives the concentration of several key constituents from the SRS Salt Batch qualification samples compared to the projected LAWPS feed chemistry. The table looks at 7 key components, 3 of which are good indictors for the viscosity and 4 of which are good indictors for potential precipitation. In the table, the lowest concentration for a particular component from all of the SRS Salt Batches is highlighted yellow and the highest concentration is highlighted blue. Note that there is significant interaction with all components and these 7 were selected to provide a general indication of potential supernate behavior.

Table 3. Comparison of SRS Salt Batch Qualification Sample Chemistry to Projected LAWPS Chemistry

Feed Batch	Impact to Viscosity			Impact to Precipitation			
	Sodium (M)	Hydroxide (M)	Nitrate (M)	Oxalate (M)	Phosphate (M)	Aluminum (M)	Carbonate (M)
SRS SB1[13]	5.05	0.76	2.82	0.0066	0.0062	0.39	0.32
SRS SB2[14]	5.66	2.05	2.13	0.0047	0.0084	0.29	0.20
SRS SB3[15]	6.73	2.75	2.50	0.0025	0.0072	0.20	0.09
SRS SB4[16]	7.51	2.68	2.50	0.0023	0.0072	0.22	0.26
SRS SB5[17]	6.56	2.36	2.77	0.0027	0.0050	0.26	0.23
SRS SB6[18]	6.61	2.07	2.21	0.0042	0.0040	0.20	0.21
SRS SB7[19]	5.96	1.93	2.39	0.0045	0.0059	0.12	0.30
SRS SB8[20]	6.30	2.41	1.95	0.0021	0.0057	0.20	0.28
SRS SB9[21]	6.26	2.52	1.76	0.0061	0.0049	0.22	0.28
LAWPS projected[22]	5.61	1.41	1.78	0.0127	0.0432	0.17	0.52

The projected LAWPS feed falls in the range of sodium, nitrate and aluminum found in the SRS salt batches. LAWPS feed is generally lower in hydroxide. Though the LAWPS projection is above the minimum concentration for hydroxide from SB1, all other SRS salt batches are noticeably greater. Also note that after processing started, additional hydroxide was added to SB1 to keep aluminum in solution. The projected LAWPS feed is significantly higher in oxalate (~2X), phosphate (~10x) and carbonate (~2X) which are likely at solubility limits.[23,24] In general, the indicators imply that the anticipated LAWPS feed would have a lower viscosity but with a higher potential for precipitation.

The intent of the comparison of chemistries is to show that 512-S has processed a range of combinations of the important constituents. It is not expected that LAWPS will match the 512-S chemistries. A recipe of the feed constituents has yet to be determined that allows for easy processing. No clear independent parameters have been determined. An individual feed's properties are a collection of all parameters and their complicated interactions. Feeds with chemistries, particle sizes and viscosities other than what has been processed in 512-S may also provide a similar or improved production rates. Conversely, subtle changes in properties of the feed may result in significant variation in filtration rates.

3.0 Discussion

3.1 Functional Comparison of 512-S and LAWPS

The 512-S and LAWPS filters share the same purpose, to filter undissolved solids from the waste to provide a clarified salt solution for cesium removal. The largest difference in operation between LAWPS and most of the 512-S operational history is that 512-S intentionally added additional solids in the form of MST. MST is a relatively durable particle with a known, narrow particle size distribution. For reference, a typical particle size distribution for MST is provided in Figure 4.
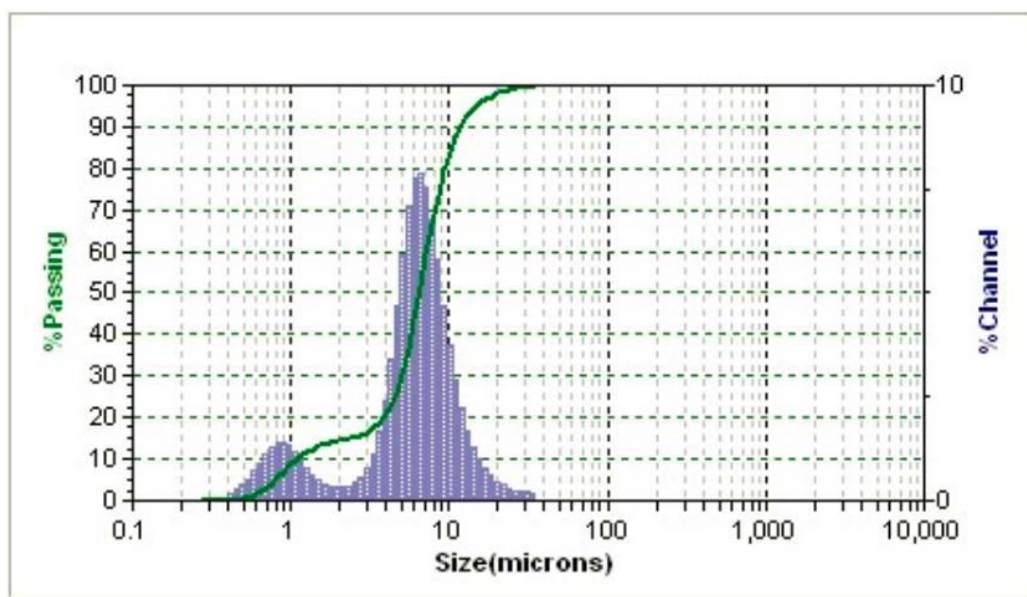
Figure 4. As‐received MST Particle Size Analysis Volume Percent by MicroTrac™ S3400 Analyzer Absorbance Mode

Most research in support of the startup of ARP looked at filtering MST with significant amounts (600 mg/L) of entrained sludge. Samples analyzed for an earlier study found no significant amount of sludge in the slurry for filtration. [25] Therefore, most of the solids that have been sent to the 512-S filter have been the added MST.

The measured insoluble solids for the individual salt batches, prior to the addition of MST, are given as Table 4.

Table 4. Weight Percent Insoluble Solids of SRS Salt Batches

Salt Batch	Wt % Insoluble Solids
1[26]	<0.01
2[27]	<0.753
3[28]	<1.04
4[16]	<1.04*
5[29]	0.32
6[30]	<0.17
7[31]	0.0147
8[32]	0.014
9[33]	<0.005

*Blend of SB3 @ 1.04 wt % and 0.25 wt %

3.1.1 Operations of 512-S

The following discussion of the 512-S facility and later discussion on filter performance with MST is given to provide a frame of reference for filter performance with added insoluble solids and to contrast the performance due to the elimination of those solids during the "no-MST "operations.

Original operation started with the addition of 0.4 g/L of MST to each filtration batch. The MST was added as two 5 gallon buckets of 14-16 wt% of slurry. As previously discussed, this was one of the main functions of 512-S, to remove the MST after it was used for the removal of Sr and actinides. Each subsequent batch added an additional 2 buckets of MST adding an additional 0.4 g/L of MST solids, increasing the solids loading of the feed until the solids were concentrated, washed and transferred.

Due to the low levels of strontium and actinides in the feed, ARP dropped the amount of MST added to the strike tanks by one-half. Starting with SB 5 Cycle 2, MST addition was dropped to 0.2 g/L, or one five-gallon bucket of 14-16 wt % MST solids. SRNL was commissioned to study the impact of the reduced MST for ARP operations including the potential impact to filtration production.[34] Using a filtration model adapted from literature, the report concluded that reducing the solids could increase the filtration rate by up to 20%.[35] However, no consistent flux improvement was observed after the reduction of MST solids. It should be noted there were several events that would impact filtration at the same time as the MST reduction. These included a change to the operation of the filter to "continuous mode" in which there was no pause between batches. During the startup of several batches the filter production spiked to 150% of the expected filtration rate, with corresponding pressure spikes. An oxalic acid leak was detected in the prior cycle and dispositioned through the filter. The axial velocity was also reduced potentially impacted the filter performance. Finally, the method of cleaning the downstream secondary filter was changed. All of these factors appeared to override the potential production gain due to reduced solids burden on the filter system and demonstrate that solids loading is only a single component to filter performance.

During the processing of SB6 the filter started to struggle. Fewer batches were being produced prior to the filter requiring cleaning. Filter cleanings were no longer restoring filter performance satisfactorily. Eventually, the decision was made to replace the cross flow filter. The replacement filter was one of the original filters for the In-Tank Precipitation Process. This filter was a direct replacement except for the media grade, which was 0.5 instead of 0.1.

Current operations are still using the 0.5 media grade cross flow filter. 512-S filtered 335 batches after replacing the primary filter and prior to the start of the "no-MST" operations.

3.1.2 Operations of LAWPS[36]

LAWPS feed is treated by pumping it from the filter feed tank through a cross flow filter loop, returning it to the feed tank. The filter feed tank receives feed from the AP Tank Farm (241-AP-107) to continually replenish the removed filtrate. Settling is assumed to occur in 241-AP-107 prior to feeding the LAWPS to minimize solids entrainment. The filter feed tank contains two submersible pumps. One circulates the feed through the CFF filtration loop, while the second returns waste with concentrated solids back to the Tank Farm. The two filter bundles will be operated in series. Each filter bundle will contain two internal tube banks in series and 102 filter tubes per bank. The cross flow filters remove the un-dissolved solids from the waste stream in preparation for treatment through the IX columns.

3.2 Secondary Filter versus Ion Exchange Columns

As previously described, 512-S has a second, dead-end style, filter downstream of the cross flow filter referred to as the "secondary filter". The purpose of this filter is to prevent passing of solids to the LWHT in the event of a leak in the cross flow filter. The secondary filter should have ideally been transparent to the filtration rate. The secondary filter was constructed with a larger pore size (0.5 media grade versus 0.1 media grade) than the original cross flow filter. This was intended to allow the majority of solids that passed the cross flow filter to pass the secondary filter. However, since the Mott® filters are not rated as an absolute pore size, but on percent passage of various sized particles, some particles can pass the 0.1 filter and be rejected by the 0.5 filter. The current cross flow filter uses the same media grade as the secondary filter.

Throughout the process history, repeated high pressure drops across the secondary filter indicated repeated plugging. The plugging was likely due to three potential causes; passing of fines through the cross flow filter, precipitation of solids between the cross flow filter and the secondary filter, or passing of soft particles that deform through the pores of the cross flow filter and are caught in the secondary filter. The secondary filter is a dead end filter that operates differently from a cross flow filter. Any material that is collected by the dead end filter has no opportunity to be removed and thus continues to collect on the filter media.

In spite of being a larger nominal pore size than the original cross flow filter, the secondary filter regularly became a limiting factor in filter system productivity on multiple occasions. This was especially noticeable after a cleaning of the primary filter. Cleaning the cross flow filter consisted of circulating 0.5 M oxalic acid on the feed side of the filter. The cleaning solution does not flush the secondary filter. Following a cross flow filter cleaning there was a consistent step-change in the amount of resistance in the secondary filter. Several attempts were made at improving the secondary filter performance by soaking, cleaning and eventual replacement. Finally, it was decided that the when the secondary filter would be replaced after cleaning the cross flow filter, the old secondary filter would be used for a few batches into the new cycle. The first few initial batches of a new cycle were run with the previous secondary filter in order to capture any post cleaning precipitates that remained on the filtrate side of the filter system prior to replacement. Though several attempts were made, analysis provided no definitive identification of the reason for the secondary filter degradation.[37, 38]

In the LAWPS design, with the cross flow filter coupled directly to the ion exchange columns, the ion exchange columns could be analogous to the secondary filter in ARP. They are essentially two depth filters in series. LAWPS should design a recovery strategy if a similar condition occurs after cleaning the LAWPS filter. Though the equivalent pore size of the ion exchange columns is significantly larger than the 512-S secondary filter, the potential exists for solids to form and get trapped in the ion exchange column beds.

3.3 <u>Performance Evaluation of the Cross Flow Filter</u>

3.3.1 Performance due to MST Additions

Operationally, the average production from the filter from SB1 through SB5 Cycle 2 in which MST was added at 0.4 g/L per batch resulted in an average filtration rate of 6.3 gpm with an average of 41 batches per cycle. Recognize that this generalization includes the impact of all factors impacting filtration. This includes feed variation of 5 salt batches, operational limitations to filtration rate, multiple cross flow filter cleanings, and multiple secondary filter cleanings and changes.

After reducing the MST additions to 0.2 g/L, the original 0.1 filter also averaged 6.3 gpm per batch but only approximately 28 batches per cycle. The replacement 0.5 filter averaged 5.2 gpm over 58 batches per cycle.

During the first "No-MST" cycle (SB8 Cycle 2), the filtration rate produced an average of 8.6 gpm over 209 batches. Note that the initial batches were intentionally restricted to a lower filtrate flow rate by operations personnel as the new cycle was started. As batches were processed, there was degradation measured in the performance of the secondary filter. The secondary filter was replaced after Batch 59 resulting in an average filtration rate of 9.5 gpm for the next 100 batches.

A second cycle "No-MST" cycle was started with the next salt batch, Salt Batch 9, after the filter went through a standard cleaning. The secondary filter was not changed. To date, 52 batches have been completed for the new cycle (SB9 Cycle 1) averaging 9.6 gpm.

As previously discussed, the cycle was typically ended when the filtrate production was deemed insufficient. Therefore, one way to compare the filter operation at the different MST concentrations is the ability to sustain filtration rate over a number of batches. The greater number of batches processed before the filter was judged to require cleaning, the stronger the filter performance. Figure 5 shows "No-MST" operation sustained not only the highest filtration rate, but continued that production for more than twice the number of batches as any other Cycle.
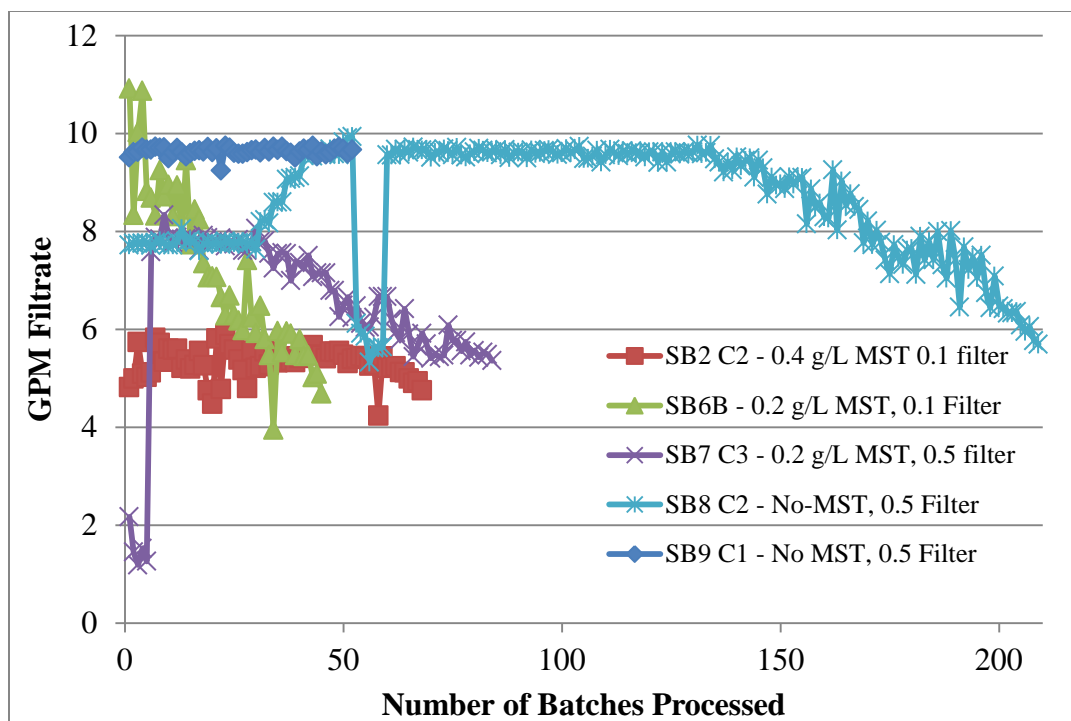
Figure 5. Filtration Rate from the Best Cycle from Each MST Concentration

An additional comparison is normalizing the filtration rate to the transmembrane pressure (TMP). The amount of pressure required to sustain the desired filtration rate also gives a good comparison of filter performance and is shown as Figure 6. At low pressures, TMP and filtration rate are directly related and normalizing helps show the relationship. In cross flow filtration, it is generally desired to obtain the required production at the lowest TMP.[39] Operation in this manner generally allows a greater amount of feed to be processed before filter cleaning is necessary.
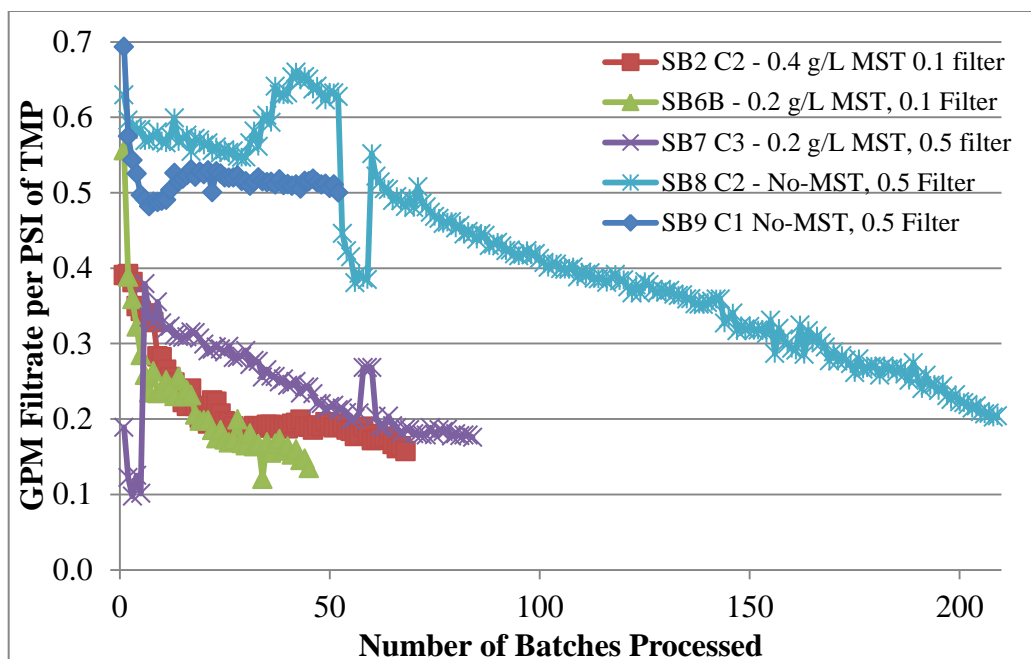
Figure 6. Filtration Rate per Driving Pressure from the Best Cycle from Each MST Concentration

The results illustrated in Figure 6 shows operation with "No-MST" was significantly more efficient, requiring less driving force (TMP) to obatin the desired production rate. This was sustained in the first full "no-MST" cycle for more than twice the number of batches from the previous cycles. The initial batches from the second "no-MST" cycle also showed a significant improvement in filter performance.

3.3.2 Performance of Cross Flow Filter with No-MST after Cleaning

One of the main concerns with the elimination of the MST solids was the potential to change the fouling mechanism of the cross flow filter. With MST solids, it was expected that the filter would develop a layer of MST solids on the filter membrane that would perform the majority of the filtration. This layer would serve to trap the majority of the particles and they would be removed during cleaning restoring the filter performance. By eliminating the solids that formed this layer, the potential existed for the small entrained solids to penetrate deep into the filter membrane where their removal would become extremely challenging. This could result in degradation of filter performance and an increase in the frequency of filter replacement. If the mechanism of filter fouling changes, the methodology for cleaning the filter would probably require modification.

An important aspect of facilty performance is the ability to sustain operations through all required functions. The cleaning of the 512-S filter has resulted in both positive and negative aspects. The ability to clean the cross flow filter properly is a requirement in order for the facility to perform its required function. As previously discussed, the 512-S cleaning process has historically resulted in a negative impact to the secondary filter, to the point that it was decided to replace the filter after every other cycle.

To date, one cleaning cycle has been completed after operations with "No-MST" started. The first batch of Cycle 1 with "No-MST" completed producing 0.62 gpm per psi of TMP. The last batch in Cycle 1 (#209) completed with the filter producing 0.198 gpm per psi of TMP. This clearly shows a fouling of the filter as a result of processing. After the cleaning cycle, the first batch from the next Cycle utilizing "No-MST" produced 0.68 gpm per psi of TMP. Therefore, the first cleaning cycle was successful in restoring filtrate production for the initial batch. Over the first 52 batches of SB9 Cycle 1, the filter has

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maintained and average of 0.52 gpm per psi of TMP. While this is slightly less than the original "No-MST" batch at this point in the cycle, it is still significantly better than historical performance with MST.

3.3.3 Performance due to Feed Variation

One of the key variables that impacts filter performance is the properties of the feed. During operation with the 0.5 media grade filter using additions of 0.2 g/L MST, a transition was made from SB6 to SB7. The tranisition of feed resulted in a noticeable increase in production. The third cycle of SB7 produced the best performance prior to the "No-MST" operations. The second cycle corresponded to the complete transition to the new salt batch and the changeout of the secondary filter.

Filter performance varied from salt batch to salt batch. Feed chemistry and the resulting properties of the waste have a signficant impact of filter performance. As discussed in Section 2.4.2, the SRS and Hanford wastes have significant differences. The compositional trend of lower viscosity for the Hanford wastes could result in slightly higher filtration rates. The increased likelihood of precipitation in the Hanford waste could have a significant negative impact on filtration rate depending on the many factors, not the least of which is when and where the precipitation occurs.

4.0 Conclusions

This evaluation has presented data and observations from the first cycles utilizing "No-MST" operations in the SRS 512-S facility. The elimination of added solids has resulted in a significant increase in filtrate production. Direct filtration of decanted tank supernate, as demonstrated in 512-S, is the proposed method of operation for the Hanford LAWPS facility. Historically, filtration has been, or is expected to be the bottleneck in waste processing. Processing decanted supernate has been demonstrated for cross flow filtration to provide better-than-expected production with the SRS Salt Batch 8 and 9 feed. The average filtration rate increased by over 35% of the historical average and sustained the increase to produce more than twice the amount of filtrate between required cleaning of the filter. Based on the operation of the 512-S facility and with **favorable feed properties,** the LAWPS filter, as currently sized (532 sq ft filtration area), has the potential to provide sustained filtrate production at the upper range of the planned LAWPS production rate of 17 gpm.

5.0 Recommendations

This evaluation is based on the first cycle and initial batches of the second cycle of SRS 512-S "No-MST" operations. The feed chemistry and the resulting physical properties will have the largest impact on filtration rates. As the design for LAWPS progresses, the performance of the 512-S facility should be closely monitored for the impact of changes in the feed chemistry as additional salt batches are processed. In addition, the ability of 512-S to maintain production after multiple cleaning cycles should be monitored. Careful attention should be paid to see if the fouling mechanism of the filter is changed from cake fouling to depth fouling. A change in the filter fouling mechanism would warrant a different cleaning strategy.

Additional benefit and reduced uncertainty could be obtained by an evaluation of historical filtration data from actual waste testing at lab-scale for Hanford and SRS wastes. Additional actual waste data may be required for the Hanford waste as most data to date is for higher insoluble solids than is planned for LAWPS. Understanding the differences in the waste between the two sites, and how accurately the SRS actual waste data translated to 512-S operations would provide additional insight for LAWPS operations.

6.0 References

[1] D. T. Hobbs, D. T. Herman and M. R. Poirier, "Decontamination Factors and Filtration Flux Impact to ARP at Reduced MST Concentration," SRNL-STI-2012-00299, June, 2012.

[2] T. C. Demeter, "ARP/MCU No-MST Demonstration Plan," SRR-SPT-2015-00017, November, 2015.

[3] Mott Corporation Porous Media Products, Product Brochure.

[4] T. B. Peters, F. F. Fondeur and S. D. Fink, "Results from analysis of Actinide Removal Process Guard Filter," SRNL-STI-2009-00456, Rev. 1, January 27, 2010.

[5] N. R. Mann, T. A. Todd, "Evaluation and Testing of the Cells Unit Crossflow Filter on INEEL Dissolved Calcine Slurries," INEEL/EXT-98-00749, August, 1998.

[6] M. R. Poirier, P. Burket, J. L. Siler, "Filtration of a Hanford AN-104 Sample," WSRC-TR-2003-00295, September, 12, 2003.

[7] K. P. Brooks, P. R. Bredt, G. R. Golcar, S. A Hartley, M. W. Urie, J. M. Tingey, K. G. Rappe, L K. Jogoda, "Ultrafiltration and Characterization of AW-101 Supernatant and Entrained Solids," PNWD-3000, October, 1999.

[8] M. R. Duignan, and S. Y. Lee, "Cross-flow Ultrafiltration Scaling Considerations," Proc. ASME Fluids Engineering Division Summer Meeting and Exhibition, FEDSM2006-98492 (2006).

[9] M. R. Poirier, J. L. Siler, S. D. Fink, "Pilot-Scale Testing of a 0.1 Micron Filter with SRS Simulated High Level Waste," WSRC-TR-2003-00469, October, 8, 2003.

[10] Mott Literature, "Porous Metal Solutions, Permeability Information 316L SS Tubes."

[11] R. Peterson, Transmittal of PNNL Deliverable, 'Review of Blended Waste Rheology Correlations and Methodology in the Meacham Report'," EMSP-0083, October, 2013.

[12] M. R. Poirier and S. D. Fink, "Investigation of Alternative Approaches for Cleaning Mott Porous Metals Filters", WSRC-TR-2002-00526, November 12, 2002.

[13] S. E. Campbell, "Evaluation of ISDP Batch 1 Qualification Compliance to 512-S, DWPF, Tank Farm, and Saltstone Waste Acceptance Criteria," X-ESR-H-00120, March, 2008.

[14] S. E. Campbell "Evaluation of ISDP Batch 2 Qualification Compliance to 512-S, DWPF, Tank Farm, and Saltstone Waste Acceptance Criteria," X-ESR-H-00158, January, 2009.

[15] S. E. Campbell, A. R. Shafer, "Evaluation of ISDP Batch 3 Qualification Compliance to 512-S, DWPF, Tank Farm, and Saltstone Waste Acceptance Criteria," X-ESR-H-00226, Rev. 1, July, 2010.

[16] S. E. Campbell, A. R. Shafer, "Evaluation of ISDP Batch 4 Qualification Compliance to 512-S, DWPF, Tank Farm, and Saltstone Waste Acceptance Criteria," X-SER-H-00303. November, 2010.

[17] S. E. Campbell, A. R. Shafer, "Evaluation of ISDP Batch 5 Qualification Compliance to 512-S, DWPF, Tank Farm, and Saltstone Waste Acceptance Criteria," April, 2012.

[18] S. E. Campbell, A. R. Shafer, "Evaluation of ISDP Batch 6 Qualification Compliance to 512-S, DWPF, Tank Farm, and Saltstone Waste Acceptance Criteria," X-ESR-H-00447, January, 2013.

[19] S. E. Campbell, C. K. Chiu, K. D. Dixon, "Evaluation of ISDP Batch 7 Qualification Compliance to 512-S, DWPF, Tank Farm, and Saltstone Waste Acceptance Criteria," X-ESR-H-00551, August, 2013.

[20] A. R. Shafer, T. A. Le, "Evaluation of ISDP Batch 8 Qualification Compliance to 512-S, DWPF, Tank Farm, and Saltstone Waste Acceptance Criteria," X-ESR-H-00739, February, 2015.

[21] A. R. Shafer, K. H. Patel, "Evaluation of Sludge Batch 8 with ISDP Salt Batch 9 Qualification Compliance to 512-S, DWPF, Tank Farm, and Saltstone Waste Acceptance Criteria," X-ESR-H-00807, March, 2016.

[22] M. A. Servin, "Project T5L01 Low Activity Waste Pretreatment System Specification," RPP-SPEC-56967, Rev. 4, January, 2016.

[23] J. R. Fowler, "Effect of Temperature on Sodium Oxalate Solubility," DPST-80-265, February 1980.

[24] D. L. Herting, "Effect of Phosphate, Fluoride, and Nitrate on Gibbsite Dissolution Rate and Solubility," LAB-RPT-13-00011, January, 2014.

[25] C. J. Martino, D. T. Herman, J. A. Pike, T. B. Peters, "Actinide Removal Process Sample Analysis, Chemical Modeling, and Filtration Evaluation," SRNL-STI-2013-00700, June, 2014.

[26] C. A Nash, T. B. Peters, "Interim Report Covering Tank 49H Qualification – Sample A and Sample C", SRNL-CST-2007-00009, Rev. 0, February 21, 2008.

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

[28] S. E. Campbell, "Blend Evaluation for Tank 49 Feed for ISDP Salt Batch 3", X-ESR-H-00209, Rev. 0, March 16, 2010.

[29] T. B. Peters, S. D. Fink, "Sample Results from the Integrated Salt Disposition Program Macrobatch 5 Tank 21H Qualification Samples", SRNL-STI-2012-00076, Rev. 0, March 2012.

[30] T. B. Peters, S. D. Fink, "Sample Results from the Integrated Salt Disposition Program Macrobatch 6 Tank 21H Qualification Samples", SRNL-STI-2012-00707, Rev. 0, December 2012.

[31] T. B. Peters, A. L. Washington, II, "Sample Results from the Interim Salt Disposition Program Macrobatch 7 Tank 21H Qualification Samples", SRNL-STI-2013-00437, Rev. 0, August 2013.

[32] T. B. Peters, A. L. Washington, II, "Sample Results from the Interim Salt Disposition Program Macrobatch 8 Tank 21H Qualification Samples", SRNL-STI-2014-00561, Rev. 1, January 2015.

[33] M. S. Hay, "Weight Percent Insoluble Solids Measurement of Tank 49H Samples (HTF-49-16-67, -68 and -69," SRNL-L3100-2016-00150, August, 2016.

[34] K. Lang, "MST Reduction Analysis for ARP/MCU," X-TTR-H-00018, April, 18, 2012.

[35] D. T. Hobbs, D. T. Herman, M. R. Poirier, "Decontamination Factors and Filtration Flux Impact to ARP at Reduced MST Concentration," SRNL-STI-2012-00299, June, 2012.

[36] M. W. Leonard, B. Atherton, "Conceptual Design Report for the Low-Activity Waste Pretreatment System (Project T5L01)," RPP-RPT-57120, Rev 2, January, 2015.

[37] T. B. Peters, F. F. Fondeur, S. D. Fink, "Results from Analysis of Actinide Removal Process Guard Filter," SRNL-STI-2009-00456 Rev 1, January, 2010.

[38] C. J. Bannochie, M. L. Restivo, T. B. Peters, "Results for Actinide Removal Process 512-S Guard Filter Analyses," SRNL-STI-2014-00518, February 2015.

[39] Jakob Murkes and Claes-Goran Carlsson, "Crossflow Filtration: Theory and Practice," New York: Wiley, 1988.

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