Parameters Impacting Crossflow Filter Performance of Hanford Tank Waste Simulants

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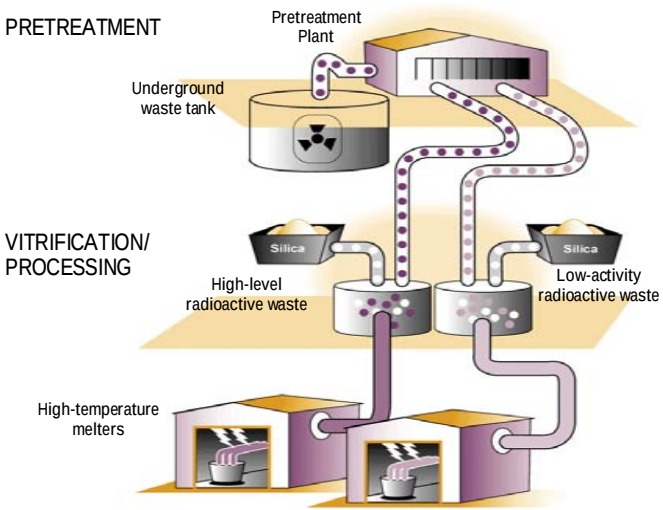
Hanford Waste Treatment Plant (WTP)

The Waste Treatment Plant (WTP) is being designed and built to process the approximately 55 million gallons of radioactive waste sludge generated by defense activities at the Hanford Site in Richland, Washington.

The planned waste treatment strategy is:

1. transfer the waste from the tank farms, where the waste is currently stored in 177 underground single- and double-shell tanks, to WTP
2. process the waste in the Pretreatment Facility (PTF) to separate low- and high-radioactivity waste streams
3. vitrify the separated waste streams

Image: double shell tanks under construction (image ID 89041306-3CN, digisource.pnl.gov)



WTP process schematic

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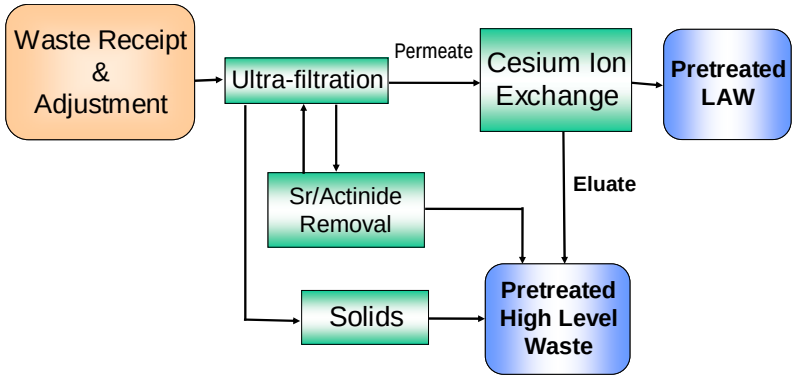
Filtration at the PTF

The pretreatment facility plans to employs **crossflow** filtration to support the caustic and oxidative leaching processes used in waste slurry pretreatment.

Specific pretreatment activities supported by filtration include:

- *separation* of high-level waste solids from low-activity liquid stream
- *washing / reconcentration* operations following chemical leaching of the waste slurry solids



Pretreatment process schematic

Crossflow filtration is key to pretreatment facility throughput

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Motivation for Process Filtration Studies

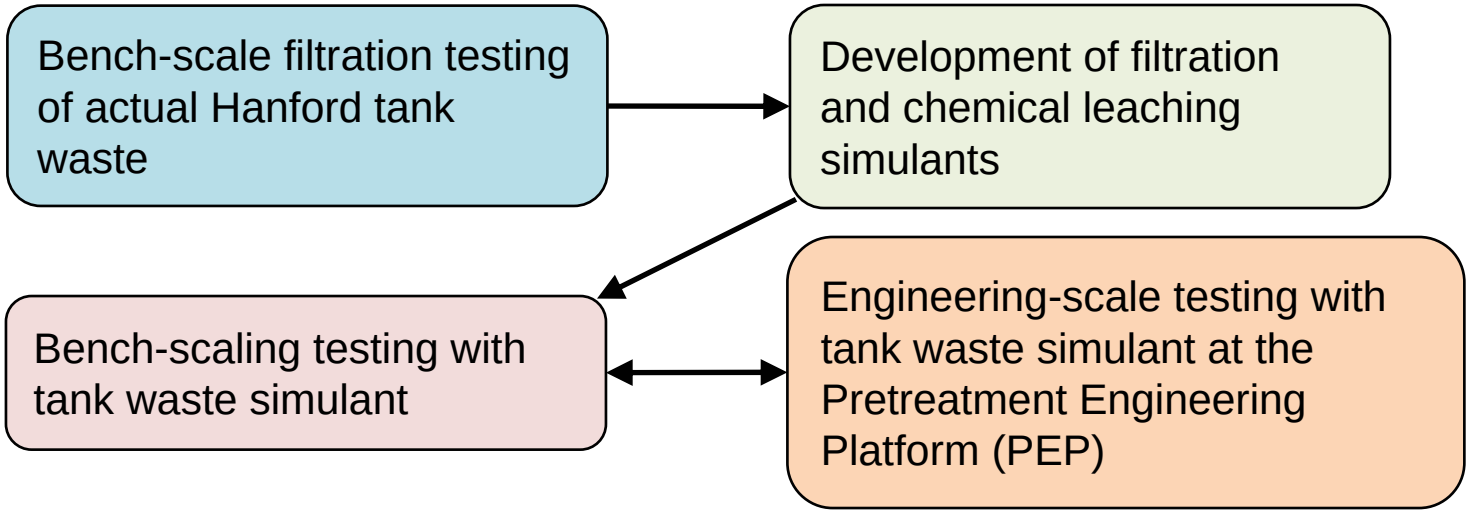
In FY2005-2006, an External Flowsheet Review Team (EFRT) conducted a critical review of the WTP process flowsheet. Seventeen major issues were identified by the EFRT. Of the issues identified, Issue M12 defines the motivation for current studies. It states that:

> *Neither the caustic leaching nor the oxidative leaching process has been demonstrated at greater than bench-scale size. The small-scale experiments are capable of defining the leaching chemistry. However, they are limited in their capability to predict the effectiveness of these processes without a scale-up demonstration.*

Issue M12 also concerns demonstration and scale-up of the crossflow filtration

PNNL Support for Issue M12 Resolution

PNNL undertook several experimental activities to support resolution of this issue:



Scale filtration test systems:

1. Pretreatment Engineering Platform (PEP) – is designed to perform engineering-scale demonstrations of the WTP pretreatment ultrafiltration and leaching processes. PEP has been scaled to be geometrically similar to PTF (with a 1/4.5 linear length scale factor).
2. Cells Unit Filter (CUF) System - is designed to perform laboratory-scale demonstrations of select WTP pretreatment operations

PNNL Support for Issue M12 Resolution Cont'd

The major finding for PNNL M12 studies was that the scale-up factor for bench- to engineering-scale tests was ~1.

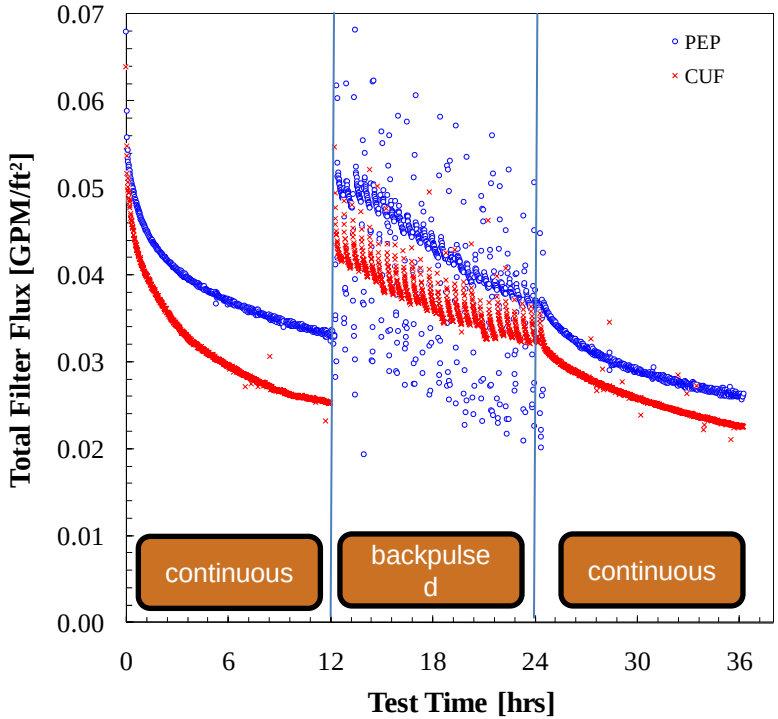
Testing identified continuing areas of concern:

1. filtration steady-state was not achieved after 36-hrs of testing
2. irreversible fouling of the filter elements (with respect to backpulsing of the filters) occurred
3. backpulsing the filters appeared to increase the degree of irreversible fouling
4. limited testing indicates that nitric acid cleaning of the filters (which is planned for use in WTP) is not the most effective means of restoring filter performance

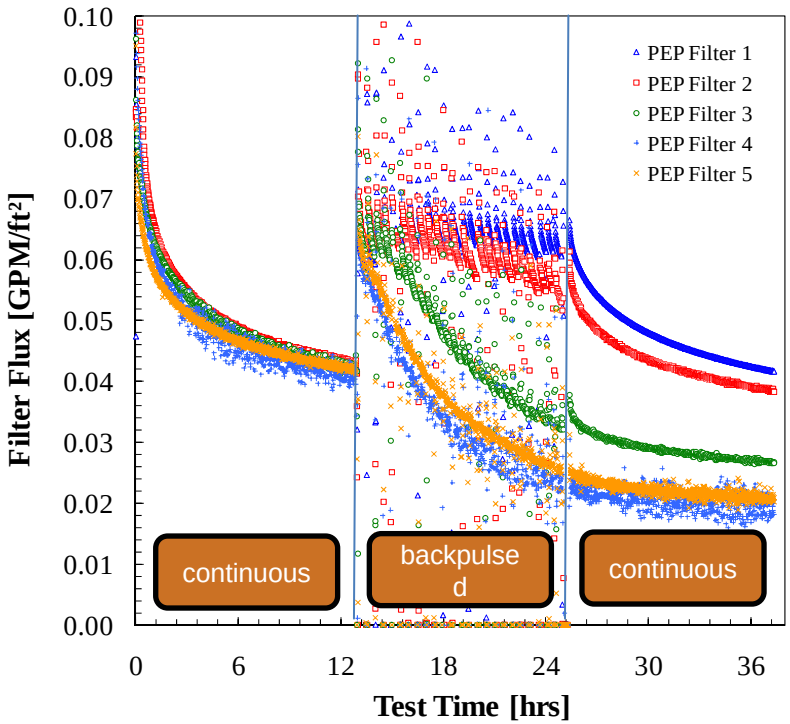
All concerns derived from a lack of understanding of filter fouling dynamics

Example M12 Results

CUF/PEP test for filter scaling



Filter fouling



Test Specifications:

- CUF employed a single 2-ft-long 0.5-inch ID tubular filter
- PEP employed five filter bundles comprised each of twelve 8-10 ft-long 0.5-inch ID tubular filters
- Transmembrane pressure of 40 psid
- Filter tube axial velocity of 15 ft/s
- Tests consist of three 12-hr segments (first 12-hr continuous, second 12-hr backpulsed, and third 12-hr continuous)

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Objective

The goal of current filtration studies is improve understanding of long-time (>12 hour) filter fouling

Filtration testing of a Hanford tank waste simulant will be done. These tests will:

- Use PEP simulant at fixed UDS and Filter Surface Area/Solids Ratio for Baseline
- Vary TMP and AV to understand operational impacts to reversible and irreversible fouling
- Run 100 hr tests to see if steady state flux is achieved

Filtration Performance
Overview

- Operational Parameters
  - Pressure Drop (TMP)
  - Axial Velocity (AV)
  - Filtration Temperature
- Waste Parameters
  - Particle Size
  - Slurry and Filtrate Viscosity
  - Slurry Concentration
  - Solid Mass/Filter Area Ratios
  - Particle Affinity to Filter Media

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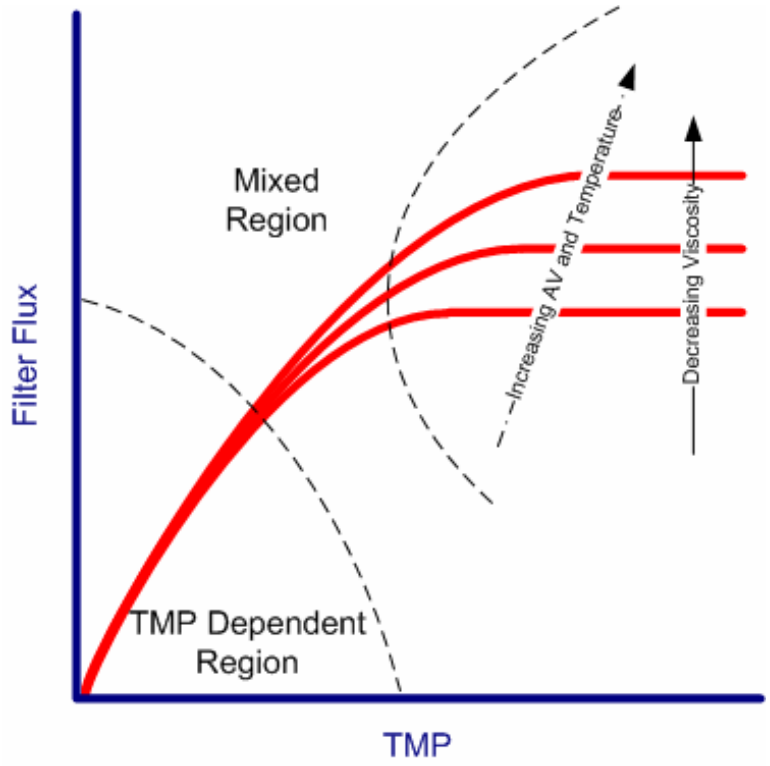
Filtration Performance
Operational Parameters Impact

- Typically at low slurry concentrations, filtration is defined by Darcy's law of filtration.
- As solids concentration increase, cake formation increases and the filtration resistance and axial velocity becomes significant.
- Temperature and filtrate viscosity also impact filtration.



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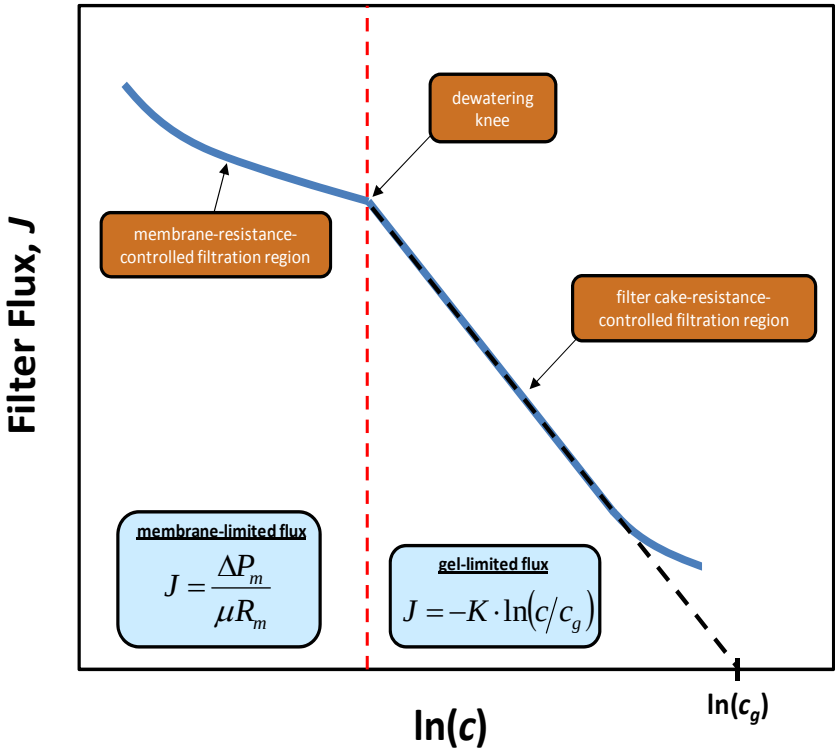
Filtration Performance
Increasing Solids Concentration

- As the concentration increases, cake filtration resistance becomes dominant and increases as a function of the ratio of slurry concentration to the gel concentration of the slurry.



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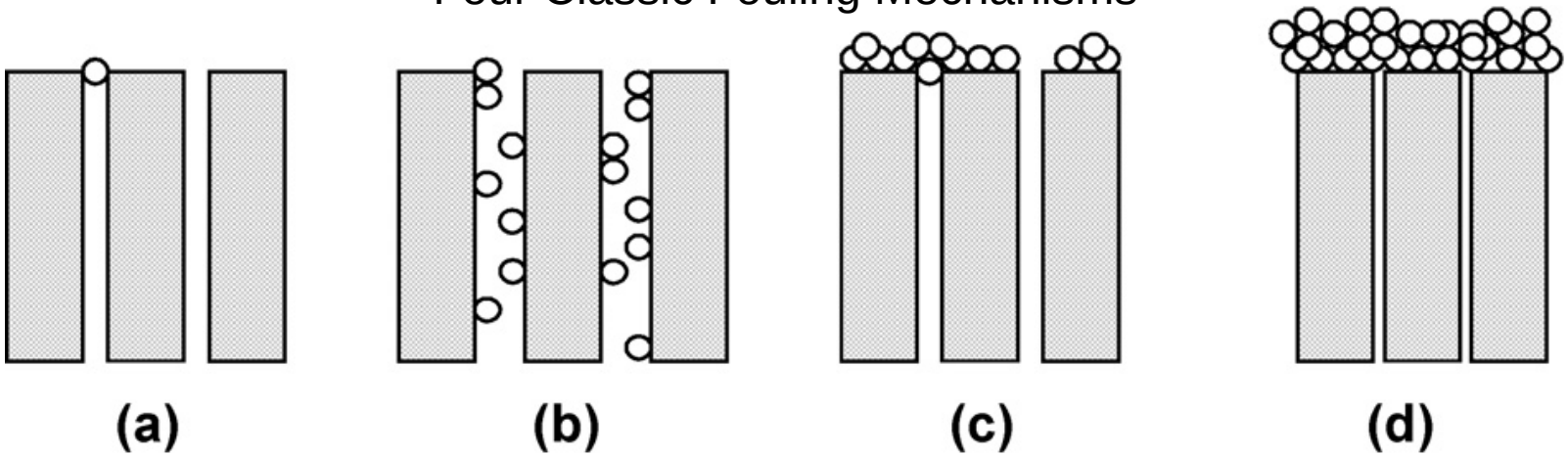
Theoretical background

Four Classic Fouling Mechanisms



- Pore blockage
- Standard depth fouling
- Intermediate blocking
- Cake formation

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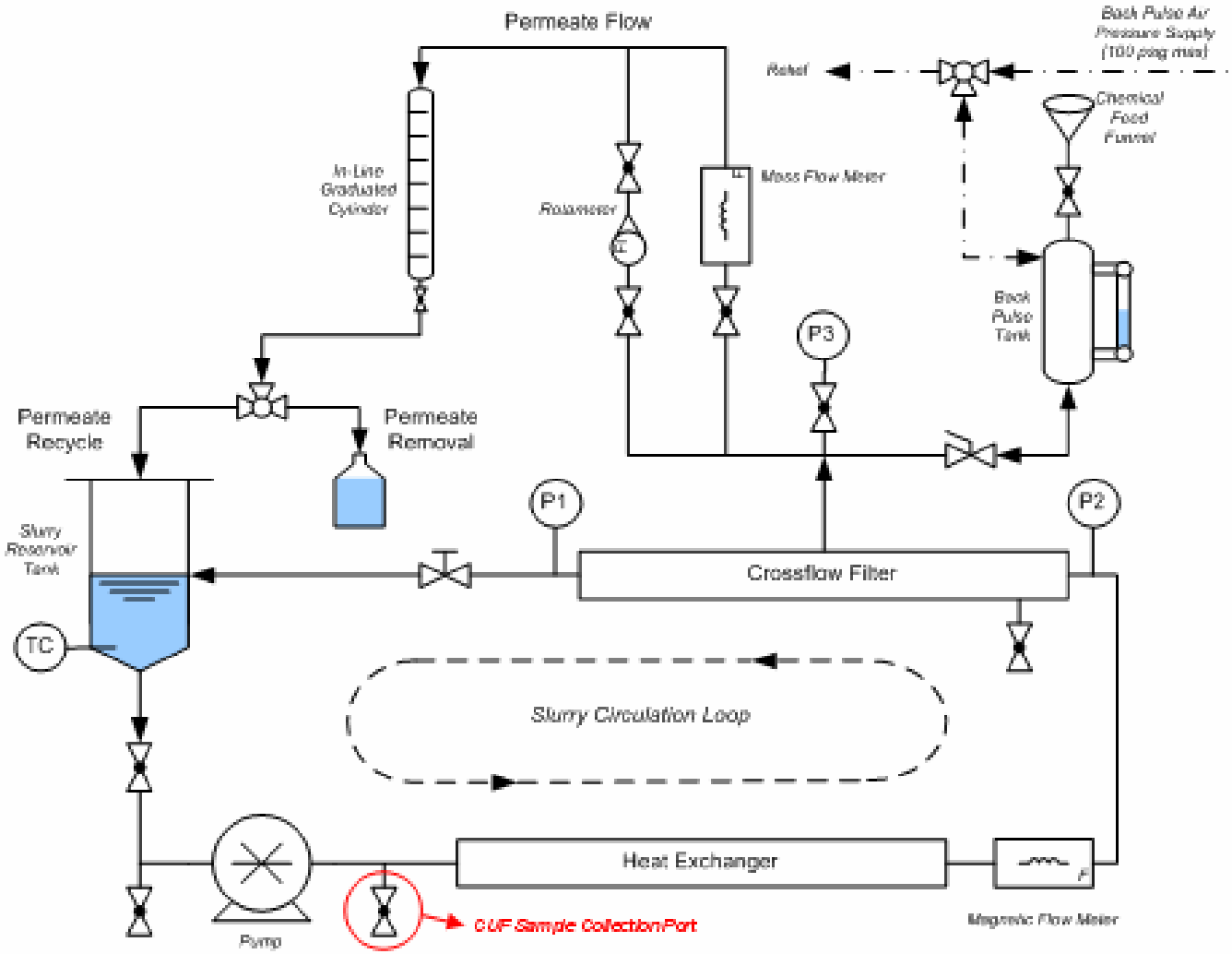
Crossflow filtration test system

A bench-scale Cells Unit Filter (CUF) crossflow filtration system used for testing. It consists of the following elements:

1. **Slurry Reservoir** – a supply, mixing, and return reservoir for the slurry circulated through the filtration/dewatering loop
2. **Slurry pump** – a rotary lobe positive displacement pump circulates the slurry through the filtration loop
3. **Filter** – a 2-ft porous tubular stainless steel filter element manufactured by the Mott Corporation (Mott Grade 0.1)
4. **Heat Exchanger** – maintains slurry temperature by removing mechanical heat created by slurry mixing and pumping
5. **Backpressure valve** – located at the end of circulation loop, this valve throttles flow to provide backpressure for the filters
6. **Permeate metering and collection** – systems that measure the rate of permeate production and direct permeate to the slurry reservoir (for continuous recycle filtration) or to collection vessels (for dewatering operations)
7. **Backpulse system** – a high pressure air supply and chamber which allows permeate to be forced back through the filter for cleaning and disruption of the filter cake

CUF Test System



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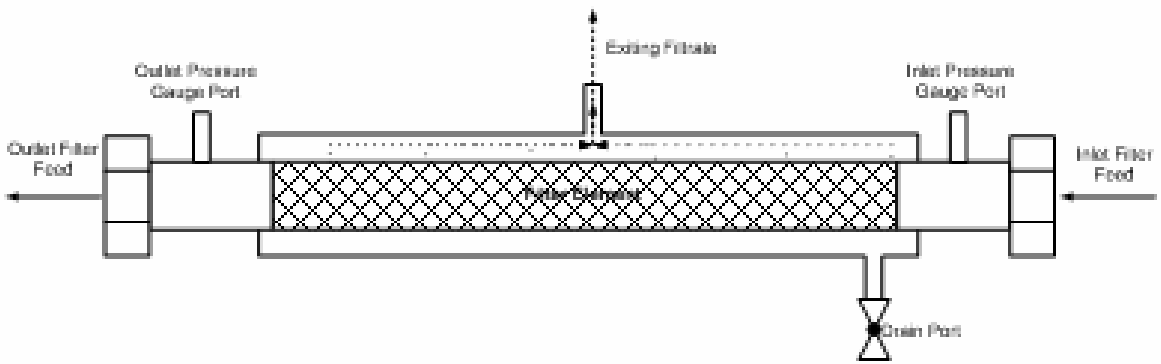
CUF Filter Element

The CUF test system employs a single 2-ft tubular filter element manufactured by the Mott Corporation:

- sintered stainless steel
- Mott Grade 0.1
- average pore opening of 1 to 3 μm (based on isopropanol flux and bubble point data)
- estimated 90% particle capture efficiency at 0.3 μm



CUF Filter Element Configuration

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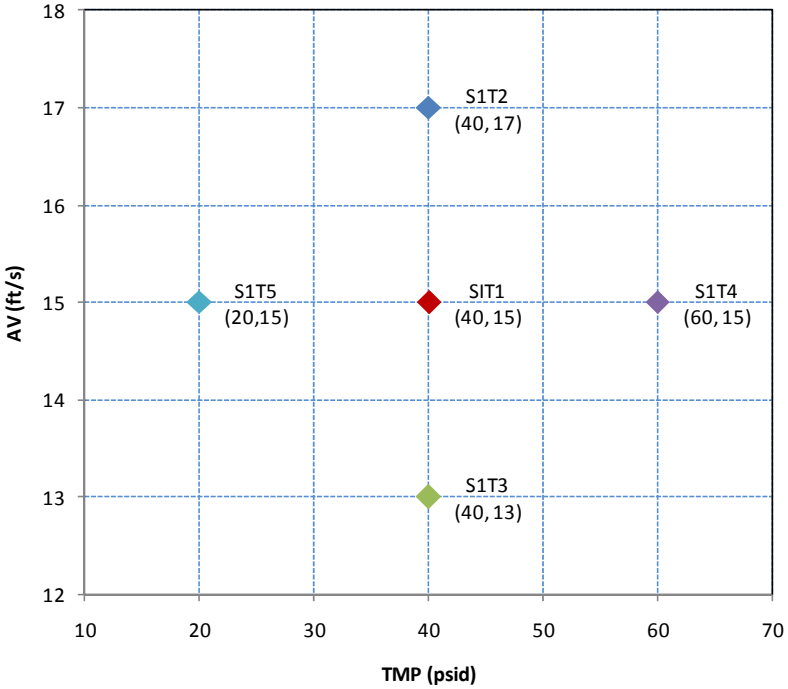
Filtration Performance

- Long Term Fouling Testing
  - Five tests performed at varying TMP and AV. Baseline conditions were TMP = 40 psid, AV = 15 ft/s
  - Simulant used was archived PEP simulant (no chromium). Weight percent solids for each test was ~6 wt%.
  - Ratio of solids mass to filter area equal for all tests and matches previous low solids CUF/PEP scaling test ratios



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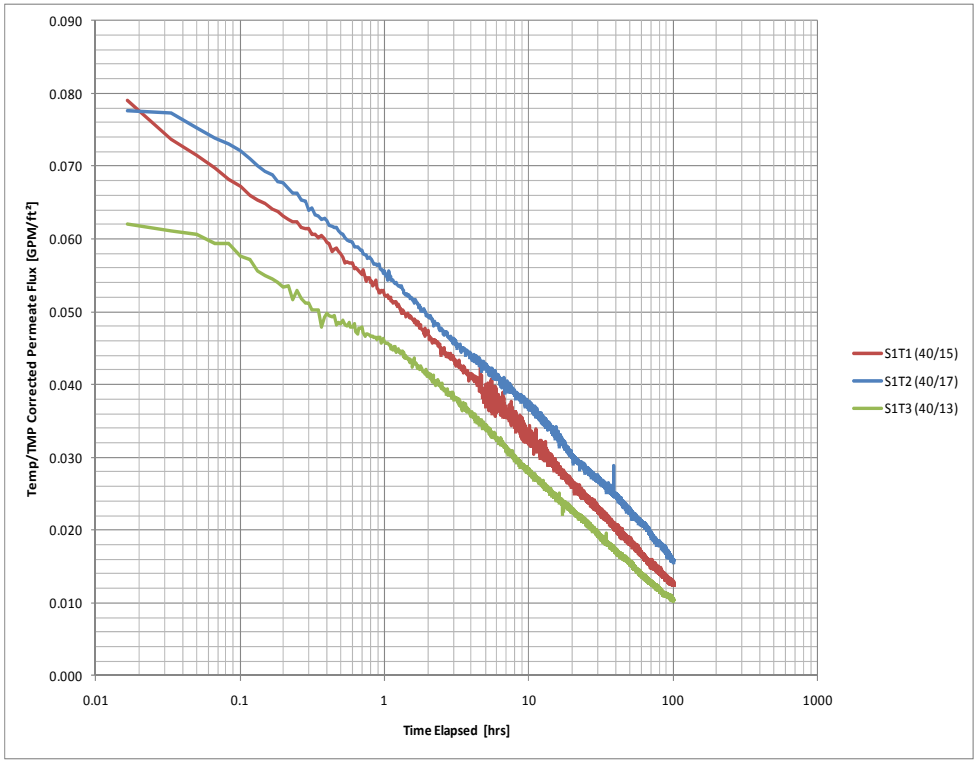
Filtration Performance

- Long Term Fouling Testing: *AV Impacts*
  - AV changes (13 to 17 ft/s) showed improvements in the starting filtration rate.
  - However, identical decay in filter flux was seen.
  - All tests indicate zero flux over time.
  - Need to assess the impact of velocity on fouling parameters.



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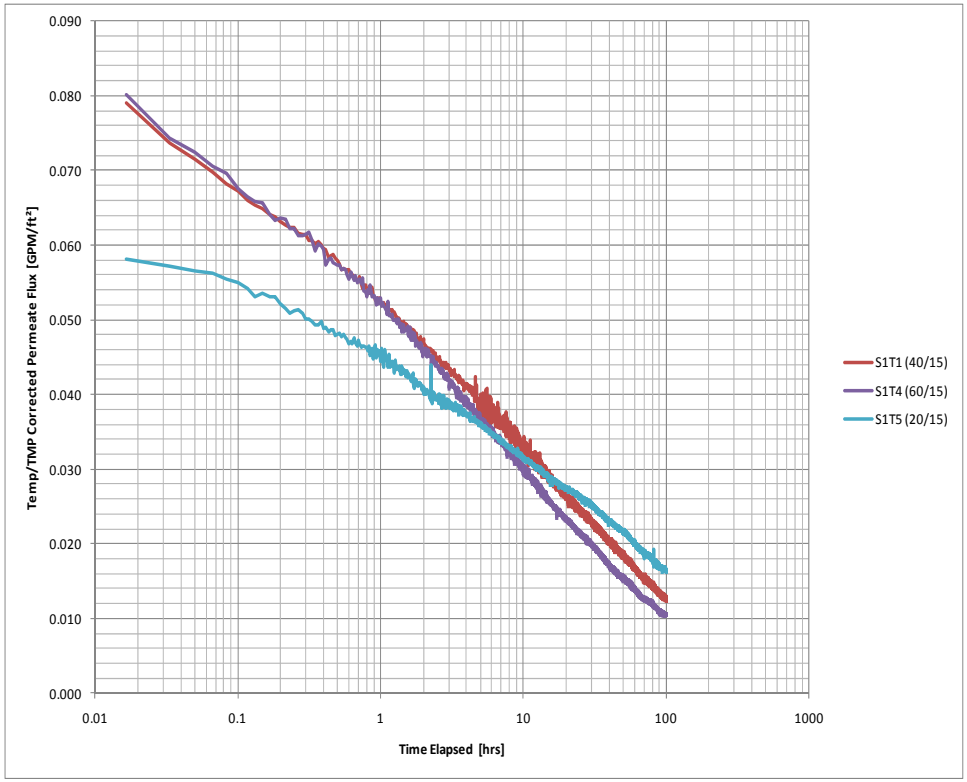
Filtration Performance

- Long Term Fouling Testing: *TMP Impacts*

  - TMP changes (20 to 60 psid) showed improvements in the starting filtration rate.
  - However, higher TMP resulted in higher rate of filter flux decay.
  - Operation of filter at 20 psid outperformed all other tests after 36 hours.
  - All tests indicate zero flux over time.
  - Need to understand the role of TMP in overall membrane fouling.



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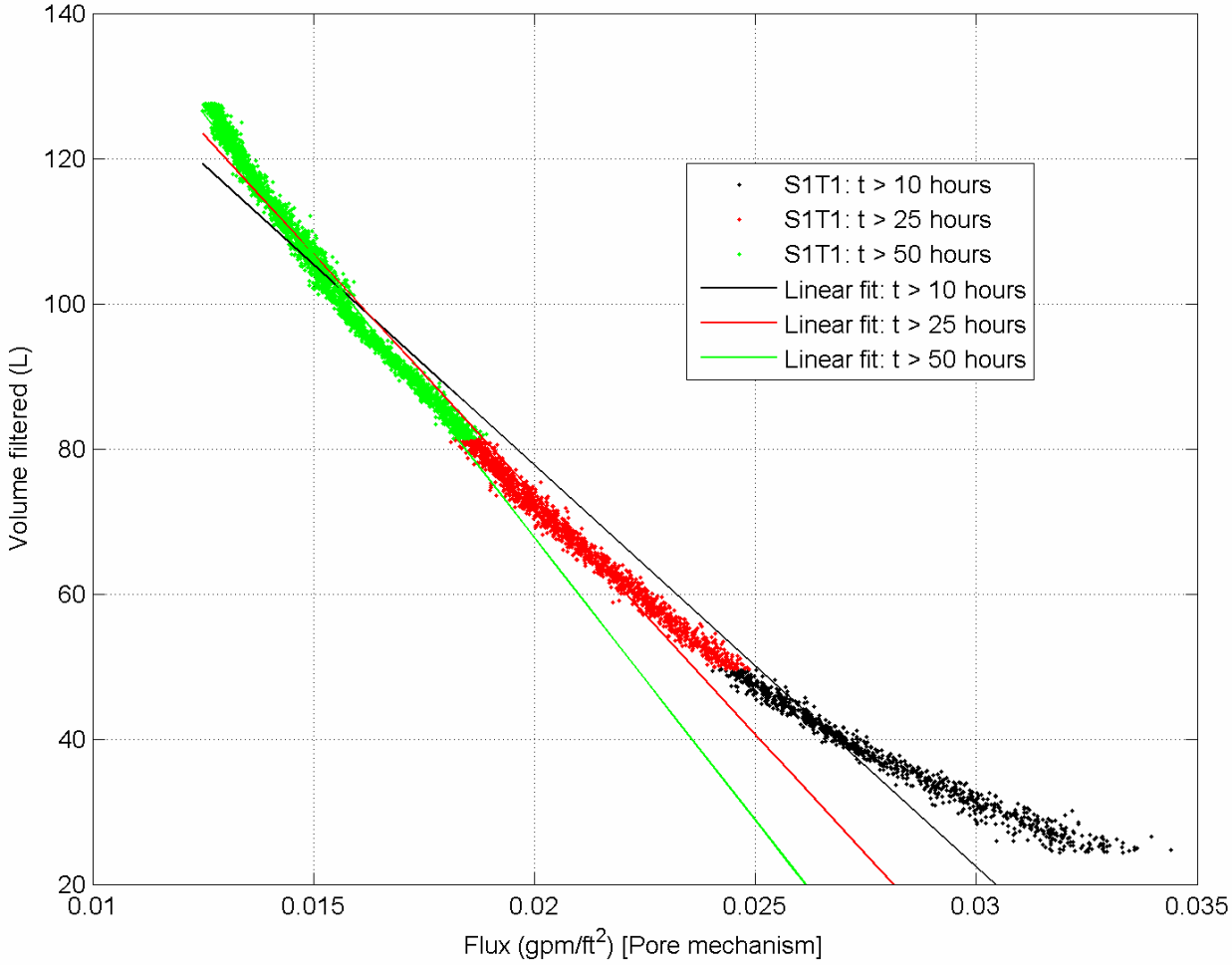
Data comparison to pore blockage mechanism



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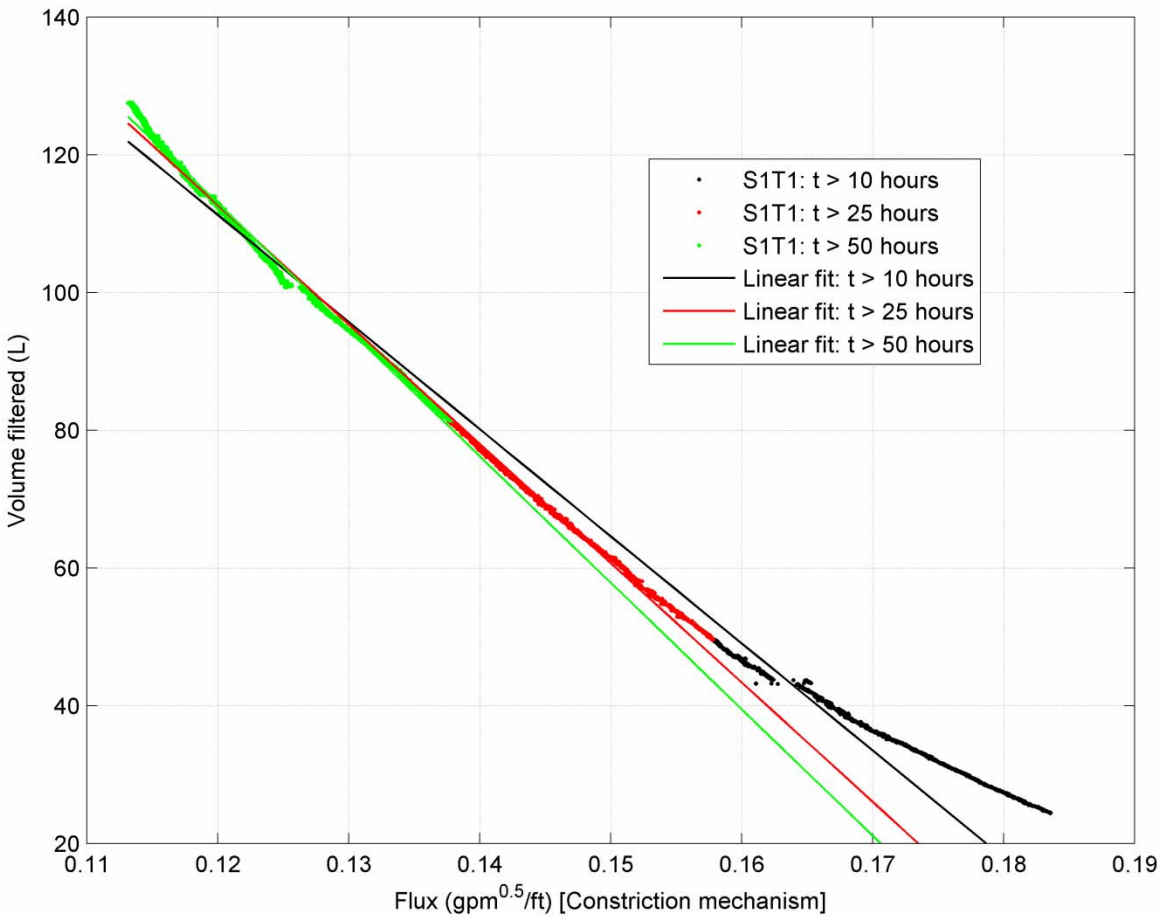
Data comparison to standard or constriction blockage mechanism



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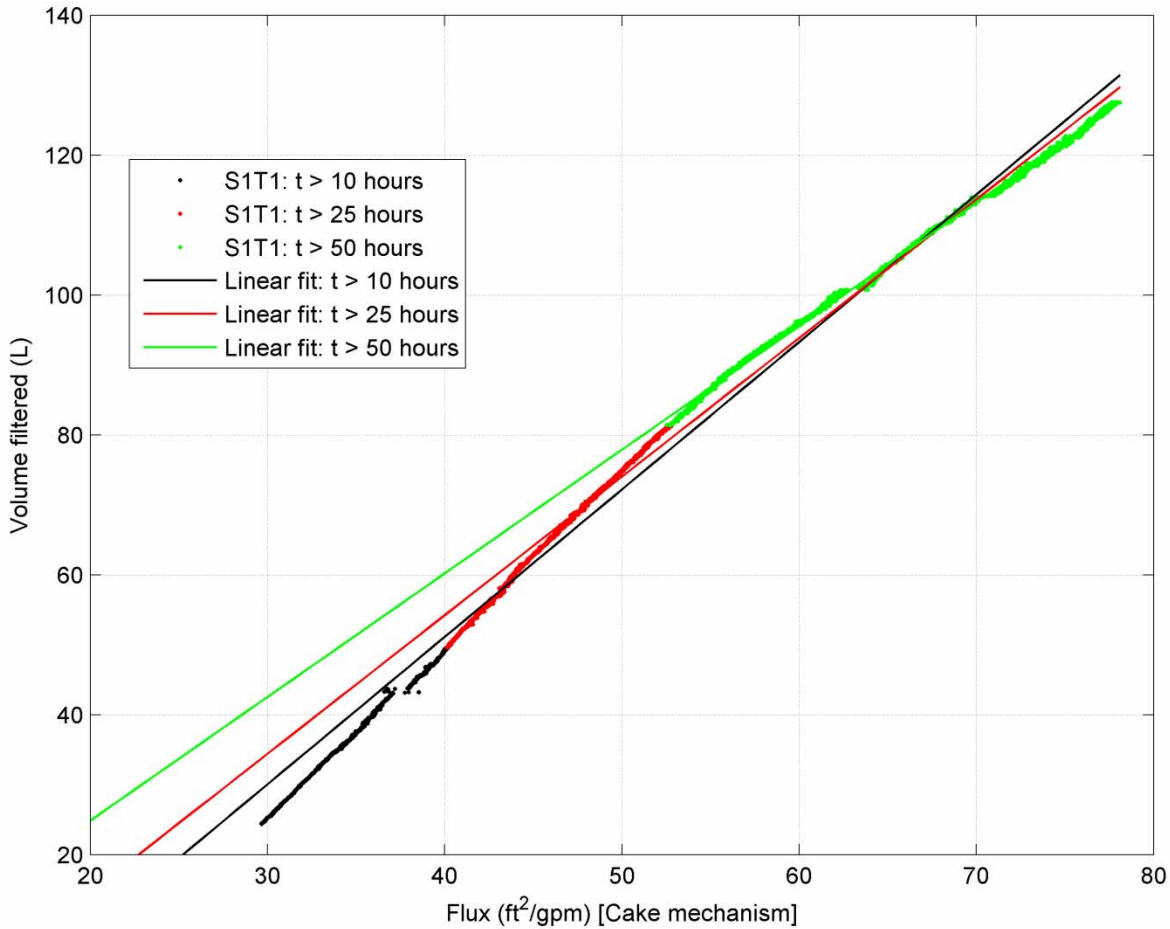
Data comparison to cake formation mechanism



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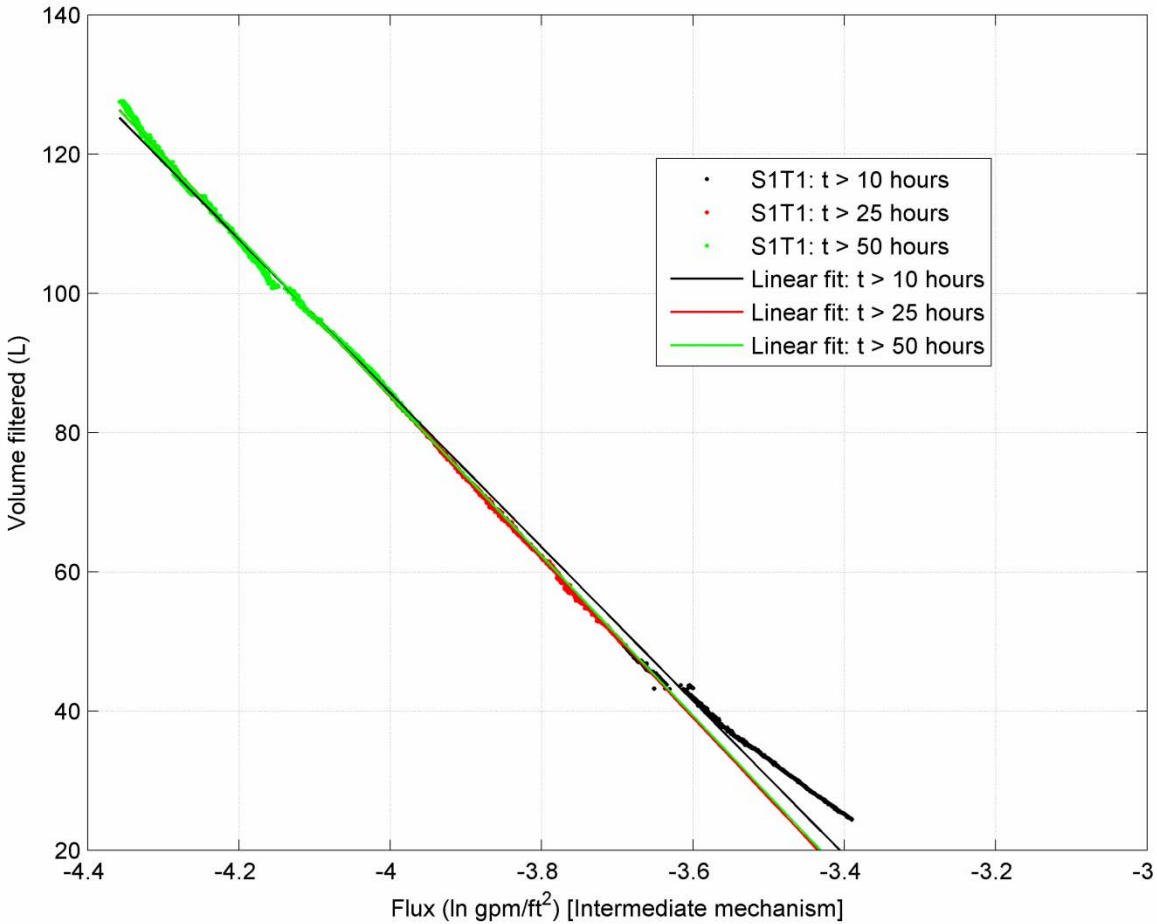
Data comparison to intermediate mechanism



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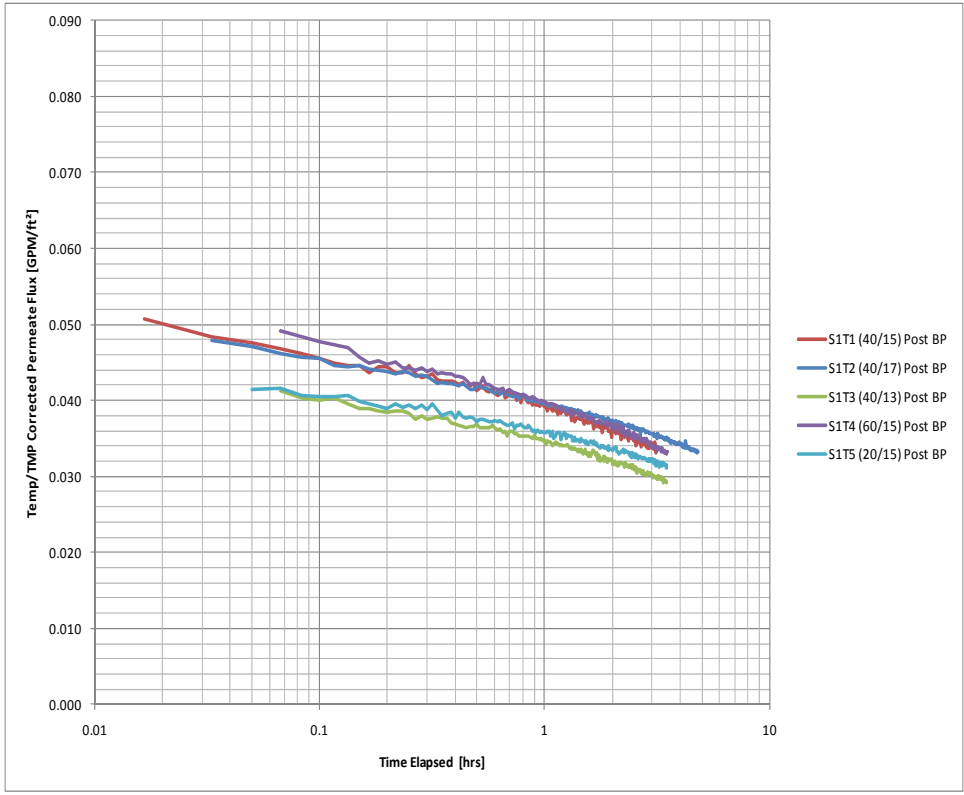
Filtration Performance

- Long Term Testing: *Backpulse Impact*
  - A series of back pulses were performed after 100 hr to compare reversible and irreversible fouling on the filter.
  - Similar depth fouling seen on all five tests, indicating depth fouling more controlled by slurry composition than TMP or AV.
  - Need to assess impacts on depth fouling at different UDS concentrations and with different waste simulant components.



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Filtration Performance

- Future Testing
  - Long Term Testing
    - 8 ft CUF Testing / 400 hr
    - Temperature impacts
    - Other simulants
  - Component Testing
    - New components (e.g. bismuth)
    - Impacts of increasing ionic strength
    - Impacts of reversing pH
    - Destructive examination of filtration elements for depth fouling identification
  - Cleaning Tests

- Program Goals
- Understand mechanisms for long term filtration fouling
- Use understanding to improve current filtration model to:
  - Optimize filter operations for long term operations
  - Understand impacts of back pulsing
  - Understand the required frequency of cleaning, and what type of cleaning

Filtration Performance
Summary

- Previous research has answered many questions on how cross-flow filtration will work with Hanford Waste.
- However, long term fouling mechanisms involved with stainless steel filtration elements have not been investigated extensively.
- Understanding the mechanisms of long term fouling are needed for:
  - Optimizing operations for extended use
  - Developing back pulsing and cleaning strategies
- By understanding the fouling mechanisms involved with using stainless steel filtration elements, predictive models can be developed for cross flow filtration for both CUF elements and RMF systems.

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Questions?

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