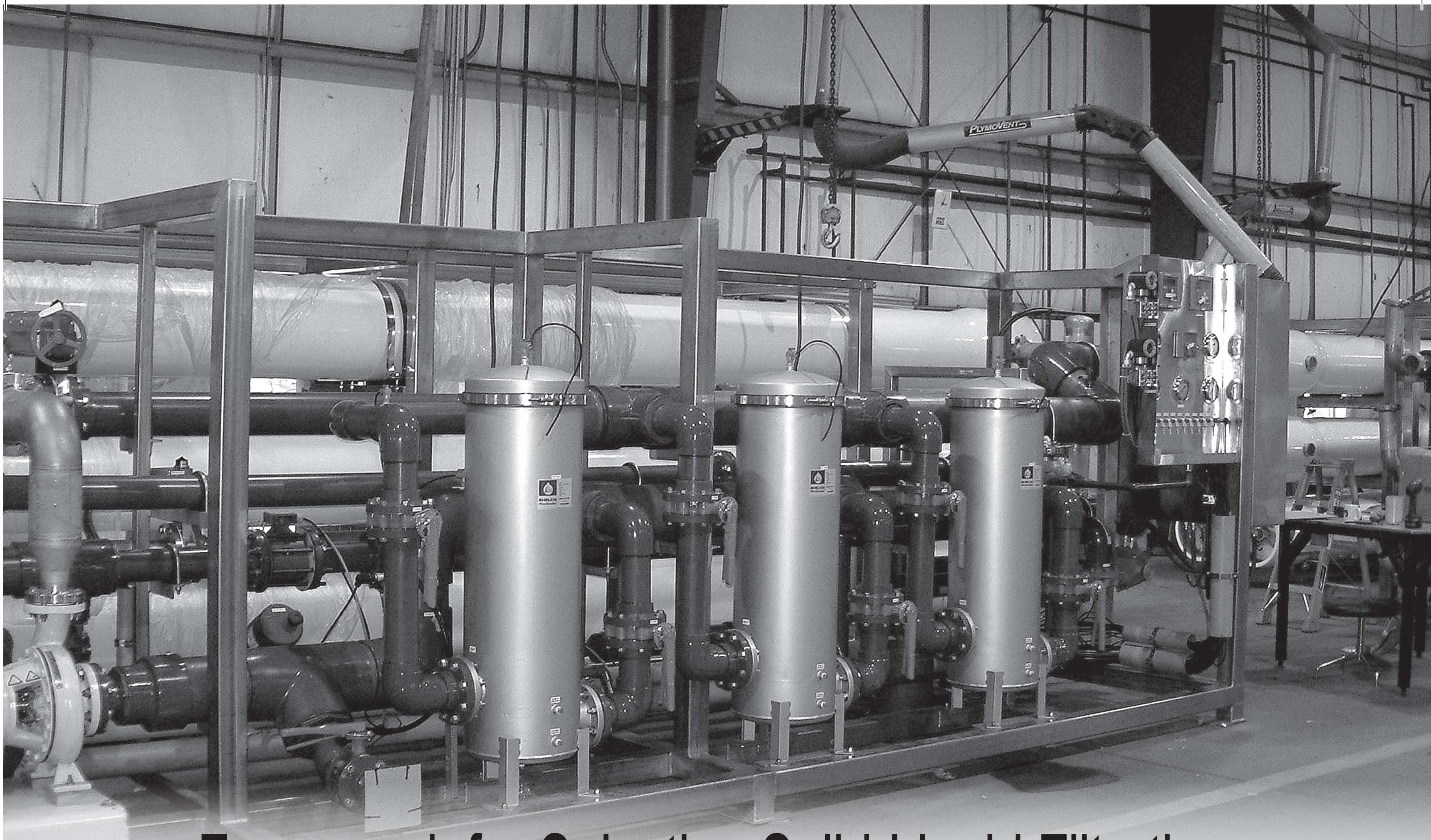

Framework for Selecting Solid-Liquid Filtration Technologies for Particle Fines Removal

Barry Perlmutter

Abstract

In the manufacturing of chemicals, petrochemicals, pharmaceuticals, etc., after the initial mixing-reactions, there is always the necessity to remove the mother liquor from the process slurry. In some cases, the liquid is the valuable component, some cases it is the solids and in other cases it is both compounds. The nature of the requirements determines the type of equipment needed for the separation process. This paper provides an overview of separation equipment and then continues with a detailed view of technologies that can remove – recover small particle fines.

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Filtration, pressure or vacuum, is the art of finding a filter media which allows the liquid to pass through while retaining the solids. The driving force may be gravity, vacuum, pressure or centrifugal.

Types of filtration systems: Batch filters

Autopress: This horizontal pressure filter operates as a contained filter press. Circular plates with welded metal or synthetic media are contained in a pressurized housing. This allows for pressure filtration, cake washing and vacuum or pressure drying. After the cycle is completed, the housing is moved and automatic cake discharge is done via scraper knives that move between the plates.

Bag filters: A bag with a connection to a high pressure inlet held captive in a metal cage. Filtrate runs through the bag and the solids stay inside.

Basket centrifuge: A metal basket rotating at centrifugal speeds and a cloth bag is fitted inside the basket. The drive mechanism runs the basket up to high speeds and feed is poured into the basket. Filtrate runs through the basket and is collected in an outer mantle. When sufficient solids have collected inside the bag, the machine is slowed to allow a mechanical scraper to remove the bulk of the solids (a "heel" stays behind). In a horizontal version, the peeler centrifuge or inverting centrifuge, the bulk of the cake can be removed without slowing the machine.

Cartridge filters: Pressure vessels which are fitted with filter cartridges where the flow is from the outside inwards. Cartridges are available in cleanable or disposable form. A wide variety of materials, pore size and physical sizes are available.

Filter press: The original filter presses were of the "plate and frame" construction. Modern presses use almost exclusively "recessed plates". A very wide variety of sizes, configurations, plate supports and degrees of automation exist.

Leaf filter: Leaf filters consist of a pressure vessel inside which a number of filter leafs are vertically mounted. The leaves are normally metal and fitted with a synthetic media. For removal of the solids different arrangements exist, ranging from opening the bottom of the vessel to mechanically spinning or vibrating the cake into a chute.

Membrane presses: The membrane press is a filter press but instead of having drainage grooves in the plates, the plates are fitted with an elastomer sheet which is inflated. By inflating the sheet at the end of the filter cycle, the cake will be squeezed, for lower cake moisture.

Nutsche filter: Circular or rectangular filters with a drainage bottom onto which a filter medium is fastened. If the drainage section is connected to a vacuum source the filters are open top. If they are closed at the top, they can be pressurized and thus benefit from a higher driving force.

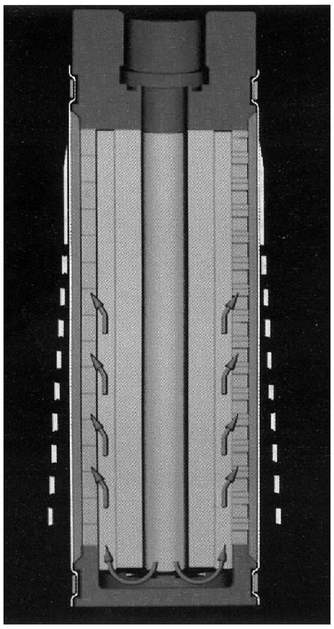
Types of filtration systems: Continuous filters

Disc filter: These consist of a flat disc mounted on a hollow shaft. The disc is made of metal and has on either side an open cloth support structure which connects with the hollow shaft which carries the filtrate. A filter cloth is fastened to the disc and the hollow shaft connects to a vacuum source. The disc, usually 30% submerged, rotates slowly in a feed trough where it picks up the solids, which can later be scraped off just prior to re-entry into the feed trough.

Rotary pressure filter: The Rotary pressure filter is a continuously operating unit for pressure filtration, cake washing and drying of slurries up to 50% solids. The filter has a rotating drum inside a housing. The drum has cells within which are cell inserts fitted with the filter media. Filtration is conducted via pressure of up to 6 bar. Positive displacement washing or counter-current washing follows filtration. Finally, the cake is dried by blowing hot or ambient gas through the cake. The Filter has a uniquely designed discharge system, which provides for atmospheric discharge from pressure filtration. After automatic cake discharge, the filter cloth is washed; the clean filter cloth the re-enters the feeding /filtration zone thereby continuing the process. All solvent and gas streams can be recovered separately and reused in the process to minimize their consumption.

Pusher centrifuge: Horizontally mounted filtering centrifuge with a filter cage made of metal bars the smallest opening of which is about 100 micron. Inside the cage is a "pusher" arrangement, basically a sturdy ring which lies very close to the filter medium. The ring is connected to a central shaft which rotates at the same speed as the filter cage but reciprocates causing the collected solids to be pushed out of the machine. Multi stage machines exist where the solids are pushed onto the second or third stage which is each time of a larger diameter. The higher linear velocity as well as the tumbling action can be beneficial for dewatering and/or cake washing, although it may cause particle fines requiring further clarification.

Candle filters provide for thin-cake pressure filtration, cake washing, drying, reslurry and automatic discharge as well as heel filtration in an enclosed, pressure vessel.



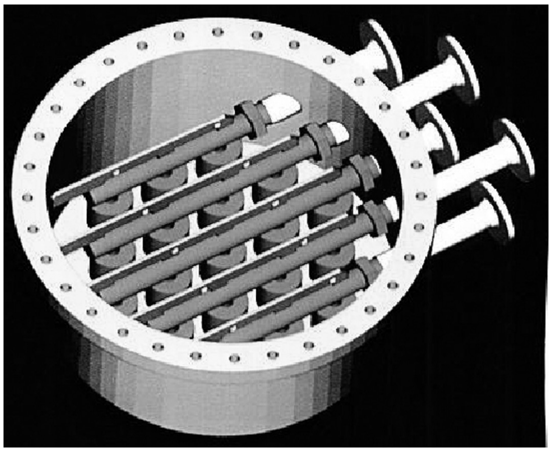


Fig 2: BHS candle filter

Fig 1: BHS Candle showing gas flow to expand the filter media sock for cake discharge

Rotary vacuum drum filter: The original rotary drum filter consisted of a cylindrical drum, fitted with a drainage grid and filter cloth. The drum had perforations and was connected to a vacuum source. The drum itself was mounted on a horizontal shaft and submerged for about 30% in a feed trough. The vacuum caused the liquor phase to be sucked through the cloth, leaving the solids behind as a filter cake. The cake was scraped off just before re-entering the feed trough.

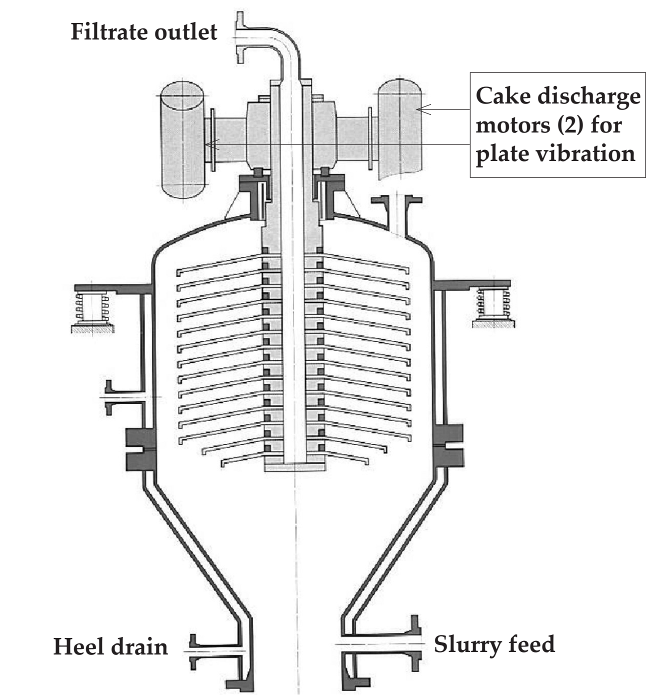


Fig 3: BHS pressure plate filter

Vacuum belt filter: The two main types are carrier belt and tray (fixed or indexing). These filters have a continuous belt as the filter medium which is subjected to a vacuum source. Feed is introduced at one end, where it is normally allowed to settle under gravity for a few seconds. The suspension is then subjected to full vacuum. Since the cake thickness can be controlled by adjusting the speed of travel or indexing time, the optimum cake thickness to obtain the required residual moisture and / or cake washing efficiency is achieved. The horizontal configuration makes this filter one of the most efficient cake washing filters.

Clarification of slurries & recovery of fine solids

As processes have become more sophisticated and quality requirements increased, there is a trend to be able to remove the residual particle fines. These fines are very small, typically, smaller than 1 – 5 micron range and are very low in concentration down to ppm levels.

Candle filters and pressure plate filters are installed for clarification and recovery applications from liquids with low solids content. The candle filters are vertical candles while the pressure plate filters are horizontal plates. The cake structure as well as the process parameters determines the optimum thin-cake technology.

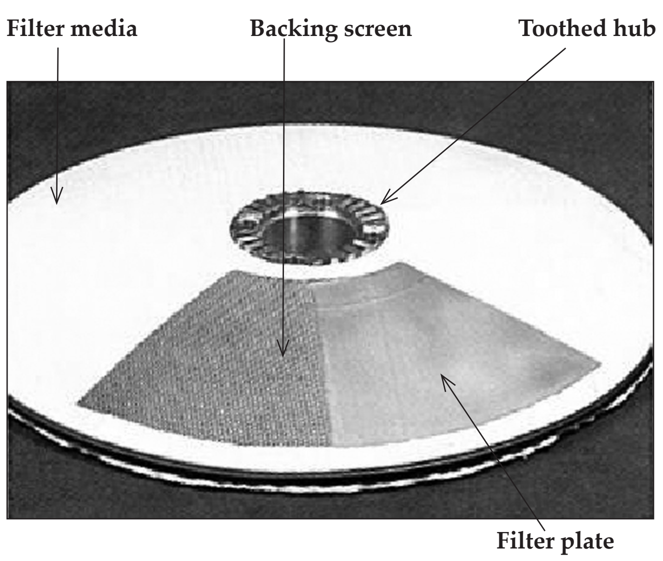


Fig 4: Filter plate

Description and operation of the candle filter

Candle filters provide for thin-cake pressure filtration, cake washing, drying, reslurry and automatic discharge as well as heel filtration in an enclosed, pressure vessel. Units are available from 0.17 m^2 up to 200 m^2 of filter area per vessel.

Filter Candles & Media

The filter candles, as shown in Figure 1, consist of three components: single-piece dip pipe for filtrates and gas, perforated core with outer support tie rods and filter sock. The filtrate pipe is the full length of the candle and ensures high liquid flow as well as maximum distribution of the gas during cake discharge. The candle can be a synthetic, stainless steel or higher alloys. The outer support tie rods provide for an annular space between the media and the core for a low pressure drop operation and efficient gas expansion of the filter media sock for cake discharge. The filter media is synthetic with clean removal efficiency to less than 1 micron (μm). As the cake builds up, removal efficiencies improve to less than 0.5 μm.

Filter vessel & candle registers

The candle filter vessel is constructed of stainless steel or higher alloys. Within the vessel are horizontal manifolds called candle registers. Each candle is connected to a register with a positive seal to prevent bypass. Each register may contain from 1-20 candles depending upon the filter size. The registers convey the liquid filtrate in the forward direction as well as the pressure gas in the reverse direction for filter media sock expansion. Each register is controlled with automated valves to ensure optimum flow in both directions. Figure 2 illustrates the candle filter vessel.

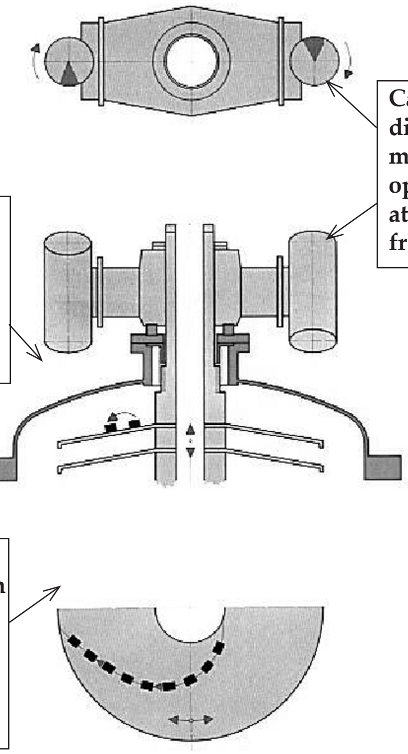


Fig 5: Cake discharge in the pressure plate filter

Description and operation of the pressure plate filter

The pressure plate filter has similar operating characteristics to the candle filter. The filter design is shown in Figure 3.

Description and operation of the pressure plate filter-cake discharge

As shown in Figure 5, the motors on the top of the filter operate at different frequencies and the plates gently vibrate for cake discharge. The plates vibrate in the vertical and horizontal planes and the solids are conveyed in an elliptical pattern to the outside of the vessel. Gas assist helps in the discharge process. There are no rotating plates, gears or bushings and mechanical seals are not required.

Table 1

Parameter	Candle Filter	Pressure Plate Filter
Slurry Filling- Pump or Gas Pressure	Bottom of vessel cone	Bottom of vessel cone
Cake Thickness	5 – 20 mm	5 – 75 mm
Filtration Pressure Differential	90 psig	90 psig
Clean Micron Removal	0.5 μm	0.5 μm
Filter Media	Synthetic	Synthetic and Metal
Cake Washing-Displacement	Yes	Yes, may be more efficient
Heel Filtration	Yes	Yes
Cake Drying-Gas Blowing	Yes, also “shock” drying	Yes, may be more efficient
Cake Discharge Mechanism	Sock Expansion	Vibration
Cake Discharge	Wet, Dry, Concentrated Slurry	Wet and Dry
Clean-In-Place (CIP)	Yes, with in-situ cleaning	Yes, with in-situ cleaning
Precoat / Body Feed	Yes	Yes
Operation by PLC or DCS	Automatic	Automatic

Fig 6: Dry cake after discharge

Selection of candle versus pressure plate filter technologies: Cake structure and process parameters

The major difference between the two technologies depends on the cake structure that is formed. Some cakes are better handled in the horizontal and some in the vertical. The table 1 outlines the selection criteria.

Application 1:

Replacing a manual plate filter and bag filter combination

This specialty chemicals manufacturer produces various resins that require filtration. Current production includes a neutralization step which yields metal salts. These salts are filtered out with a manual plate filter followed by a bag filter for polishing. Two solvent washes follow the filtration step to recover as much resin as possible. After washing, the filters are steamed and opened. The solids are disposed manually for each batch and the filter paper is replaced. The goals are to eliminate exposure to heptane, reduce the maintenance and operation on the two filters and to recover a dry, as possible, catalyst. Current production is 3000 gallons in 4 – 5 hours.

Results & Conclusions

The filtration flux rate from the BHS laboratory tests ranged between 10-30 L/m^2 min at approximately 20 psi feed pressure. The filter cloth for the sock is polyester with an air permeability of 1.0 cfm/ft^2.

The tests showed that one BHS candle filter with 10 m^2 of filter area can complete the cycle in a time of 4.3 hours and replace the manual plate filter and bag filter.

The cycle time is as follows (Table 2):

Table 2. Cycle Times		
Filling	5	min
Filtration	10	min
Wash	4	min
Drain	10	min
Dry	5	min
Vent	2	min
Discharge	5	min
Reserve	9	min
TOTAL	**50**	**min**

This specialty chemicals manufacturer produces various grades of polyols from ethylene glycols requiring filtration of small particles in the 1 – 2 µm range. Current production includes a manually-operated filter press at 250 degrees F. The goals are to eliminate operator exposure, reduce the maintenance and operating costs and to increase the polyols yield. Current batch sizes are 45000 pounds of slurry.

Results & Conclusions

Lab tests conducted in the BHS lab showed that the slurry temperature was between 200 – 250 degrees F at a pressure of 90 psig. The filter cloth for the sock was successful using PTFE or PEEK material.

The tests showed that a BHS candle filter, with 27 m^2 of filter area, can complete the required batch is three (3) cycles, each of 6-hours. The cycle time is as follows (Table 3):

Application 3:

Replacing centrifuge & cartridge for tin hydroxide slurry

This process was previously done with a centrifuge which did not provide much separation at all and the fines were causing issues in the downstream operation at their sister plant.

Process Observations:

> Precoating with Hyflo (5 lbs) and water – filtrate goes to sump

> Precoating based on volume and then switch over to feed slurry (0.4 – 0.5% body feed)

> Filtration - Pressure built to around 20 psi in about 30 minutes, batch size is approximately 3000 lbs. (10-15 gpm)

Table 3. Cycle Times		
Filling	12	min
Precoat	8	min
Filtration	60	min
Drain	15	min
Dry	3	min
Vent	2	min
Discharge	15	min
Reserve	5	min
TOTAL	**120**	**min**

Fig 7: Jacketed Candle Filter with Register-Filtrate Piping & Junction Box

Fig 8: Complete skid package with candle filters, plate filter, tanks, pumps and PLC controls

> Washing with water- 40 psi until filtrate looks clean with 12 μm PEEK filter sock

> Draining - initially through candles first (25 psi) and then the heel drain

> Drying – Blowing of gas for 5 minutes at 20 psi

> Cake discharge – dry cake with a cake thickness of 15-20 mm

Results:

A BHS candle filter with 10 m^2 of filter area replaced the centrifuge and cartridge polishing filter. The results are shown in Table 4.

Table 4. Cycle Times

Filling	5	min
Precoat	10	min
Filtration	45	min
Wash	5	min
Drain	10	min
Dry	5	min
Discharge	5	min
Reserve	5	min
TOTAL	**90**	**min**

Application 4:

Replacing a filter press using paper media

This specialty lube oil process, for final clarification, is conducted in a filter press using a paper media at 170^o C, and using carbon, lime or celite as a body feed. There are five (5) grades of lube oils and cleaning between each campaign is required. The material is dried with nitrogen and the solids are removed and burned in the power plant as fuel. The process has the manual problems associated with a filter press plus the safety concerns of being burned with hot oil. The average particle size distribution (PSD) is 0.7 μm.

Results:

The pilot testing demonstrated that the oil slurries could be filtered to meet the customer's specifications, that the resultant cake could be dried to the customer's desired moisture content, and that the cake could be automatically discharged satisfactorily from the candles. The purchased system was a 10 m^2 jacketed BHS candle filter using PEEK filter socks for the current five (5) products with expansion possibilities.

Application 5:

Dual stage candle and pressure plate filters for fines removal at refineries, gas plants and grey water for coal gasification

The fines generated in these above applications are generally less than 1 μm in size and very low concentration. For these large flows, upward to 800 gpm, simple bag or cartridge filters or filter presses cannot be used. BHS has developed a dual-stage process using candle filters for concentrating and then followed by a pressure plate filter for the final filtration, cake washing and drying. The benefits include increased reliability, much lower consumption (25% less) of compressed air/gas for drying and cake wash water. A typical example and photo is below.

Process & Results:

Total Flow: 94 gpm

Design Solids Load: 28 lb/hr (600 ppm)

- Two (2) Candle filters, each with 20 m^2 of filter area, for concentration
- One (1) Pressure plate filter, 4 m^2 of filter area, for final filtration, cake washing and drying

Conclusion

There are many choices for the initial filtration steps in a process. The take-away is that one filtration system may not achieve those quality requirements. Engineers must evaluate all outcomes to make an informed and successful decision. A secondary filtration system for fines removal, while adding capital expense to the project may result in an overall more reliable and optimum process solution. While not discussed in this article, laboratory and pilot testing is critical for a successful decision and project.