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VERSATILITY OF THE MULTIMODE POROUS METAL FILTER IN OPTIMIZING SOLIDS/LIQUIDS FILTRATION PERFORMANCE

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ABSTRACT

The multimode porous metal filter offers the user significant operational versatility and design alternatives that are required in a myriad of process operations, thereby resulting in improved net filtration efficiency. Process data are compared to pressure filtration techniques used in standard candle filter and the inside-out filter arrangement. There are two methods of operating: 1.) Static or barrier type filtration and 2.) Dynamic or crossflow type filtration. The variations exist primarily in the method of backwash or blowdown, and secondarily in the method of feeding and concentrating. The multimode filter can be operated as a light solid polishing filter where liquid clarification is the objective, to a high solids recovery filter of catalyst or product solids.

This paper will emphasize the importance of feasibility testing, beginning with simple leaf tests to qualify media and determine filtration characteristics, to progressing to more advanced pilot testing to verify filter operating parameters for scale up design. Filter sizing will have a direct impact on both capital and operating costs.

MULTIMODE FILTER: DESCRIPTION AND OPERATION

The multimode filter is a tubular element or cartridge, using porous sintered metal media, with the ability to filter on either the element outside diameter or inside diameter. The cartridge orientation is altered depending on the filter housing configuration used. The media is re-useable due to its structural integrity, chemical and thermal compatibility. Consequently, it developed into a backflushable, cleanable filter that can employ filtrate, gas or some other process compatible fluid for backwash.

The multimode filter is easily adapted for changes in process and filtration requirements, which makes it ideal for pilot plant operations. The filter housing design will vary to optimize filter efficiency. It is a surface filtration unit that can be precoated or used with filter aids added to the feed to increase dirt-holding capacity. The filter provides a positive barrier to prevent contamination of downstream operations. Operation can be manual or automatic with fully automated controls. A considerable advantage is its simplicity of operation and minimal labor requirement to operate it. Three types of filter configurations for solid/liquid filtration are described:

1. Outside-in filtration: traditional solid/liquid barrier separation occurs on the outer perimeter of a closed-end tubular filter element.

2. Inside-out filtration: solid/liquid barrier separation occurs on the inside of a closed-end tubular filter element.

3. Inside-out (multimode) filtration: solid/liquid (barrier or crossflow) separation occurs on the inside of open-ended tubular filter element. Filtration with multi-option top or bottom feed inlet.

In the barrier method, solids are deposited on the wall of the tube and fluid passes through the wall as filtrate. Fluid flow is generally perpendicular to the element wall. Barrier type filtration is more effective with solids that produce high porosity cakes.

1.) Outside-In Filters

Outside-in filtration, as illustrated in Figure 1, is a traditional layout that is well recognized in the filtration industry. Conventional outside-in candle filter configuration is recommended for polishing applications, or other low dirt applications were thin filter cakes would occur, and backwash concentration (volume) is not a consideration. Typically used for high flow rates and low suspended solids loadings (<100 ppm).

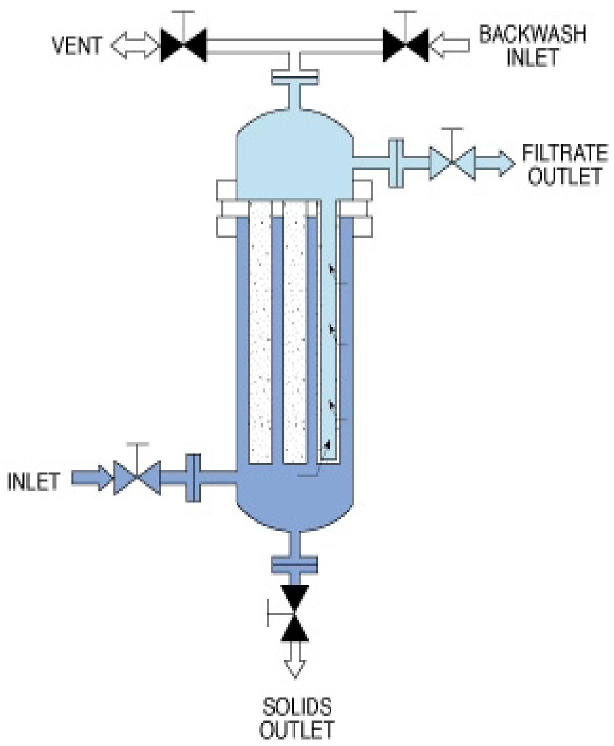

Figure 1. Outside-in filter configuration.

Outside-in filtration of a high solids concentration liquid will result in greater element spacing that will require larger filter housing. Solids overload can result in bent or broken elements after backwash. Overall mechanical pressure drop is limited by element collapse rating. Cake washing is not practical using this element configuration, as process fluids cannot be drained or replaced without losing solids from the filter elements.

Polishing or final filters may operate for several months or over a process campaign. In-situ backwash cleaning is not required. The condition of the filter is determined by the increase in differential pressure over the service life. Usually when a terminal pressure or the end of a campaign is reached, the elements are removed from the filter and cleaned for reuse. Because of the rugged construction of sintered metal cartridges, long service life with multiple cleaning can be expected.

The outside-in configuration is not recommended for high solids load applications. Large spacing between elements is required to prevent bridging. This results in larger filter housing and large volumes of liquid being expelled during backwash. Bending stresses imposed on elements during backwash that can cause element failure.

Slurry Backwash: After loading to specified cake thickness and differential pressure, the filter cake is backwashed and removed using a hydraulic pulse of liquid filtrate. The filter is isolated, and then the housing dome is pressurized with air or other compatible gas, creating an air spring within the dome. (Backwash pressure is typically 20 PSI over the terminal pressure.) The sudden opening of the backwash drain valve releases the air spring, creating a hydraulic pulse that blasts caked solids from the filter surface. Continued expansion of gas flushes the solids and liquid from the filter surface, removing the solids and liquid from the housing to a sump or holding tank, for discharge or recovery.

2.) Inside-Out Filtration

Mott developed inside-out filtration in 1984 for catalyst recovery applications. Inside-out filters, as illustrated in Figure 2, are ideal for applications with solids with low settling velocity to ensure that solids will be carried into the element. A more stable cake forms on the inside of the element. Each element operates independently. Elements can be close to each other resulting in smaller housings and less liquid holdup volume.

This configuration is more efficient than outside-in filtration as there is less heel, minimal loss of filtrate, and easier discharge of solids. Elements can be selected based on solids holding capacity, therefore optimizing packing density.

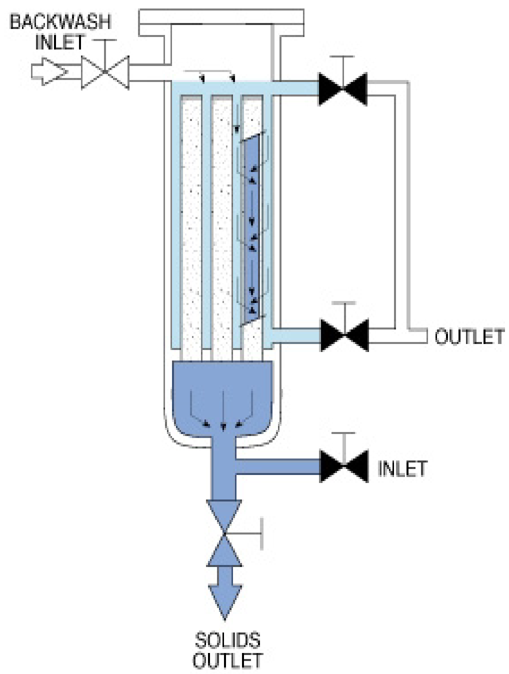

Figure 2. Inside-out filter configuration

Using the upper filtrate outlet assures filter cake deposition through the full length of the element. Using the lower filtrate outlet allows displacing of the filtered liquid from the shell with gas, increasir concentration slurry backwash. Solids can be washed and backwashed via a variety of backwash modes such as: full shell slurry backwash, empty shell gas backwash, and empty shell and empty element (drain lower heel) wet cake discharge.

3). Inside-Out Multimode Filtration

The inside-out multimode filter, as illustrated in Figure 3, is similar to the inside-out filter, but the element is open on both ends, and is sealed within two tube sheets. The filter provides high efficiency solids removal, stable cake and excellent cake washing capabilities. Backwash is similar to inside-out barrier filtration mode. Additional backwash capabilities include bump-and–settle, which allows concentration of solids without draining the filter element or housing. The bump-and-settle type backwash is effective and optimizes product yield.

The top-feed configuration is most advantageous with high specific gravity solids that have a high settling rate. Classification of the solids can occur in an upflow mode.

The feed recirculation feature has proven successful in several continuous loop reactor systems. The downward velocity controls the cake thickness of the catalyst, the lower the velocity the thicker the cake.

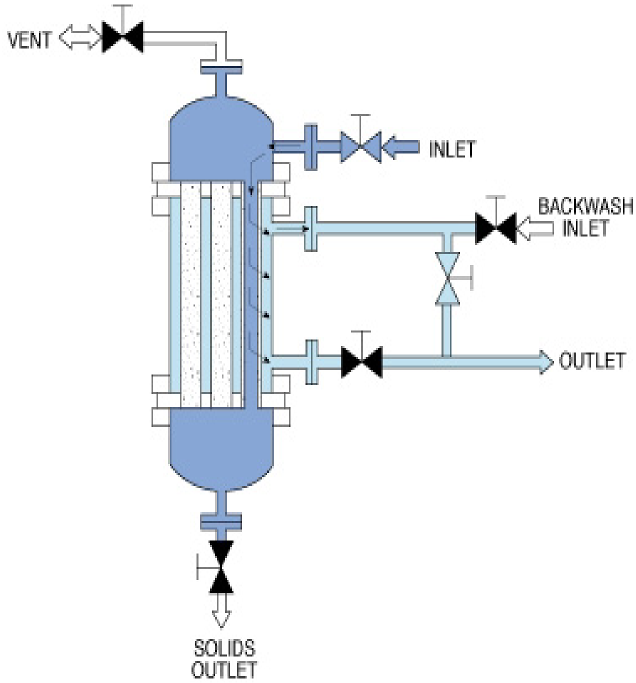

Figure 3. Inside-out multimode configuration

Multimode Crossflow Filtration

The dynamic or crossflow mode, as illustrated in Figure 4, incorporates a fluid flow of circulating solution axially through the element of sufficient velocity to prevent significant solids accumulation. The resulting effect is to concentrate a dilute feed stream to high solids content and reduce pressure drop due to flow through the solids cake. Dynamic operation of the filter incorporates a re-circulation loop to maintain a moving stream preventing appreciable build up of solids until concentration is increased.

The system can be operated continuously, with a side stream removal of the concentrate. Or it can be batch with the re-circulation terminated after desired concentration is reached, then commence with barrier filtration for slurry backwash or wet cake discharge via dewatering cake with air, steam or other gas for removal of concentrated (40-50% solids). Dynamic or crossflow operation is successful with very fine particles that pack tight and have low flow velocities.

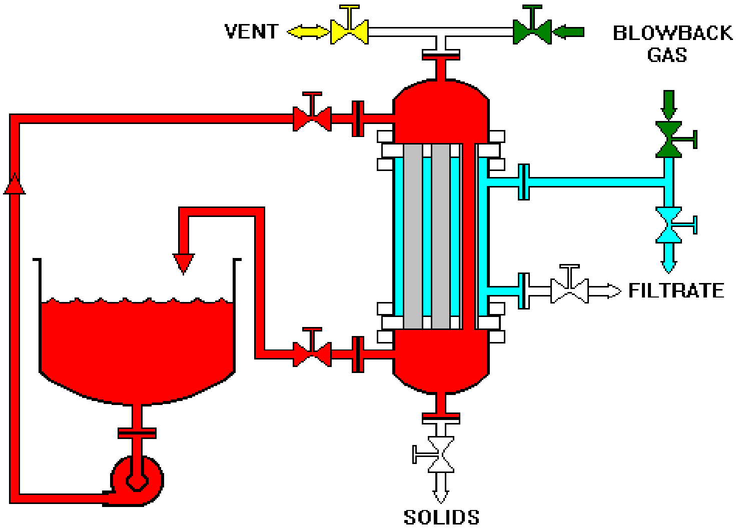

Figure 4. Mulitmode (crossflow) recirculation mode

The Importance of Feasibility Testing

Filtration properties are dependent on the filter media characteristics, the surface area available, and the process conditions of the application. Laboratory feasibility assessment provides a suitable basis in determining filter design specifications. Pilot scale testing ensures the filter meets operational specifications under process conditions. Testing can provide the following information: verification of solids particle size, shape, concentration and filtering characteristics. The only valid way to evaluate sizing and performance is through testing. Information obtained from feasibility and pilot scale testing includes:

- Obtain sizing data for scale-up and verify operation conditions
- Introduce and train operating personnel in filter operation
- Challenge the filter with variations in the process conditions
- Obtain long term operating information for cleaning and maintenance scheduling
- Evaluate the effect of extended operation on different media
- Materials compatibility testing

CASE STUDIES

The following feasibility studies utilized Mott HyPulse® filtration technology in the comparison of inside-out barrier (HyPulse LSI) and inside-out multimode (HyPulse LSM) barrier filter operation. Use of the HyPulse LSM multimode crossflow filter, as a continuous flow stirred tank reactor for catalyst recovery, is also discussed.

Case Study 1: Comparison of the LSI and LSM Filter Operation

The primary purpose of these tests was to demonstrate the operability of the LSI and LSM filter system for backwashable catalyst recovery application. Palladium-on-Carbon catalyst mixed in toluene (47%) and water (54%). Tests were conducted using sintered metal cartridge, Grade 0.5 media, 3.75 ft^2 area, 0.188 ft^3 internal volume, 2.4" ID, and 72" porous length.

The LSI element will handle feed concentrations ranging from 15 - 100 gm/l slurry and contain solids at a level of 1.5 lbs/ft^2. Backwash was affected by compressing an air pocket in the dome to about 40 PSI, and then rapidly opening the discharge valve. The solids were backwashed with less than 2.5 gal/ft^2 liquid volume. Table 3 is a summary of the data.
Backwash with air assist was more efficient, requiring only 1.33 to 1.6 gal/ft^2 and achieved complete solids recovery with one backwash. Backwash efficiency is near 99+% at these conditions. In all cases filtrate was optically clear with no evidence of catalyst breakthru.

Results indicate the LSM performed similarly to the LSI with a slight increase in solids capacity, 1.7lbs/ft^2. The filter operated repeatedly in the wet cake discharge mode. The backwash technique used a pumped pressurization of the shell to 40 PSI at 0.5 gpm/ft^2 with flow maintained as the dump valve is opened. Complete solids removal was effected with a 45 - 50% solids cake.

Table 3: Case 1 Summary Data

Type	Backwash Type	No. Cycles	Flow Rate Gpm/ft^2	Solids Capacity lbs/ft^2	Backwash Volume Gal/ft^2	Solids Recovery %	Heel Volume Gallons	Wet Cake % Solids
LSI	Slurry	6	1.0	1.5	1.1 -1.5	112.33	0.29	10.8 – 14.5
LSM	Slurry	8	1 – 1.5	1.6	2 -2.5	111.25	0.449	8.87
LSM	Wet Cake	4	1.0	1.7	1.6	100.5	-	47.56

Case Study 2: Multimode LSM Top-feed Precoat Filter
The filter assembly used was a LSM pilot filter. This configuration was chosen because it allowed precoating in the conventional method (upward flow) and top feed (downward flow), which allowed the heavier solids to settle out in the bottom of the vessel. Filtrate exit was from the lower shell, minimizing the amount of liquid generated during backwash.

The filter consists of (7) tubular Grade 2 elements of 2.5 inch ID, 60 inch OAL, made from porous 316 L stainless steel. Total filter area is 21.6 ft^2. The elements are installed within a 10 inch diameter housing as a tube bundle assembly between two vessel flanges. The housing consists of three pieces: an upper head, a lower head, and a main body.

Feed material was simulate $Fe(OH)_3$ wastewater (pH 9 – 12) contaminant. Filter elements were precoated (upward flow) at 1 gpm/ft^2 using DE/Zeolite. The feed was introduced in a (downward flow) top-feed configuration at a flowrate of 0.2 gpm/ft^2. The filter was tested over a 5 days to evaluate performance of the tubular precoat filter with respect to thruput, pressure drop and filtrate quality.

Results of the pilot tests using the LSM configuration indicate that there was some settling of solids using a down flow feed. Filter aid bodyfeed was reduced from a 6.6: 1 to a 1:1 ratio filteraid to contaminant without effecting filter performance. The top feed configuration also resulted with longer cycle time. Throughout testing there was no indication of media fouling. Backwash effectiveness was excellent, with 98.3 - 99% recovery, as determined in material balance. Filtrate was optically clear with total suspended solids measuring 0.2 PPM.

Case Study 3: Inside-out Multimode Continuous Flow Reactor
Laboratory testing with a 4 wt.% catalyst sample showed feasibility for repeated cycles with excellent filtrate quality (< 1 ppm TSS), and consistent throughput and cake release during backwash to justify pilot scale testing. Pilot testing validated the multimode filter concept at process operating conditions.

Inside-out filtration utilizing a multimode filter is being used to recover fine, suspended catalyst (0.5 – 100 µm) from a continuous flow stirred tank reactor (CSTR). The filter unit is described in Figure 5. Traditionally, multiple candle type filters with holding tanks have been required to maintain constant product flow. Operation of the multimode filter, in a recirculating loop around the reactor, minimizes catalyst activity loss due to depressurization and mechanical stress. The filter cake is controlled dynamically with the slurry recirulation rate, assisted by on-flow reverse pulsing. Spent catalyst is purged from the reactor system by operating the filter in the dead-end mode without recirculation. The filter cake is discharged via the spent catalyst purge line.

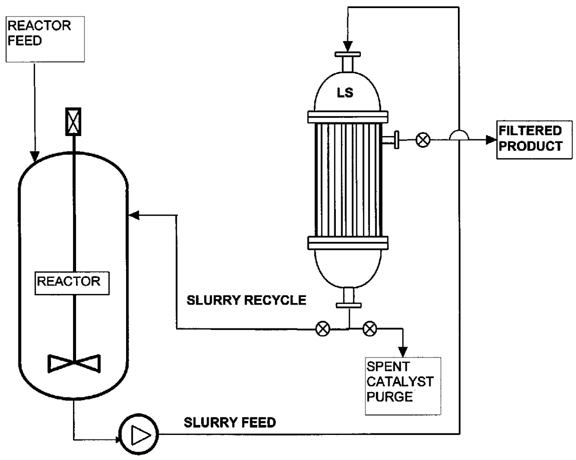

Figure 5. Inside-out multimode continuous flow stirred tank reactor

APPLICATIONS

Filter systems utilizing sintered porous metal filters in both the inside-out and outside-in configurations are used in multiple industries. Some examples are described in this section.

Applications using Outside-in Filtration

Application: Removal of lead carbonate from battery manufacturing wastewater stream.
Particle Size: 1 to 5 µm
Flowrate: 160 GPM
Design Fluxrate: 0.67 gpm/ft^2
Filter: (68) 2.5 x 60 elements- Grade 0.5
Area: 222 ft^2
Benefit: Environmental pollutant efficiently removed from effluent discharge in compliance with EPA standards.

Application: Removal of suspended iron particles from effluent liquor.
Particle Size: 100% < 1 µm
Flowrate: 160 GPM
Design Fluxrate: 0.6 gpm/ft^2
Filter: Dual System each housing (68) 2.5 x 72 elements - Grade 0.5
Area: 267 ft^2 per filter
Benefit: Effluent quality less than 1 PPM average, exceeding EPA requirements.

Application: Recovery of Nickel-on Kieselguhr catalyst in organic resin.
Particle Size: Avg. 4 µm
Flowrate: 240 GPM
Design Fluxrate: 0.25 gpm/ft^2
Filter: (144) 2.5 x 60 elements- Grade 2
Area: 471 ft^2
Benefit: Catalyst recovery filters have been in operation successfully for 5 years.

Application: Palladium-on-Carbon (160 lb.) catalyst recovery from liquid reaction process.
Particle Size: <1 to 40 µm
Flowrate: 5 GPM
Filter: (13) 2 x 40 elements- Grade 0.5
Area: 21.7 ft^2
Benefit: Catalyst loss reduced to zero; reaction time reduced more than 75%

compared to systems using conventional filtration.

Application: Concentration and recovery of spent resin from condensate polishing.
Batch: 7000 Gallons / 300 lb. resin
Solids Load: 0.5 wt.%
Flowrate: 20 GPM
Benefit: Environmental pollutant efficiently removed from effluent discharge in compliance with EPA standards.

Application: Concentration and recovery of spent resin from condensate polishing.
Precoat: 0.24 lbs/ft^2, 1.8:1 Cation/Anion
Filter: (13) 1 x 58 elements- PDS Media
Area: 15.7 ft^2
Benefit: Sintered metal suitable survives severe upset conditions. Filtrate quality < 0.2 PPB total suspended solids.

Applications using Inside-out Barrier Filtration

Application: Recovery of Pd-on C in food grade oil hydrogenation batch process.
Batch: 800 Gallons
Solids Load: 0.5 wt.%
Filter: (19) 2.5 x 60 elements- Grade 0.5
Area: 60 ft^2
Benefit: This filter provided high product recovery in the filtrate and concentrated catalyst for recycle.

Application: Hydrogenation catalyst recovery from aqueous organic alkaline.
Particle Size: 4 to 100 µm
Flowrate: 40 – 60 GPM
Design Fluxrate: 0.16 – 0.24 gpm/ft^2
Filter: (68) 2.5 x 70 elements- Grade 0.5
Area: 249 ft^2
Benefit: LSI with heel drain for maximum product recovery and minimal operator exposure. Catalyst loss was eliminated.

Application: Refinery FCC Slurry Oil
Batch: 10,000 BPD
Solids Load: 1000 ppm
Filter: (3) LSI Filters with 2” x 80” elements- Grade 0.5 Media
Benefit: The efficiency of recovered product as a percentage of feed slurry exceeds 99.8%. For every 1000 barrels of product filtered, 2 barrels are lost to backwash.

Application: Slurry oil from tankage
Batch: 3500 BPD
Solids Load: < 1000 PPM
Particle size: 5 µm average
Filter: Grade 0.5 media
Area: 432 ft^2
Benefit: Same set of elements in service since 1990.

Applications for Inside-Out Multimode Filtration

Application: Catalyst recovery from continuous flow stirred tank reactor.
Particle Size: 0.5- 100 µm
Filter: (91) 1.5” x 100” elements-
Grade 0.5
Area: 327 ft^2
Benefit: The original filter elements operated successfully on an 8000hr/yr-production schedule. Savings in labor and replacement costs recovered the filter capitol costs during the first year of operation.

Application: Catalyst recovery from a re-circulation loop coupled to a hydrogenation reactor.
Solids: RANEY Nickel catalyst
Filter: (127) 2” x 80” elements-
Grade 0.5
Area: 415 ft^2
Benefit: The filter system provided for this service delivers 200 GPM of filtered product with minimal downtime for backwashing.

SUMMARY

Sintered metal media is bi-directional and will perform equally well with either inside-out or outside-in design. The selection of the most cost-and performance-effective configuration depends on the type of application and process requirements. The following concepts should be followed to optimize filter performance using specially designed process filter equipment.

- The filters should be operated within the design fluxrates to prevent premature blinding of the media.
- Filter efficiency increases as the filter cake forms. The cake becomes the filter media and the porous acts as a septum to retain the filter cake.
- A gas assisted pneumatic hydro-pulse backwash has proven to be the most effective cleaning method for sintered porous metal filters.
- Single vessel filters are recommended where flow rates allow and flow can be stopped for a few minutes for the backwash, or if off line periods can be tolerated for maintenance.
- Two filter dual systems are recommended where continuous flow is required and short periods of off line can be tolerated for maintenance.
- Three filter systems are recommended for continuous operation, even during maintenance periods.
- Filter system should be fully automated to eliminate operator exposure and lower labor costs.

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