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## **SINGLE-STAGE FILTRATION WITH SINTERED METAL TUBULAR BACKWASH FILTERS**

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# Single-Stage Filtration with Sintered Metal Tubular Backwash Filters

## Abstract

Solid-liquid separation is often successfully practiced with filter systems where successively finer filter media are set up in stages. Tubular backwash filters with sintered metal media are an attractive alternative because they achieve the same degree of clarification in most cases in a single-stage separation. Specific examples will be discussed.

## Introduction

A majority of solid-liquid separations in the chemical process industry employ sedimentation; centrifugation and pressure filtration that require a secondary polishing step to remove fines that pass through the primary equipment. Traditionally, stand-alone filter units with disposable cartridges or bags are set up downstream of the primary equipment to achieve the desired liquid purity. The solids collected then have to be disposed with the filter cartridges or bags, and the cost associated with replacement, disposal, labor and product loss are a burden for plant operators.

Employment of evolved backwashable filter designs with re-usable filter media can significantly reduce separation costs associated with disposables (i.e., replacement, labor or disposal). Although these re-usable substitutes represent capital equipment expenditures, this is often a beneficial trade for the reduced operating and maintenance costs mentioned above. Recent developments in Mott's line of tubular porous metal backwash filters offer additional cost savings by achieving required performance with single-stage filtration (Ref. 1). These backwashable filters can either replace a traditional multi-stage separation scheme with a single-stage filtration, or integrate the polishing step with the primary solids recovery step. Single-stage or integrated separation units are attractive due to reduced operating costs, and simplified material handling.

## Porous Metal Media

The tubular backwash filters described in this paper employ sintered powder porous metal media with properties beneficial for solids removal in single-stage filtration. High-efficiency particle retention results from the pore size uniformity, as sinterbonding size-controlled metal powders forms the pores (see Fig.1). The rigid matrix formed by these sintered powder particles imparts mechanical strength to the filter element and prevents solids unloading at increased differential pressure, a phenomenon observed with less rigid media. The all-welded element eliminates particulate bypassing at the end connectors of

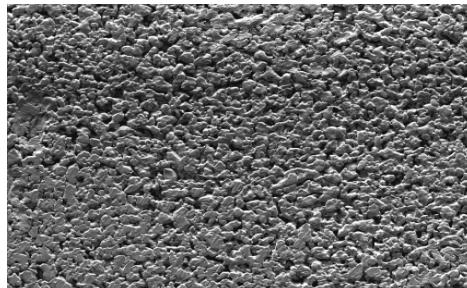
the element. These properties are advantageous for surface filtration type of solids accumulation. Porous metal media are available in several discrete grades ranging from 0.1 to 100 micrometer. The filtration characteristics and mechanical properties of 0.5 grade media are shown in Table 1.

**Table 1. Properties of Mott 316 LSS Porous Metal 0.5 Grade Media.**

<b>Mott Micron Grade</b>	<b>MFP<sup>1</sup> Size, µm</b>	<b>Minimum Bubble Point<sup>2</sup>, Inches of Water</b>	<b>Minimum Tensile Strength, PSI</b>	<b>Wall Thickness, Inches</b>	<b>Pressure Drop<sup>3</sup>, PSI</b>
<b>0.5</b>	1.4	40	23,500	0.047	2.4

1. Mean Flow Pore per PMI Capillary Flow Porometer      3. At 1.0 GPM/ft<sup>2</sup> water flow rate  
 2. In IPOH per ASTM E128 modified

The inert nature of the stainless steel (SS) powder assures liquid purity during filtration. For severe process conditions of high temperature or in corrosive environments, alloys like Monel<sup>®</sup>, Hastelloy<sup>®</sup>, or Inconel<sup>®</sup> are recommended.



**Figure 1. SEM Photo of 0.5 Grade 316 LSS**

Hastelloy is a registered trademark of Haynes International Inc.  
 Monel and Inconel are registered trademarks of Special Metals Corporation.

### **Mott Tubular Backwash Filters**

The Mott HyPulse<sup>®</sup> tubular backwash filters use a “static tube in vessel” design where all moving parts like pumps, valves and flow control devices are outside of the filter housing.

The defining feature of the HyPulse filters is the inside-to-outside flow of the process fluid with the collection of captured solids on the inside surface of the tubular filter element (Ref. 2). The HyPulse LSI model with single open-ended elements is used as a dead end filter as shown in Figure 2.

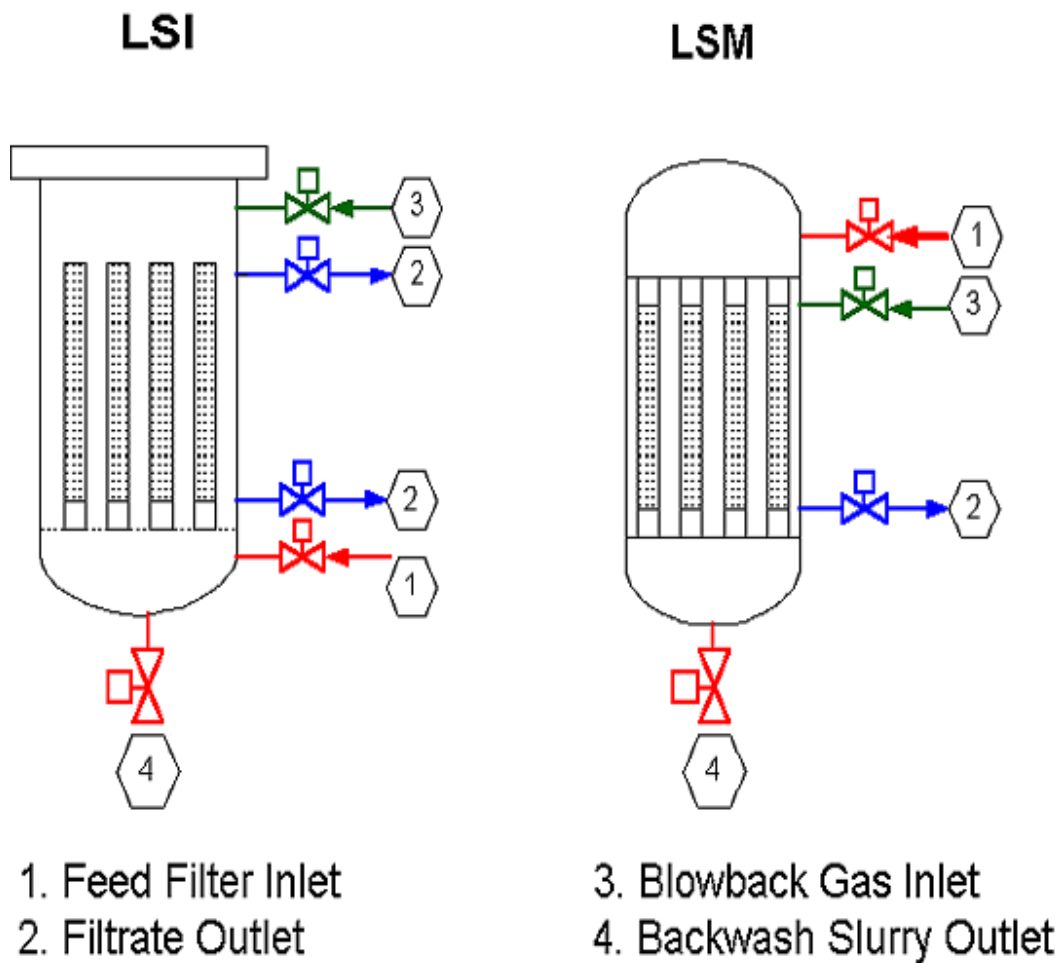


Figure 2. Mott HyPulse<sup>®</sup> Filter Options

The benefits of inside-to-outside flow are: (a) cake stability throughout the complete filtration cycle, ensuring consistent filtrate clarity; (b) post-filtration cake washing with minimal consumption of wash liquor due to plug-flow type liquid displacement in the filter elements; and (c) cake dewatering by gas displacement of free liquid inside and outside the filter elements (see Fig.3).

In a single-stage piece of equipment, three important steps are carried out in the LSI filters: clarification, solids concentration and cake washing.

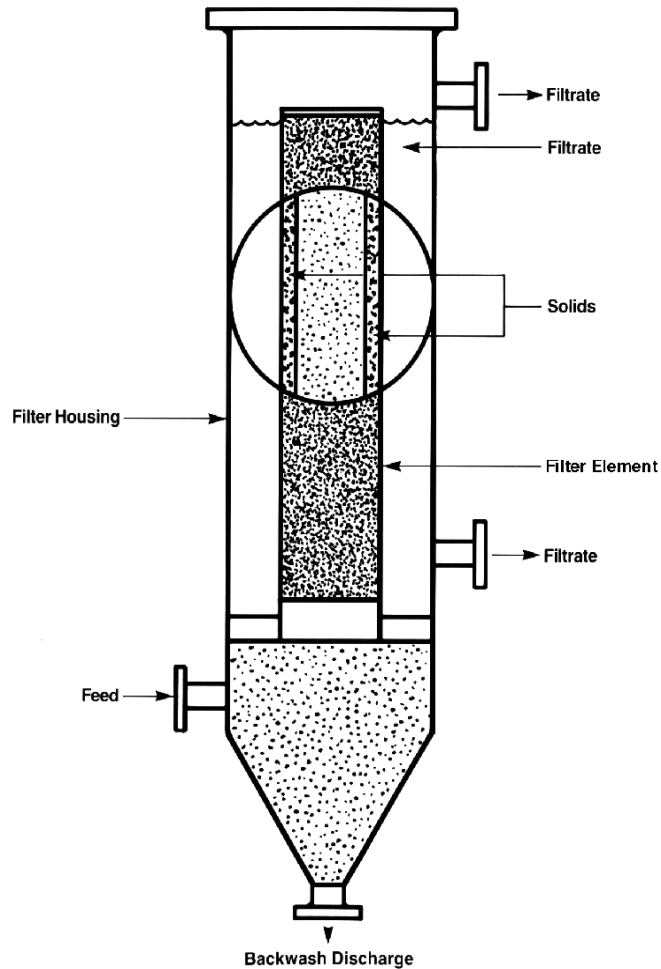


Figure 3. Mott HyPulse LSI Filter Configuration

### Case 1: Sedimentation and Polishing

A petrochemical plant needed to clarify a 120gpm continuous flow process stream containing catalyst fines, silica and metal oxide fines to < 20ppm total suspended solids (TSS). A settling tank was in use upstream of the filter where the feed solids of 2000 ppm were reduced by 90%. In order

to upgrade the clarification, both feed and decant samples were first analyzed at the Mott Laboratory using a Horiba LA-910 Laser Scattering Particle Size Distribution Analyzer (Refer to Table 2).

The particle size distributions of both samples indicated a bimodal distribution by volume (see Figure 4), whereas the number distribution had about the same mean size for both samples as shown in Figure 5. The number % mean size of 0.65  $\mu\text{m}$  indicates the suitability of Mott 0.5 grade media for filtering both streams.

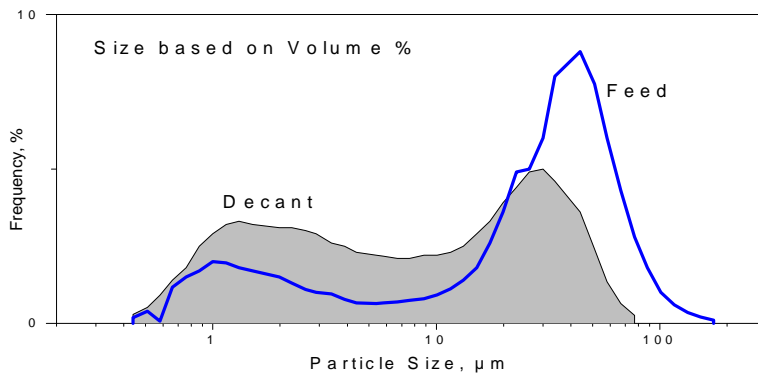


Figure 4. Comparison of Feed and Decant Particle Sizes Based on Volume %.

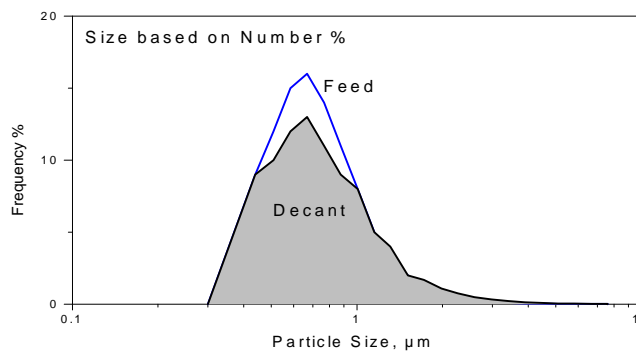


Figure 5. Comparison of Feed and Decant Particle Sizes Based on Number %

**Table 2. Comparison of Particle Size Distributions of Feed and Decant Samples.**

	<b>Feed</b>	<b>Decant</b>
<b>Feed Solids, ppm</b>	2600	221
<b>Median Particle Size (vol), <math>\mu\text{m}</math></b>	30.6	6.4
<b>Median Particle Size (num), <math>\mu\text{m}</math></b>	0.65	0.65

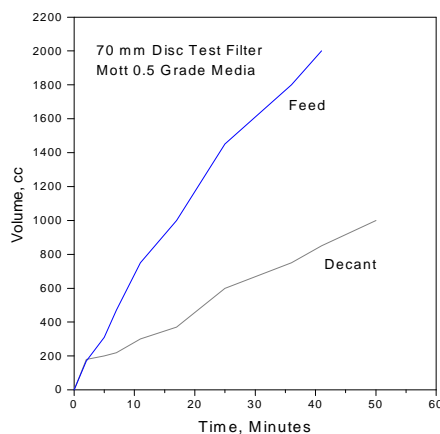
Testing was then conducted with a 70 mm disc filter and with feed and decant samples to determine retention, flux and pressure drop with Mott 0.5 grade media. Solids content of suspensions and filtrate was measured via gravimetric analysis using 0.45 µm Durapore membranes.

**Table 3. Filtration Test Data of Feed and Decant using Mott 0.5 Grade Media.**

	<b>Feed</b>	<b>Decant</b>
<b>Total Throughput, gal/ft<sup>2</sup></b>	17.04	8.52
<b>End Pressure, PSI</b>	15	40
<b>Average Fluxrate, gpm/ft<sup>2</sup></b>	0.4	0.2
<b>Filtrate Quality, ppm TSS</b>	7.8	21.5

Analysis showed that feed sample with 2600 ppm TSS was polished to a filtrate quality of 7.8 PPM, whereas the decant stream flowing out of the settling tank with 221 ppm had 3 times higher filtrate solids content (See Table 3).

The volumes of filtrate collected over time for both samples are shown in Figure 6. The feed stream filtered at twice the rate of the decant stream (i.e. 0.4 vs. 0.2 gpm/ft<sup>2</sup>) at about half the pressure drop. This would indicate that the feed with 10 times higher solids content would require a filter of half the size of the decant polishing filter.



**Figure 6. Disc Test Volume Collected vs. Time for Feed and Decant Samples.**

At this point a Mott 0.5 grade pilot filter was tested in the plant to further investigate performance differences between the two streams.

Tests showed the feed stream could be operated to a solids loading of 1.5 #/ft<sup>2</sup> when the flux was reduced to 0.15 gpm/ft<sup>2</sup> and the pressure drop increased to 60 PSID. By contrast, the decant stream reached a pressure drop of 60 PSID at a solids loading of about 0.05 #/ft<sup>2</sup> even at the low flux. The better filterability of the feed stream is the result of the presence of a higher volume fraction of large particles that increase the cake porosity .

In the final step of the evaluation, scale-up was performed using a 811 ft<sup>2</sup> LSI filter for both streams. The difference in performance is shown in Table 4. In conclusion, single-stage operation in this case produces slightly better filtrate quality at significantly reduced cost.

**Table 4. Comparison of Single-Stage and Dual-Stage Scale-up Options.**

<b>Separation Option</b>	<b>Single-Stage Filter</b>	<b>Dual-Stage Sedimentation and Filter</b>
<b>Filter Cycle Length</b>	7 hours	4 hours
<b>Underflow Slurry Rate</b>	2 gpm	3.4 gpm
<b>Underflow Solids Concentration</b>	15 wt.%	0.6 wt.%
<b>Solids Settled in Tank, lbs/year</b>	None	1.14 x 10 <sup>6</sup>



## Case 2: Integrated Polishing of Centrifuge Overflow

A producer of detergent intermediates removes a metal-based fine catalyst from hydrogenation batches with a centrifuge. The reaction slurry contains around 10 wt.% catalyst mass with 20 – 40  $\mu\text{m}$  average particle size; depending on the age of catalyst, there could be fines present below 1  $\mu\text{m}$  in size. These fines represent a loss of catalyst and contaminate the product when they are carried over with the centrate.

Overflow polishing with disposable cartridges is a fire hazard due to the pyrophoric nature of the catalyst surrounded with a combustible liquid. Therefore, as a first upgrade, sintered metal elements were substituted in stand-alone polishing filters. These filters reduced loss of catalyst fines, but needed external cleaning, because the stand-alone filter housings were not designed for in-place cleaning.

During the next plant expansion, HyPulse backwash filters were installed with automatic blowback controlled by pressure drop. The blowback slurry was sent back to the centrifuge as shown in Figure 7. With the new filter materials, handling was simplified: manual transfer of the slurry from the previously used stand-alone filters was eliminated. The sintered metal media tended to pass fines after a backpulse and required filtrate recycle until a cake had formed on the element surface. A finer media, which would have captured the catalyst fines breakthrough, was ruled out due to limitations of the system pressure supply.

The final separation optimization was realized by precoating the polishing surface filter with a small volume of feed material (see Figure 7). The large size fraction of catalyst particles in the reaction slurry readily bridge surface pores on the media and allow a more permeable cake to form. Typical loadings are 0.01 to 0.05 lbs/ft<sup>2</sup>. Precoating a surface-type sintered metal filter media produces two benefits a) instant filtrate quality and b) significantly longer filter cycles.

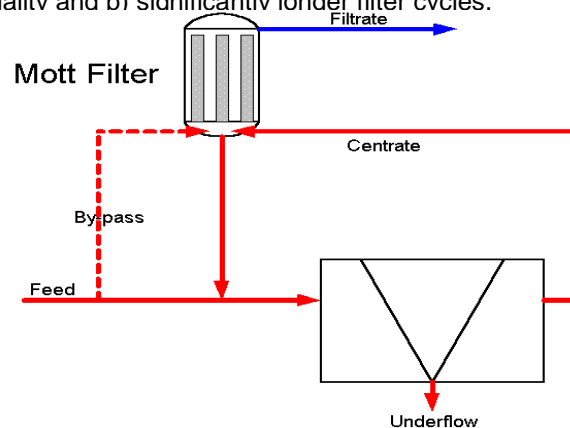


Figure 7. Integrated Overflow Polishing of Centrate

### **Case 3. Integrated, Single-Stage Catalyst Recycling**

This case concerns the separation of fine suspended catalyst particles (0.5 - 100  $\mu\text{m}$ ) from a continuous flow, stirred reactor tank (CSTR) (Ref.3). In the past, in-tank filter candles covered with either felt, cloth or PTFE laminated socks were used to retain the catalyst particles. With a typical media life of four weeks, sock replacement would require frequent CSTR shutdown. The sock media also allowed passage of fine attrited catalyst particles, requiring secondary back-up cartridge filters. This is a traditional two-stage separation scheme with disposable media.

This two-staged filtration scheme is common with disposable filter media, especially depth filter cartridges, and is based on the idea of maximizing media utilization at each stage. A re-examination of the overall CSTR process objectives established the following criteria for selecting catalyst recycling filters: (a) maximum operation time before shut down, (b) high efficiency catalyst retention, and (c) minimal hold-up volume.

Based on laboratory testing, and successful pilot testing, a Mott HyPulse LSM filter was proposed as the filter of choice. The customer decided to recover the catalyst outside of the reactor. This afforded both unit operations (i.e., reaction and separation) to perform at their respective optimal conditions.

This novel LSM (Ref. 2) filter type utilizes double open-ended tubular porous metal elements (see Figure 2) and is installed in a pumped loop around the reactor (See Figure 8). A portion of the reaction slurry entering the filter from the top is continuously filtered by inside to outside flow to maintain residence time in the reactor filter loop aggregate. Slurry exiting from the bottom of the filter is recycled to the reactor. The recirculation is set at a rate such that the filter cake thickness in the elements is dynamically controlled without the need for filter shutdown.

The benefits of the HyPulse LSM filters with tubular, backwashable porous metal media have been demonstrated for over 4½ years. The plant has been operating continuously, except for regular maintenance shut down required for other equipment, with the original porous metal elements still in use with consistently high efficiency ( $\leq 0.01$  ppm of TSS in filtrate). Last, but not least, feedstock conversion has increased over the old two-stage filter set-up because the LSM filter is operating completely enclosed.

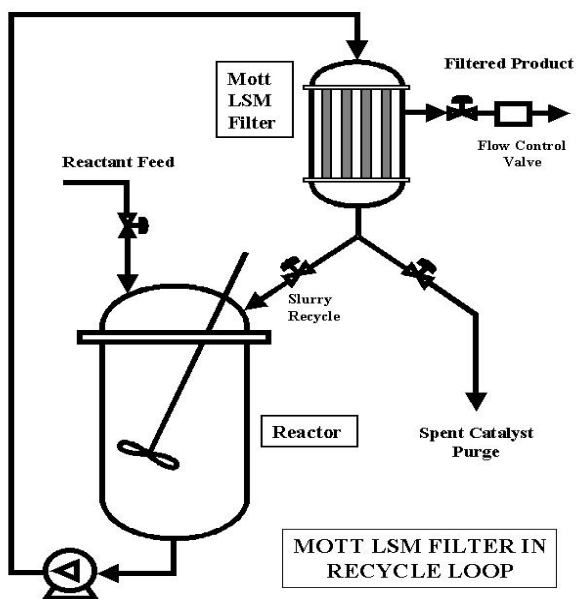


Figure 8. Mott LSM in Recycle Loop

## Conclusions

The discussion and case histories here have demonstrated the viability of rigid Mott sintered-porous tubular backwash filters for single-stage separation in clarification applications. This technology in many instances can replace the traditional sedimentation / centrifugation / pressure filtration - cartridge filter approach.

## References

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