

Performance of a Scaled Tank Side Cesium Removal Test System at High Solids Loading – 22409

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ABSTRACT

The Direct Feed Low-Activity Waste process requires pretreatment of tank waste supernatant prior to vitrification in the Low-Activity Waste (LAW) Facility at the Hanford Waste Treatment and Immobilization Plant (WTP). Initially, this function will be performed by the Tank Side Cesium Removal (TSCR) system, which is designed to conduct two separations to prepare LAW for transfer to the WTP LAW Facility for vitrification. The separation steps are (1) dead-end filtration using a Mott Grade 5 sintered stainless-steel filter and (2) ion exchange to remove Cs-137 using crystalline silicotitanate (CST). Testing of TSCR separation technologies at multiple scales with actual waste and simulant has demonstrated that unit operation performance at the nominal solids loading is sufficient to achieve the target throughput (nominally 5 gpm). The nominal supernatant tank waste fed to the TSCR system is anticipated to have a low solids concentration (approximately 200 ppm solids) and the system was designed on that solids concentration basis.

However, the TSCR waste acceptance criterion related to solids concentration allows waste feed(s) containing up to 15,000 ppm solids (1.5 wt%). Elevated solids loadings would be off-normal, but there was uncertainty regarding the TSCR system's performance if it would have to operate at such a condition. As reported by the manufacturer, the Mott filter has a 90% collection efficiency for 5- μm particles and 99.9% collection efficiency for 13- μm particles. Particles that comprise a waste feed with a higher-than-nominal solids loading may contain a significant fraction of particles that are less than 13 μm in size and could collect in appreciable quantities on the filter (thereby increasing pressure drop and backwash frequency) or even pass through the filter. Particles that pass through the filter may also foul the CST ion exchange beds, increasing pressure drop and potentially restricting access to Cs-137 exchange sites via physical blockage or flow channeling.

Assessing the potential impact of higher solids concentration in the TSCR feed necessitated the use of a scaled TSCR system, designed and assembled at Pacific Northwest National Laboratory. Testing was performed with representative waste simulants formulated using relevant precipitation mechanisms, with solids concentrations up to 3,000 ppm. The scaled system was devised to mimic most TSCR operations prototypically and integrate filtration and ion exchange equipment to dynamically observe the effect of processing higher solids loadings. The key elements of the system are a single full-height CST column [2.34-m (92-inch) bed, $\sim 0.0041 \text{ m}^3$ ($\sim 1.1 \text{ gal}$) bed volume] and a pair of backwashable filters with approximately 0.05 m^2 (0.54 ft^2) of surface area each. The test system is briefly described, followed by a discussion of test data and implications for TSCR operation.

INTRODUCTION

The Tank Side Cesium Removal (TSCR) project is a technology demonstration that will pretreat Hanford tank waste supernatant in support of the Direct Feed Low-Activity Waste (DFLAW) mission. The TSCR system employs two key separation technologies: dead-end filtration (DEF) and ion exchange (IX) using crystalline silicotitanate (CST) media. DEF will be used to remove undissolved solids from tank waste to protect the functionality of the IX columns, and the IX system will remove Cs-137 from tank waste. TSCR provides a waste stream that will be fed to the Hanford Waste Treatment and Immobilization Plant (WTP) Low-Activity Waste (LAW) Vitrification facility as part of efforts to accelerate waste treatment and immobilization [1].

The TSCR system has been designed and constructed by AVANTech Incorporated for Washington River Protection Solutions and was recently installed in the Hanford AP tank farm. The separation technologies (DEF and IX) used in TSCR are technically mature and have also been successfully deployed at the Savannah River Site in a similar facility known as the Tank Closure Cesium Removal system [2-5]. Therefore, TSCR is expected to achieve its design throughput when processing feed streams with the nominal (≤ 200 ppm) solids loading.

Less certain is the performance should TSCR encounter an off-normal solids loading ($\gg 200$ ppm); to address the uncertainty, Pacific Northwest National Laboratory (PNNL) proposed collecting data with a scaled test system at elevated solids loadings. Previous investigations at PNNL have included extensive testing of both filtration [6-9] and IX with CST [10-14] on actual waste samples, all of which contained solids loading of ≤ 200 ppm. AVANTech Incorporated also conducted scaled filter testing to select the DEF media in the design phase. The scaled filter testing was performed at a solids loading of 300 to 1,000 ppm, although the majority of tests were performed at ≤ 500 ppm [15]).

The testing described in this paper was conducted to understand the consequence of operating the TSCR system at elevated solids loadings up to $\sim 3,000$ ppm (i.e., 0.3 wt%).¹ Although the system is not required to make throughput above the nominal solids loading, the testing was intended to provide important information related to potential off-normal operations. At off-normal levels near the high-solids limit, there are potential implications for TSCR performance in the areas of throughput, DEF pressure drop, filter backflush frequency, and IX column pressure drop. In addition, intrusion of solids into the IX column was postulated to impact the Cs-137 loading behavior by promoting channeling or flow maldistribution in the column; since the magnitude of the postulated effect was unknown, assessing it was also of interest. These performance topics are best assessed in an integrated system that is appropriately scaled and operated prototypically (to the extent practical). Since a prototypic, integrated TSCR system of any scale did not exist, PNNL designed and assembled a test system to conduct the high-solids performance assessment. The test system, its operation, and key results are the subject of this paper; for additional details, the reader is referred to Schonewill et al. [16].

METHODS

The methodology used in the testing can be broken into three major elements: the development of a simulant formulation to use for the tests; the scaling basis used to design and assemble the test system; and test operations. These three elements are briefly summarized in the subsections that follow.

Simulant Development

A simulant development effort was undertaken to provide chemistries suitable for testing scaled TSCR unit operations, namely DEF and IX, at both nominal saltcake waste supernatant solids loadings (200

¹ This is less than the maximum solids loading for the testing – 15,000 ppm (1.5 wt%) – which is the maximum permitted by the TSCR design basis. However, operating at that level was anticipated to be impractical based on other test data and so it was not attempted during the testing.

ppm) and at solids loadings approaching the TSCR specification limit (15,000 ppm) as described in references [1] and [17]. Simulant development efforts involved design of simulant recipes for procurement of four 300-gal batches from an external vendor (NOAH Technologies, San Antonio, Texas). The specific targets for the four simulants were as follows:

- A nominally solids-free supernatant simulant recipe based on the nominal 5.6 M Na simulant described in [18] [hereafter referred to as the nominal batch (NB) simulant]
- A solids-bearing AP-tank farm representative simulant [hereafter referred to as the high solids (HS) simulant] with solids loading target of 0.3 wt% (3,000 ppm)
- An HS simulant with a solids loading target of 0.9 wt% (9,000 ppm)
- An HS simulant with a solids loading target of 1.5 wt% (15,000 ppm)

The NB simulant did not undergo a significant development process and was produced as described in Russell et al. [18], except that sodium oxalate solids were not added to keep the solids content consistent with expected DFLAW feeds (solids content < 200 ppm). The HS simulants were adapted from a previously studied formulation found in Daniel et al. [19] that used controlled precipitation of solids to generate the desired solids loading targets. The precipitation chemistry exploits the instability of calcium in a medium with high salt and caustic content. The HS simulants all started with the same concentrated composition (with a sodium concentration of 8.53M) presented in TABLE I.

TABLE I. High Solids Simulant Composition Prior to Dilution.

Component Name	Component Formula	Formula Weight (g mol ⁻¹)	Composition ^a (g kg ⁻¹)	Composition ^b (g L ⁻¹)
Deionized water ^c	H ₂ O	18.02	330.55	464.42
Aluminum nitrate nonahydrate	Al(NO ₃) ₃ ·9H ₂ O	375.13	204.84	287.81
Iron nitrate nonahydrate	Fe(NO ₃) ₃ ·9H ₂ O	404.00	0.036	0.050
Cesium nitrate	CsNO ₃	194.91	0.0211	0.0297
50% sodium hydroxide solution	NaOH (50%)	40.00	273.85	384.76
Sodium phosphate dodecahydrate	Na ₃ PO ₄ ·12H ₂ O	380.12	3.972	5.581
Potassium chloride	KCl	74.55	8.74	12.28
Calcium chloride dihydrate	CaCl ₂ ·2H ₂ O	147.02	0.247	0.347
Sodium fluoride	NaF	41.99	0.387	0.544
Sodium sulfate	Na ₂ SO ₄	142.04	2.596	3.647
Sodium formate	NaCOOH	68.01	7.032	9.879
Sodium acetate	NaCOOCH ₃	82.03	4.242	5.960
Sodium oxalate	Na ₂ C ₂ O ₄	134.00	0.289	0.406
Sodium nitrite	NaNO ₂	69.00	92.51	129.98
Potassium nitrate	KNO ₃	101.10	1.519	2.135
Sodium nitrate	NaNO ₃	84.99	10.07	14.15
Sodium meta silicate nonahydrate	Na ₂ SiO ₃ ·9H ₂ O	284.20	0.461	0.648
Sodium carbonate monohydrate	Na ₂ CO ₃ ·H ₂ O	124.00	58.63	82.38
^a Represents the simulant composition in grams of component per kilogram of final as-prepared simulant [i.e., g component (kg simulant) ⁻¹]. ^b Represents the simulant composition in grams of component per liter of final as-prepared simulant [i.e., g component (L simulant) ⁻¹]. ^c Deionized water shall be used for simulant preparation.				

The dilution was accomplished using batches of water with specific amounts of calcium chloride salt; once combined, the simulant had the target sodium molarity of 5.6M. The amount of calcium chloride required to produce a particular target solids loading was determined using bench-top formulations

diluted with a range of diluent compositions. The precipitated solids were filtered, dried, and weighed to determine the solids content resulting from each diluent composition. The data was used to pinpoint the diluent compositions to use for simulant production as described in TABLE II.

TABLE II. Dilution Schedule Used for the Three High Solids Simulant Batches.

Batch	Target Solids Concentration (wt%)	Required Quantity of Baseline 8.56 M Na Simulant		Diluent Composition (salt as CaCl ₂ ·2H ₂ O)		Final Simulant
		Volume (gal)	Mass (kg)	Water (kg)	Salt (kg)	Volume (gal)
HS1	0.3	200	1,050	382.85	4.15	300
HS2	0.9	200	1,050	380.73	12.77	300
HS3	1.5	200	1,050	378.60	21.48	300

The simulants were produced off site at NOAH Technologies, shipped to PNNL in intermediate bulk containers, visually inspected upon receipt, and prepared for use in the test system once they had arrived on site. Simulant batches were transferred from the shipping containers to the test system feed vessel after sparging the contents with air for at least 15 minutes.

Test System Scaling

The processing rate for the test system was defined by the ratio of test and full-scale IX column cross-sectional areas, i.e., selecting a basis of matching the superficial velocity between the test and full-scale columns and operating at essentially the same rate in terms of both filter flux [nominally $4.41 \times 10^{-5} \text{ m s}^{-1}$ [0.065 gpm/ft²]] and BV h⁻¹ (nominally ~1.9). This approach ignores the small difference in bed volumes between the TSCR IX column’s constant cross-section [0.602 m³ (159.1 gal)] and the actual volume able to be packed with CST media due to excluded volume from internal components [0.596 m³ (157.5 gal)]. The resultant difference in laboratory-scale flow rate is ~1% (130.1 vs. 131.4 mL min⁻¹) and was considered to have negligible impact on the IX performance. In addition, matching the superficial velocity was preferable for IX column hydraulic comparisons. Other important scaled parameters for the test system are summarized in TABLE III. More detailed information on the basis for scaling the test system is available in references [16] and [20].

Importantly, cesium removal by CST is a well-studied phenomenon and its quantitative determination was not a primary objective of this testing. Aside from the impact of higher solids loading on pressure drop in the CST bed, a secondary objective was to observe whether operation with higher solids loading in the feed had any impact on the cesium removal functionality of the IX column. This is a consequential distinction because the processing time needed to obtain the full cesium loading curve with CST is considerable and spans many more filtration cycles than are needed to collect an appreciable measure of filter performance. Therefore, the analysis of CST cesium removal performance did not measure the complete cesium loading on the IX column during each test because the simulant volume used (a target value of at least 250 BVs) did not permit a full loading cycle to be conducted. Instead, only the detection of initial breakthrough (approximately 0.1% cesium effluent concentration/cesium feed concentration, or C/C_0) was expected.

TABLE III. Comparison of Scaled Parameters for the Test System to the Full-Scale TSCR Parameters.

System Parameter	Test System Value	TSCR (full-scale) Value	Scaling Basis
Column bed height	2.34 m (92 in.)	2.34 m (92 in.)	Full-height CST bed for characteristic hydraulic performance
Column inner diameter	0.0475 m (1.87 in.)	0.584 m (23 in.) [with ~0.114m (~4.5-in.) annulus]	Existing full-height column size that is large enough to keep wall effects small
Bed volume (BV)	0.0041 m ³ (1.09 gal)	0.602 m ³ (159.1 gal)	Defined by column size parameters, ignoring excluded volume
Planned BVs to process	≥ 250 <i>Actual BV processed: 158 to 300</i>	n/a – TSCR has a carousel and switches columns based on breakthrough, not BVs processed	Selected based on PNNL test data to characterize initial cesium breakthrough (> 0.1% of the feed concentration) at an elevated feed concentration
Minimum volume of simulant needed to process to BV target	1.033 m ³ (273 gal)	n/a – see note above	Minimum volume representing the BV target (250 BVs) selected
Scaled process flow rate	130.1 mL min ⁻¹ (0.0344 gpm)	18,927 mL min ⁻¹ (5 gpm)	Flow rate that matches full-scale BV hr ⁻¹ processing rate based on bed cross-sectional area
Filter length needed to achieve flow rate	1 tube of 0.622 m (1 tube of 24.5 in.)	98 tubes of 0.914 m (98 tubes of 36 in.)	Ratio of full-scale filter to scaled filter area needed to achieve the scaled flow rate
Operating time to process BV target	132.6 h	n/a	Defined by the BV and scaled process flow rate
Scaled filter housing volume	0.568 L (0.13 gal) [0.038-m (1.5-in.) diameter shell]	187.4 L (49.5 gal) [0.457-m (18-in.) diameter shell]	Maintain same superficial velocity between the shell and tube as the full-scale filter
Volume of air accumulator	0.5 L (0.13 gal)	75.7 L (20 gal)	Maintain same ratio of filter area to air volume as full-scale filter system (The initial pressure in the air accumulator will match full-scale system, so using same ratio of filter area to air volume should result in the same average flow rate through the filter in both the test and full-scale systems)
Criteria for switching filter unit	2 psig increase in pressure drop or at 24 h	2 psig increase in pressure drop or at 24 h	Criteria for switching filters are the same in both the test and full-scale systems
Solution for soaking filter not in use	0.1 M NaOH	0.1 M NaOH	Solution for soaking the filter not in use is the same for both test and full-scale systems
Range of solids concentration in feed	200 – 15,000 ppm <i>Actual range tested: 0 – 3,000 ppm</i>	0 – 15,000 ppm	Maximum solids concentration the same for both systems. For the low end of the range, laboratory-scale system will use 200 ppm, which is the TSCR nominal value

Test Matrix and System Operation

A representation of the scaled test system is shown in Fig. 1. The key elements of the system were the feed tank TK-01, feed pump PMP-01, dual dead-end filters DEF-01 and DEF-02, the IX column IXC-01, the flow controller FM-02, and various temperature and pressure instruments. The feed tank and pump were designed to produce the needed driving pressure (>60 psig) as well as sufficient mixing energy to keep solids suspended via a recirculation loop that returned to the tank. Each DEF was able to be brought on-line independently so the other DEF could be simultaneously backwashed with compressed air and 0.1M NaOH. Both the DEFs and IX column were instrumented with dedicated differential pressure instruments to monitor pressure drop in real-time. Flow was controlled at FM-02 using a flow meter coupled with an actuated control valve. Other vessels in the system are representative of destination for each process stream but were sized for operational convenience.

Four tests were conducted in the test system using, as much as was practical, prototypic operating sequences; each test used a freshly prepared simulant batch of approximately 1,140 L (300 gallons) and contained four elements:

1. Preparation (as required) of the simulant and loading it into the test system
2. Preparation of the test system and startup activities
3. Test operations at the target conditions
4. Shutdown of operations and post-test observations

Of these four elements, the first two preparation steps sometimes occurred simultaneously in practice, but both were complete before proceeding with testing. For other details on operation, refer to Schonewill et al. [16].

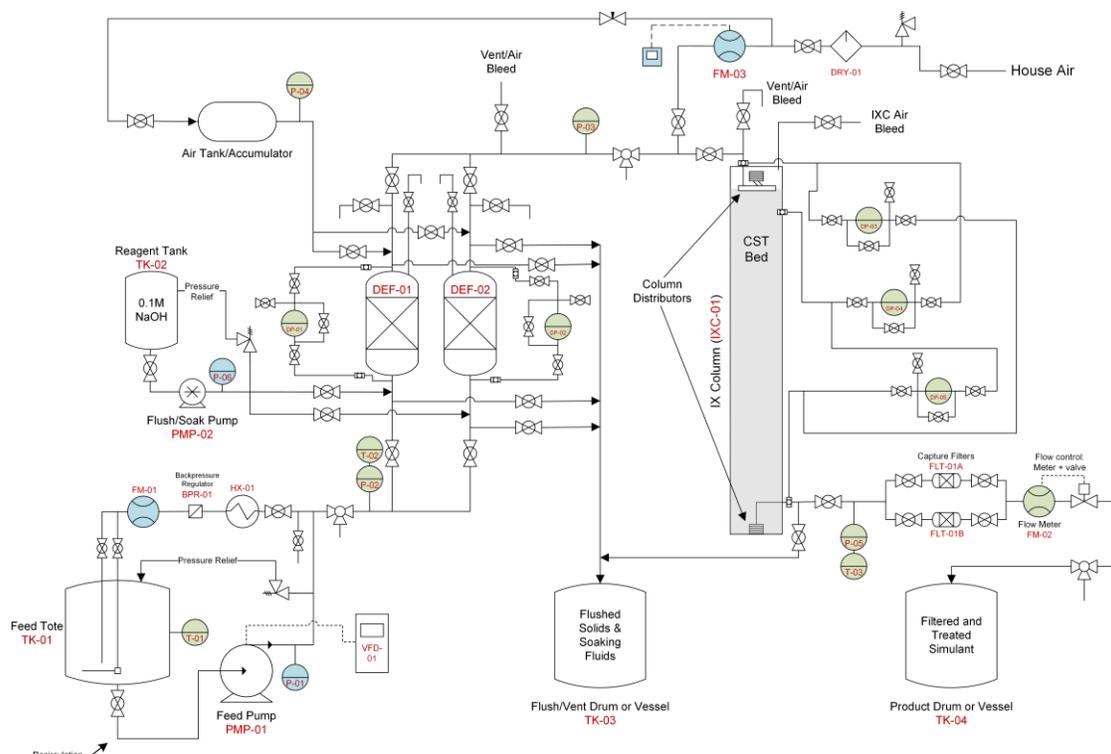


Fig. 1. Schematic Representation of the PNNL Test System Used for High Solids Performance Testing.

The conditions of the four tests are summarized in TABLE IV. Flow rate and temperature control to the target values was achieved readily in the test system and there were no significant deviations. The actual solids loading measured from feed samples collected from the test system was generally below the intended values by a significant amount (approximately a factor of three for HS1 and HS2). This is attributed primarily to the effect of exposure, during shipping and prolonged storage, to uncontrolled environmental conditions that complicated mobilization of the simulant into the feed tank; to a lesser extent, simulant make-up at larger scale could have also been a contributor (this cannot be assessed because the simulant was not assessed by the vendor prior to being shipped). The solids concentration of Test HS3 was purposely adjusted to obtain additional relevant information from the test system rather than attempting to operate at a higher solids concentration – maintaining the target throughput at solids loadings > 3,000 ppm was expected to be extremely challenging.

TABLE IV. Matrix of Tests Performed Using the Test System.

Test Identifier	Actual Solids Loading in Feed (ppm)	Actual Mean Liquid Flow Rate (mL min ⁻¹) ^a	Actual Mean Simulant Feed Temperature (°C) ^a	Simulant Volume Actually Processed (L [gal])	Simulant Used
NB1	Negligible ^b	130.0 ± 0.1	22.0 ± 0.2	~1058 [279]	5.6 M Nominal Simulant
HS1	670, 930 ^c	130.0 ± 0.7	21.9 ± 0.2	~1115 [295]	High-Solids Simulant
HS2	3,000	129.3 ± 4.1	21.8 ± 0.4	~598 [158]	High-Solids Simulant
HS3 ^d	970 / 500	129.9 ± 1.0	22.3 ± 0.2	~1137 [300]	High-Solids Simulant

^a Based on an average of all measurements over the test operation; also shown is one standard deviation of the average. The targets for flow rate and temperature were 130.0 mL min⁻¹ and 22 ± 3 °C, respectively.

^b A small amount of solids was present in the sample, but not enough to quantify.

^c In Test HS1, the solids loading was measured on two feed samples that were collected during the test – the first at the beginning of the test, and the second at approximately 50 hours. Shown in the table are both values from the solids analysis of the samples.

^d Test HS3 modified the simulant in the feed tank approximately halfway through the test. The modification was an ~50% dilution with solids-free simulant supernatant. The values are the solids loadings for the two halves of the test.

The primary methods by which the test system performance was measured included the following:

- Quantifying the control of system flow rate to its target value
- Assessing the rate of increase in the pressure differential across DEFs when active
- Observing the frequency of backflushing needed to maintain the target flow rate
- Measuring filter recovery, e.g., the DP at t = 10 minutes on the active DEF after swapping filters
- Monitoring pressure differentials measured across the IX column
- Collecting effluent samples for cesium concentration
- Examining post-DEF samples for evidence of solid particles

The methods listed above, except for the effluent sample analyses, were executed directly from the recorded data collected during the tests. Only simple post-test analyses, such as removing known low-quality data points and statistical calculations (averages, standard deviations), were performed.

RESULTS

Summary data from the four tests is presented in TABLE V. The table presents the number of filter cycles required to perform the test (each cycle is one evolution on either DEF-01 or DEF-02), the average initial

and overall slope in differential pressure data measured from the filters over all cycles, the average time between DEF swaps, the cesium concentration ratio at the end of the test, and the maximum increase in IX column bed pressure over the course of the test. General trends observable from the summary data are the sharp increase in filter slopes (and corresponding decrease in filter swap times) as the solid content increases and the lack of noticeable impact of solids on the IX column – there was not an abnormal early cesium breakthrough or any significant increase in pressure drop as the solids concentration changed. Fig. 2 also demonstrates that, for all four tests, there were only minor increases in CST bed pressure drop over operating time; as no solids were observed at the top of the bed at the end of each test, this is likely caused by consolidation in the CST bed.

TABLE V. Summarized Test Data for the High Solids Performance Tests.

Test	Number of Filter Cycles	Average Initial (0-10 min) Filter Slope (psid h ⁻¹)	Average Filter Slope during Operations (psid h ⁻¹)	Average Swap Time (h)	End of Test Value of C/C ₀ (%)	Maximum Increase in IX Bed ΔP (%)
NB1	8	1.77 ± 0.29	0.11 ± 0.07	17.0	0.17	12.2
HS1	60	7.19 ± 2.27	8.41 ± 2.54	2.39	0.18	7.46
HS2	92	14.9 ± 3.9	27.0 ± 7.0	0.84	0.13	19.7
HS3 ^a	30	6.22 ± 1.00	10.4 ± 2.2	1.85	0.15	21.6
	40	3.69 ± 0.41	1.86 ± 0.47	2.26		

^a Since Test HS3 had two distinct periods of operation, the filtration data was separated for the statistical summary in this table. The upper value is from the first half of the test (Part 1, where the solids loading was approximately double the second half of the test). The second half of the test (Part 2) is the lower value.

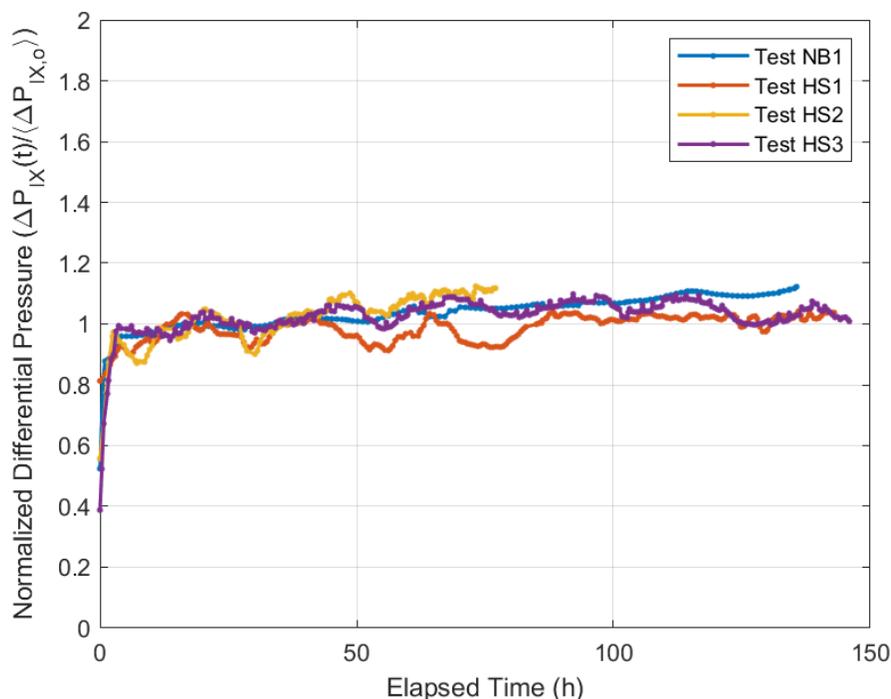


Fig. 2. Normalized Differential Pressure across the IX Column (CST Bed) for All Four Tests.

Closer examination of the cycle length data shows that there was no discernable trend in the time between swaps (see Fig. 3), except for a noticeable drop in duration during Test NB1. The tests with appreciable amounts of solids (HS1, HS2, HS3) all exhibited repeatable filter operations over many evolutions. This occurred despite the relatively short period of operation between filter swaps and the rapid increase in pressure differential observed during each cycle. This point is illustrated in another way in Fig. 4, which shows the pressure differential measured immediately after swapping DEFs for the test with the highest amount of solids (HS2). There are some gaps in the data set shown in Fig. 4, which occurred when the filter plugged or needed additional recovery during a swap. Data from those cycles were removed since they are not directly comparable to the operationally prototypic cycles. After conducting 45 swaps for each filter element, the initial pressure reliably returned to approximately the starting value of the preceding cycles; no trend of significance appears to be present. Thus, although the increase in pressure was permitted to exceed the 2-psi benchmark for swapping filters (to preserve a 2-hour 0.1M NaOH soak time as part of the backwash evolution), filter backwash appeared to repeatedly restore filter performance during test operation.

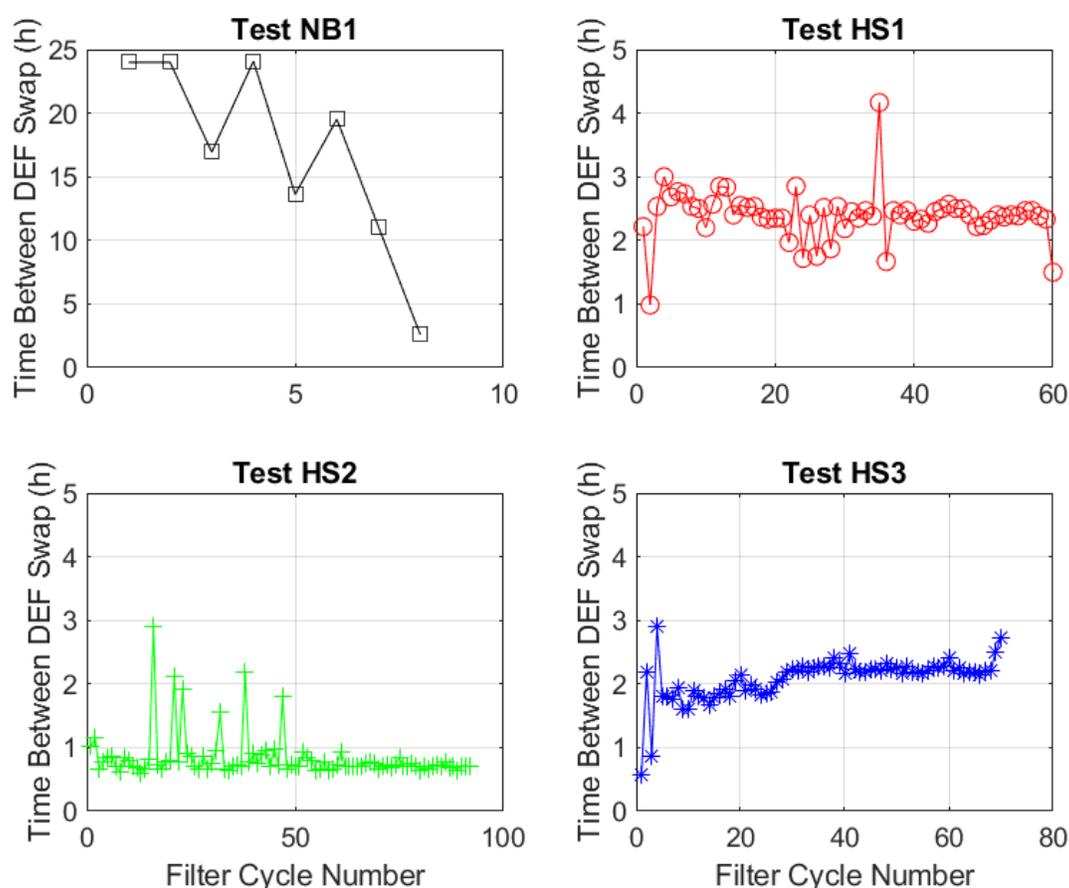


Fig. 3. Time Between Each Filter Swap, Presented Chronologically for the Four Tests.

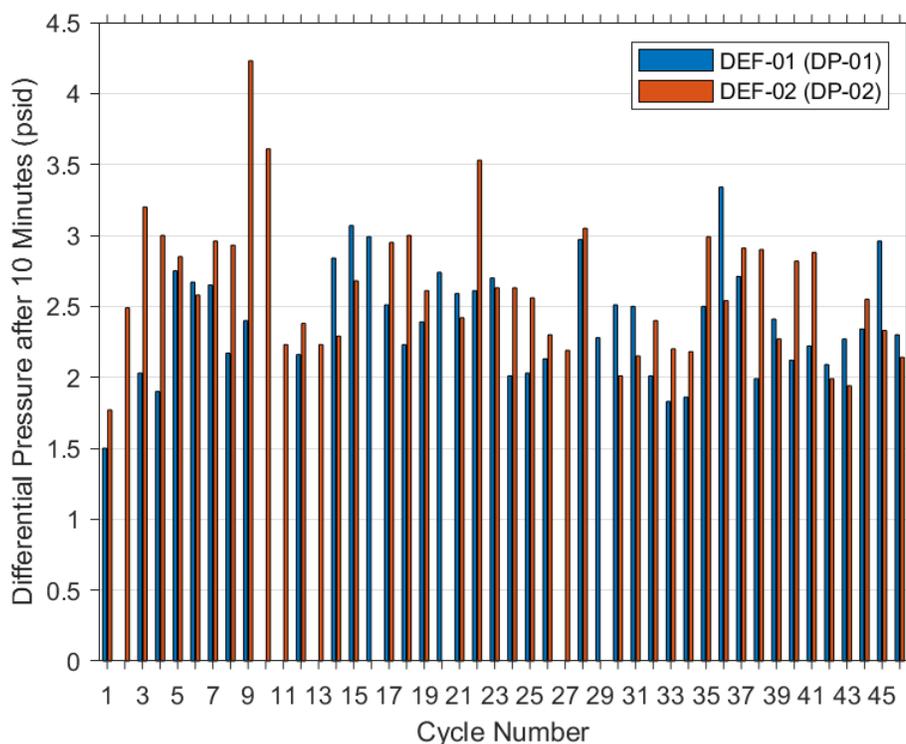


Fig. 4. Initial Differential Pressure (after 10 minutes) Observed for Each Filter Cycle in Test HS2.

The rapid increase in pressure is represented by the slope for each DEF evolution calculated from the measured test data. The slopes, expressed in psid h^{-1} , are shown for every filter cycle for all tests in Fig. 5. The appreciable change in slopes measured during Test NB1 compared to subsequent tests with the HS simulants is readily observed from the Fig. 5 data. The data also shows that performance became a bit more erratic at the highest solids loading (HS2), although the data for the HS2 evolution is sparser. Of note is Test HS3, which used HS simulant that initially had a solids loading of 970 ppm and at approximately cycle number 30 diluted the simulant to reduce the solids loading by approximately a factor of two (500 ppm). The increase in pressure differential reflects the impact of the dilution step clearly: There is a reduction in the measured slope for cycles > 30 of about a factor of five. The substantial reduction suggests the sensitivity of the DEFs to solids loading even at solids loadings of $< 1,000$ ppm.

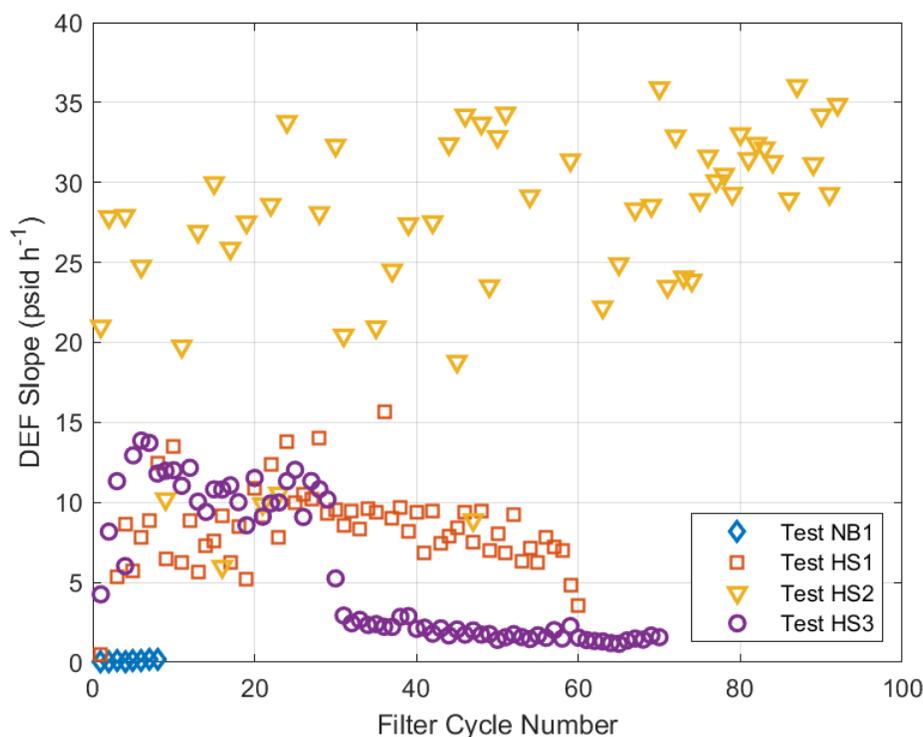


Fig. 5. Slope Determined from DEF Data as a Function of Cycle for All Four Tests.

CONCLUSIONS

The test data did not indicate that TSCR will have any difficulty in maintaining throughput when a nominal level of solids is present based on the results of Test NB1. However, based on analysis of test data and operational observations of Tests HS1, HS2, and HS3, the following are some important conclusions regarding operation at higher solids loadings:

- The dead-end filters successfully performed their primary function of protecting the IX column at all tested solids loadings. This was supported by several pieces of evidence collected during the testing:
 - There was no observable plugging of the IX column during each test.
 - Visual observations of the top of the CST bed after each test showed no evidence of particle accumulation and particles were not visually observed in the effluent collection tank.
 - There was an absence of visually observed solids in post-DEF samples collected periodically during operation and process lines downstream of the DEFs.
 - The initial cesium loading behavior onto the CST was not discernably impacted by higher solids loadings.
- The filters exhibited a rapid rate of change in pressure differential even at modest solids loadings, i.e., ~1,000 ppm and greater. Though the target throughput of the system was maintained, the observed system performance at off-normal solids loadings challenges the planned operational approach for TSCR because:

- The ΔP across each DEF increased above the 2-psid target in as little as ~10 to 15 minutes for the highest solids loading tested (~3,000 ppm). Swapping between filters when the 2-psid pressure target is reached demanded rapid response by operators, required operational vigilance, and generated an appreciable amount of flushed waste (which would ultimately collect in tank AP-108 during TSCR operation).
- Above the 2-psid target, the rate of change in ΔP usually accelerated, especially above ~10 psid. This introduces a risk that the pressure could suddenly increase beyond the maximum allowed pressure differential of 25 psid and an interlock could be activated in the TSCR facility.
- Rapid swapping would significantly reduce the duration of the 2-hour 0.1 M NaOH soak time that is planned for TSCR. While there was not a noticeable impact on backflush efficacy when the soak time was shortened during the scaled testing, it is not certain that this would also be the case for full-scale radioactive operations.
- The filter swapping frequency may significantly reduce the amount of “net” treated waste since every backflush evolution sends the equivalent of two DEF volumes to tank AP-108. The DEF shell volume in the tests system was not scaled to the full-scale TSCR shell volume, so the breakeven point cannot be projected directly from the test data.
- Despite pressure differentials that increased up to 25 psid over time periods of less than an hour, the DEFs were backflushed repeatedly and reliably during test operations. Backflushing and a 0.1 M NaOH soak (even if the soak period was truncated) consistently returned the DEF to its baseline ΔP . DEF performance, as observed during these tests, is well-described by the term “cyclic.”
- Following the completion of a test run, the system was readily returned to its baseline performance level (as determined by a 0.1 M NaOH flow measurement conducted before each test) without any significant interventions. The only “cleaning” conducted between tests involved flushing out simulant material with 0.1 M NaOH, water rinsing the pH down to ~7 or 8, and a handful of backflushes on each DEF.
- The scaled system tests were conducted in such a way as to be faithful to the planned TSCR configuration and procedural steps as possible. No significant issues were identified with the operational configuration during testing. One minor observation was that when the CST was contacted initially with simulant after being loaded with 0.1 M NaOH, a significant number of fines were released and flowed downstream. A similar effect would be anticipated when first contacting CST with actual waste feed.

Overall, the test data suggest that operating TSCR at target throughput with a higher solids loading in the feed is possible by exercising some operational flexibility but operating in that regime is likely to require more frequent filter swapping than is generally expected.

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