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DESIGN AND OPERATION OF POROUS METAL CROSSFLOW MICROFILTERS

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Porous metal crossflow (LSX) filters concentrate and clarify suspensions of particulate solids. The tubular filter media is a porous matrix of sinter-bonded metal powder with absolute retentions in the micron range. The strength of the media allows in-situ regeneration by hydraulic backpulsing. LSX filters have long service life, excellent filtration efficiency, and high solids concentrating capacity. The rugged filter media combined with the flexibility of crossflow filtration offers the design engineer new economy and efficiency with process integrated solid/liquid separations.

The design of LSX filters is similar to double open ended shell-and-tube heat exchangers with single or multiple filter tubes. Feed slurry is pumped in axial flow through the element, while clear filtrate is driven by transmembrane pressure radially outward into the shell (see Figure 1). All-metal filter construction, as required in radioactive waste applications, has elements welded into the tubesheets. Removable elements are individually sealed with O-rings. Materials of construction are specified for each application. Typical element dimensions include the inside diameter of 0.625 inches, wall thickness of 0.062 inches, and maximum length of 120 inches. Filter modules with up to 244 ft^2 area per housing are available in discrete micron grades of 0.2, 0.5, 2 and 5.

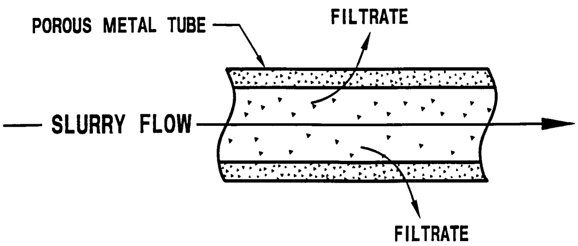

FIGURE 1

LSX filters are operated at axial velocities of 3 to 20 ft/sec to keep solids in suspension and to pinch solids from the filter surface. The axial fluid flow generates tangential shear forces that constantly sweep the media surface. Limiting factors for axial flow are pumping costs and particle attrition. Even at high axial velocities, there is a decline in filtrate flow which stabilizes asymptotically over a few hours of operation as shown in Figure 2. This decline is attributed to the formation of a ‘dynamic membrane’ made up of fine particles that are deposited a very short distance into the subsurface pore structure. The filtration efficiency increases during membrane formation, such that a 2 micron media retains particles down to 0.2 micron in size.

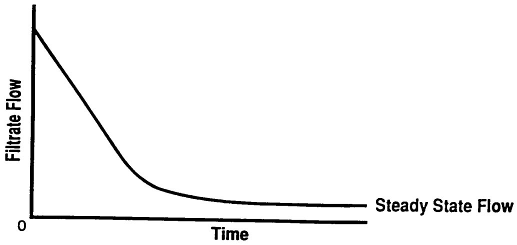

FIGURE 2

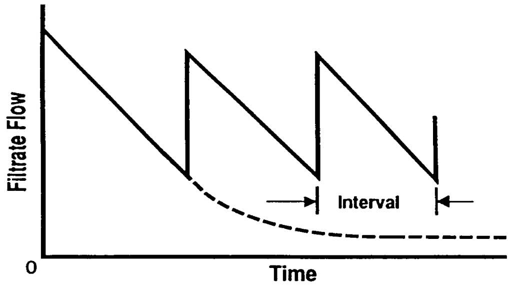

FIGURE 3

In many applications, LSX filters are periodically backpulsed to maintain a high average filtrate rate as shown in Figure 3. For in-situ backpulsing, a pressure differential of 20 to 60 psi above the steady-state slurry pressure is applied from the shell side for a duration of one second while axial flow is maintained. This causes a momentarily high reverse flow of filtrate through the pores that dislodges solids embedded in the subsurface cake layer. An attractive feature of this technique is that it does not require externally supplied fluids for media regeneration. (Figure 4 illustrates a typical LSX filter with backpulse.) The backpulse interval is determined by testing, and can range from less than one minute up to 24 hours. Fouled or contaminated elements that cannot be rejuvenated by backpulsing can be cleaned chemically. Detergent solutions containing oxalic, nitric, citric or phosphoric acids or caustic solutions are compatible with the filter media. Ultrasonic cleaning is used for elements fouled with insoluble contaminants.

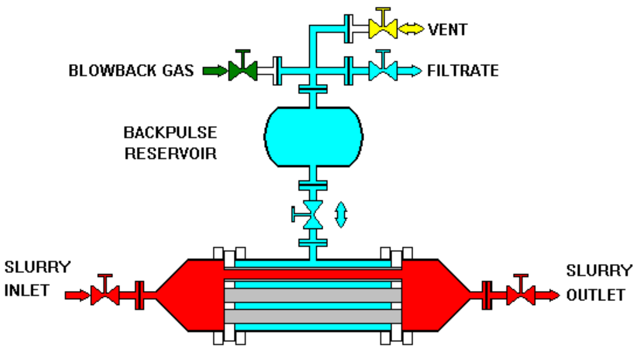

FIGURE 4

Typical flux, i.e. filtrate flow rate per unit area, tends to range from 0.1 to 0.25 gpm/ft^2 at transmembrane pressures of 10 to 60 psid. However, some applications have low fluxes of 0.03, while others can operate at high rates of 1.5 gpm/ft^2. Testing is recommended to optimize flux for a given solid-liquid system as a function of media, axial velocity and transmembrane pressure. Objective of the testing is the development of a stable dynamic membrane that produces the required filtrate quality. The size distribution and surface characteristics of the solids ultimately determine the steady-state flux. It is recommended to condition a new LSX element to stable flux by the gradual opening of the filtrate outlet until design flow is reached.

An LSX filter system can be operated in once through or recirculation mode. Continuous liquid sampling of streams with suspended solids is the most common use of once through systems.

Single pass solids concentrating of suspensions requires multiple filter modules in series and is economically attractive with high flux processes.

The majority of LSX filter applications are set up in a recirculation loop with a holding tank as shown in Figure 5. The pump head supplies the pressure for the solid-liquid separation. Axial flow rate is adjusted with a backpressure control valve at the slurry outlet of the filter. Filtrate flux and transmembrane pressure are controlled with the filtrate flow valve to stabilize the dynamic membrane. The filter is backpulsed either at preset intervals or when low filtrate flow is indicated.

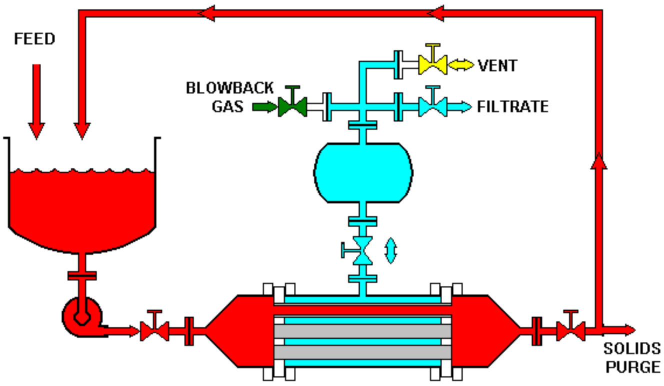

FIGURE 5

In batch operation, filtrate is extracted until the desired solids concentration is reached. The limiting factor for solids concentrating is the ability of the pump to circulate the slurry. The large element diameter allows slurries to be concentrated to about 40 WT% solids without clogging.

In continuous solid-liquid separation processes, the LSX filter operates at constant solids concentration. Solids are purged from the loop to maintain a solids material balance. LSX filters with continuous recirculation are used as stand alone concentrators, as preconcentrators for filter presses, and as centrate polishers for centrifuges. Several LSX filter applications are discussed in the next section.

A petroleum refiner eliminated maintenance problems with the blend analyzers for reformulated and oxygenated fuels with a self-cleaning LSX sampling filter. The single element filter was installed on the fast loop that delivers a continuous stream of fuel sample to the analyzers in a piping bypass to the blend header. Utilizing the rapid flow in the fast loop for filter cake control the LSX operates at steady state filtrate flow. Rust, iron, catalyst fines and liquid droplets have to be removed to protect the instruments from fouling and against false reading. Prior to the retrofit, the refinery had to exchange coalescing and dead-end type disposable filters on a daily basis. Plugging filters prevented real time analysis of fresh samples every 5 to 8 minutes and off spec blends could not be detected. The use of larger disposable filters was ruled out, again due to unacceptable delays in response time. The LSX sampling filter paid for itself in less than three months based on replacement costs only.

An iron oxide pigment plant was facing increasing disposal costs for wastewater containing pigment fines that were bleeding through the primary product recovery drum filter. 95% of the fines were smaller than one micron in size. By concentrating the solids in the wastewater with an LSX filter and recycling the concentrate to the drum filter, the plant has increased the pigment yield. Furnished with 0.5 micron media, the continuously operating LSX filter produces clear filtrate with less than 0.5 ppm suspended solids. This saved the plant annually over 10 million gallons of process water in an area where water is scarce. Automatic backpulsing several times per hour keep the filtrate flux between 0.5 and 1 gpm/ft^2 while the solids are concentrated to sludge consistency and recycled to the drum filter. The filter elements are chemically cleaned in-situ with acid solutions on weekends and last for over 6 years of daily operation.

A manufacturer of nuclear fuels pre-concentrates uranium oxide fines suspended in ammonium diuranate (ADU) solution with LSX filter for subsequent centrifuge separation. The fines occur at this processing step at very low concentrations where centrifugation would be inefficient. The ADU solution that is stored in slab tanks is concentrated batchwise to 4 WT% total suspended solids. Remote operation and high efficiency fines recovery returned the cost of the LSX filter system to the customer in a very short time.

A nuclear waste processor removes suspended solids from radioactive solutions that are fed to a cesium adsorption column with four (4) in-series operating LSX filters. Objective is protection of the packed bed adsorber against plugging and fouling while providing continuous flow. The concentrate from the LSX filters is returned to the rad waste storage tanks on-site and mixed with fresh wash solutions. All welded design was required to prevent media bypass by radiation degraded seals.

A continuous flow fatty acid production with suspended fine catalyst is set up with the reactor and LSX filters in a closed loop. Reaction slurry is constantly pumped through the filters to maintain steady-state filtrate flow. The closed loop provides reliable control of reactor catalyst inventory and reaction yield.

In conclusion, reliable performance, flexible operation and low maintenance make LSX filters attractive for solid-liquid separations in many industries. As shown in the application cases above, the LSX filters offer unique solutions for demanding situations.