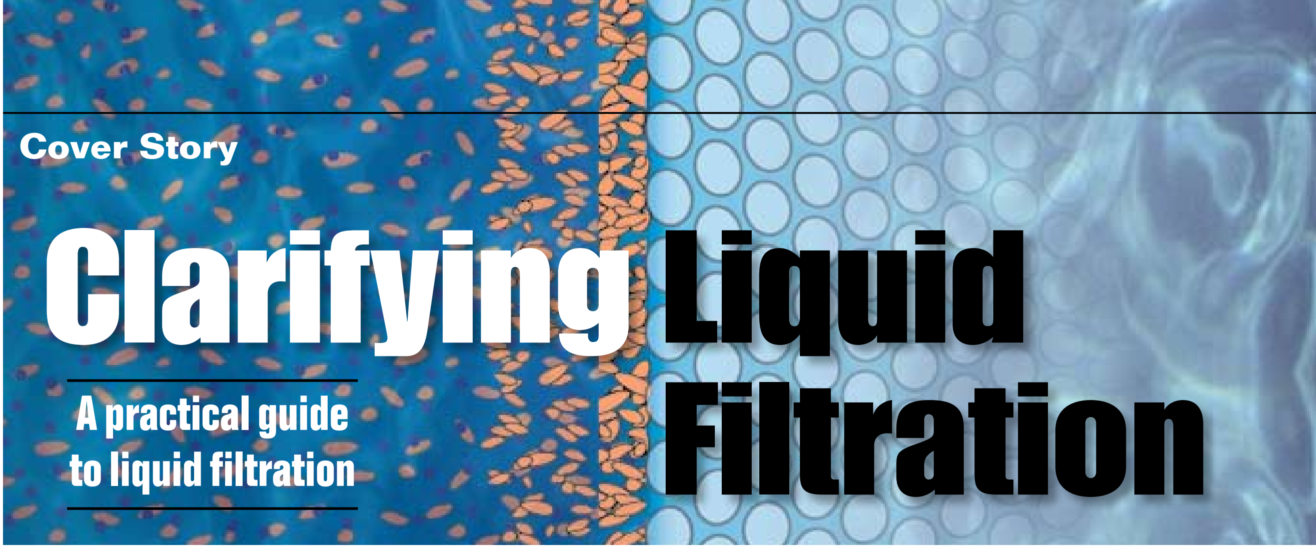

Cover Story

Clarifying Liquid Filtration

A practical guide to liquid filtration

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There are various reasons that make filtering necessary in processes. The raw materials might have impurities that require removal at the start of the process. After the initial mixing to produce the process slurry, the mother liquor could have solids that need a separation process. Unwanted solids could also form by a chemical reaction during the production of the process liquid. The nature of the solid impurities will ultimately determine the type of equipment needed for the separation process.

Sometimes, a preliminary crude separation is done by decantation, clarification, settling, coalescing or centrifuging. For some processes, a preliminary coarse prefiltration with a basket filter or a strainer is used to remove the bulk of large crystalline solids, using a relatively open filtering medium. After this coarse separation (if needed), the actual fine liquid-filtration process is performed to produce the final, clear filtrate product.

This article offers recommendations and guidelines to apply in the selection, operation and troubleshooting of liquid filters. The first step in deciding which filtration method to use in a process begins with laboratory testing.

LABORATORY TESTING

The importance of laboratory testing cannot be over stressed. The laboratory is where you will determine the nature and properties of the solids, and the ease or difficulty of the filtration process. Also, knowing the amount of solids and the particle size are factors necessary in specifying the filter media, filter aids, filter area, cake space needed and cake discharge technique. The experimental data gathered in the laboratory are also necessary for the design of the filtration system needed for production.

Preliminary testing

First, you need to produce a realistic and comparative test sample for the actual process fluid. Once this sample is available, run it through a small laboratory centrifuge to determine the amount of suspended solids. The separated solids should then be examined visually because the nature of these solids will greatly affect the filtration process. Solids that are crystalline can be relatively easy to filter, whereas amorphous, slimy or gelatinous solids are more difficult to separate, requiring more complex techniques.

In addition to the visual inspection, particle-size analysis of the suspended solids is always recommended to determine the percentage of solids and the particle-size distribution you are dealing with in the process.

Laboratory procedures

Figure 1 shows three different laboratory filtration setups. Testing stations such as these are used to establish the filterability of the product in question and to calculate the filter area and the thickness and weight of the filter cake. Filter testing also establishes the process filtering pressure and the required air pressure for blowing down the filter to remove all liquid from the filter tank. The test data will help determine the size and recommendation for the filter type.

The filter area of the laboratory filter is established prior to testing. The laboratory filter must have pressure-measuring devices to measure the feed and the discharge pressures. A small pump is used to feed the process liquid into the filter. In the absence of a pump, air or nitrogen is used to push the liquid through the filter.

A representative sample of the process liquid is prepared and properly mixed to keep the solids in suspension. The feed solution is prepared in a container that allows measurement of the volume of the test batch for filtration. The filtered solution (filtrate) is collected in a receptacle that allows measurement of the filtrate volume after a measured filtration time. A stop watch or timer is used to track the time required for the filtration process from start to finish.

For constant flow operation, the test solution is fed into the filter, and the discharge pressure of the pump (or the air or gas pressure) is increased gradually in order to maintain a constant flow. For constant pressure testing, the process solution is fed into the filter at a constant pressure. In this case, the flow through the filter will gradually decrease as the filter cake is built up and resistance to flow increases.

The test data are then used in the following formulas to calculate filter sizing requirements to meet the process flowrate, batch throughput and the solids removed in the filter cake:

$$\text{Throughput} = V/A \quad (1)$$

$$\text{Flowrate} = (V/\Delta t)/A \quad (2)$$

$$\text{Cake thickness} = W_s/\rho_s A \quad (3)$$

Where:
V = total volume filtered, gal
A = total filtration area, ft^2
Δt = total time to filter, min
W_s = total weight of solids filtered, lb
ρ_s = density of wet cake, lb/ft^3

If laboratory testing is not feasible at your plant, filter equipment companies, filter aid suppliers and consultants are available to assist you with test work.

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FIGURE 1. Laboratory testing is crucial for the design of a filtration system. Shown here are a Walton test filter station (left), a horizontal-leaf pressure filter test stand with multiple plates (middle), and a plate-and-frame test stand with two plates (right)

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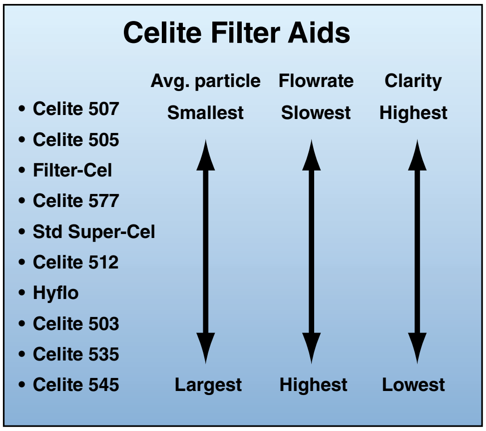

FIGURE 2. Various grades of calcined diatomaceous earth are available

Filter aids

Laboratory tests will help determine if precoating is necessary. Precoating, as the name implies, is a technique in which the filter media is first coated with a filter aid. These filter aids are used to do the following:

- Protect the filter media from plugging or blinding with suspended solids
- Obtain the desired initial clarity
- Facilitate the filter cake release during the cleaning of the filter

Filter aids are also used as a body feed to help keep the filter cake open for good cycle times. The most common filter aids are as follows:

Diatomaceous earth. This material is made from silica fossils of unicellular organisms that come from salt water or fresh water deposits. Various grades of diatomaceous earth are available, depending on the degree of fineness required. Some of the finest grades are flux calcined (Figure 2).

Perlite. Perlite is made of expanded ground volcanic-lava rock. It, too, is available in various grades depending on the degree of fineness needed.

Cellulose. Expanded cellulose material is also graded by fineness.

Blends. Blends of diatomaceous earths with either coarse fibers or graded fibers of cellulose can be used to aid filtration.

Carbon-based aids. Carbonaceous-type filter aids are normally used when the chemistry of the process liquid may react with the silica in diatomaceous earth or perlite products.

Other materials. Calcium carbonate or similar solids can serve as a filter aid due to their crystalline nature, and may already be present in the process liquid.

The selection of the best filter-aid material for the process feed should include consultation with a representative from the manufacturers of filter aids. More detailed information on filter aid types can also be found on many suppliers' Websites.

Filter media

Laboratory tests also help determine the type of filter media needed for placing over the filter elements. The filter elements consist of a porous or coarsely open member that supports the filter media, which is the base or septum for holding the filter cake. The filter media is the separation point for the flow of clean filtrate into the process.

Types of filter media available are the following:

Paper. Paper media are disposable filter sheets made of either cellulose-type filter paper or non-woven type synthetics.

Pads. Filter pads are disposable and thick pads of cellulose fibers or a blend of cellulose fibers and diatomaceous earth, which actually serve as a precoat and do not require an additional filter aid precoat to perform the filtration.

Textiles. Cloths made of natural cotton, wool or synthetic fibers are used. Cotton and wool cloths have limited use due to their resistance to chemicals. Synthetic cloths have better chemical resistance, depending on the nature of the fibers. Synthetic cloths are made of polyolefins, such as polyethylene or polypropylene, polyesters, nylons, Nomex, fluorocarbons (Teflon, Kynar), Saran or a variety of high chemical and temperature resistant man-made fibers.

Felts. Felts of natural cotton, wool or synthetic fibers are available in various materials and porosities like textile cloths. The most widely used are polypropylene and polyester felts.

Metallic wire mesh. Made in various wire weaves for different uses and retentions, wire meshes are available in various metals according to the chemical resistance required, including 304 stainless steel (SS), 316-SS, 316-LSS, Monel, nickel, Inconel, Hastelloys, and other chemical- and temperature-resistant metals.

Porous or sintered metals. Multi-layered, fused-wire mesh weaves and metal felts are also available.

Filter paper or pads are typically used only once, whereas cloth, wire mesh, felts and sintered metals or multilayer wire mesh are more permanent or reusable filter media that do not require replacement after each filter cycle.

FILTER SYSTEMS

In choosing the filter, selection depends on several considerations. What is the duty of the filter? What is the sizing requirement to carry the process flowrate and contain the solids removed? What filter area (ft^2) and cake capacity (ft^3) is needed? Is there a requirement to prefilter? Is the filter for a fine-filtration requirement? Is manual or automatic operation preferred? Is the process batch or continuous operation?

Manually operated filters include basket filters, plate-and-frame filter presses, plate filters and some pressure leaf filters.

Pressure-leaf type filters have features to achieve self-cleaning or automatic cake discharge. These features allow discharge of the filter cake by washing the cake off the filter medium with internal spray headers or by vibrating the cake off with a pneumatic vibrator. Sometimes pressure leaf filters are operated manually with respect to valve operation, but their self-cleaning features remove them from the manual classification. Both horizontal and vertical tank designs are available with hydraulically operated quick-opening closures to speed the opening of the tank for dry cake discharge. Filter media types used are cloth covers, felt covers and wire mesh.

Pressure-leaf type filters handle large volumes of process flow with long filter cycles. Loosely, these filters are referred to as continuous type filters. However, in reality they are not continuous, since they still require a stop in the process for cleaning.

Basket filters

For coarse filtration, the basket or strainer filter type is selected, and consists of a pressure-vessel type housing with a perforated internal member that separates the coarse solids from the process liquid. The internal element is made of perforated metal or is a coarse wire-woven basket. The internal element is removable to clean by simply dumping the solids or by washing them off. These coarse filters remove the larger solids, allowing the finer ones to pass through and are selected based on the process flowrate and the amount of solids to be removed. In some cases the inner element is lined or covered by a woven liner made of either cloth or wire. Cleaning is done by manually removing the basket or strainer or backwashing or flushing in place. These filter types have low maintenance requirements.

Plate-and-frame filter press

The oldest filter type is the plate-and-frame filter press (Figure 3). In simple language, if you can manage to pump the process slurry into the plates and frames pressed together with compression rods, the slurry will stay there and filter. These filters rely on the type of media used, which is generally the filter sheet or pad for depth filtration not requiring a precoat. The chamber between the filter plates becomes filled by the removed solids until full. There are no concerns about solids settling inside the filter tank or premature filter-cake dropping due to pressure or flow fluctuations.

Once the sludge chamber is full, the filter cake is washed by pushing the wash liquid forward and extracting the mother liquor from the cake prior to drying the cake by blowing air or gas through the cake. These filters are cleaned by simply loosening the compression mechanism and removing the filter sheets or pads with the cake on them and disposing of the cake and the filter media. Media for these filters include filter papers, sheets, pads and cloths. The plate-and-frame filter press is very popular with beverage, winery, and pharmaceutical processors.

A more modern version of filter presses offers advantages like automatic cake removal. Plate shifters allow the remote controlled shifting of the filter plates, so that the cake is popped-off the filter media. Air pressure is applied into an internal bladder that pops off the cake, leaving the filter cloth media in place. Other features are devices to wash the cloth media after the cake is discharged, hydraulic compression of the filter plates, recessed filter plates and molded plates. These newer design filters also offer larger filter areas and cake holding capacities and are preferred for high-solids loading applications in mining, quarries, wastewater and waste-sludge processing plants as well as other similar high-solids applications.

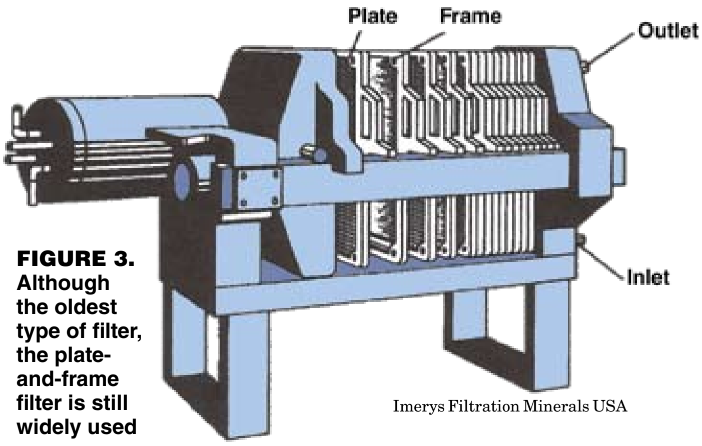

FIGURE 3. Although the oldest type of filter, the plate-and-frame filter is still widely used

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Horizontal leaf filters

Plate filters evolved from the original plate-and-frame filter presses to eliminate the concern of leaks or drippings of the process liquid from between the plates and frames. In plate filters, containment of process fluids is achieved by placing the filter plate bundle in a pressure vessel housing (Figure 4). Horizontal filter plates are assembled in a bundle by means of compression rings at the top and bottom and compression center and side tie rods. The plate bundle is placed inside of a vertical pressure vessel. The design varies, depending on the location of the feed port and flow direction across the plates.

In standard horizontal plate filters, the feed liquid fills the tank, then the liquid passes through inlet flow holes in the filter plate rings that separate the filter plates into the sludge chamber. Pressure from the process forces the liquid through the filter medium, supported by a perforated media-support element, down into the clean filtrate chamber and out the center hole of the filter plate into the center outlet opening and out of the filter tank at the center bottom outlet. To filter the remaining unfiltered heel in the tank, some filters have a special bottom-most filter-plate element or scavenger plate in the bundle with a separate outlet to allow filtration of the tank heel contents at the end of the cycle.

Horizontal plate filters are cleaned by removing the filter plate bundle from the tank, disassembling the filter plate bundle and removing the filter medium from each plate with the filter cake. Media used are paper, sheets, pads, felts, cloths and in some instances metal wire-mesh circles.

Figure 4 shows typical horizontal leaf filters with standard forward flow (left) and with reverse flow (right). In the reverse-flow filter design, the feed flows into the bottom-inlet center port of the tank, then into the center feed column formed by the filter plates stack, through holes in the center column at each plate. Pressure forces the feed slurry into the plate chamber and solids are retained on top of the media. Clean feed liquid flows through the filter media, through the filter media support, into the filtrate chamber and out through the side holes in the

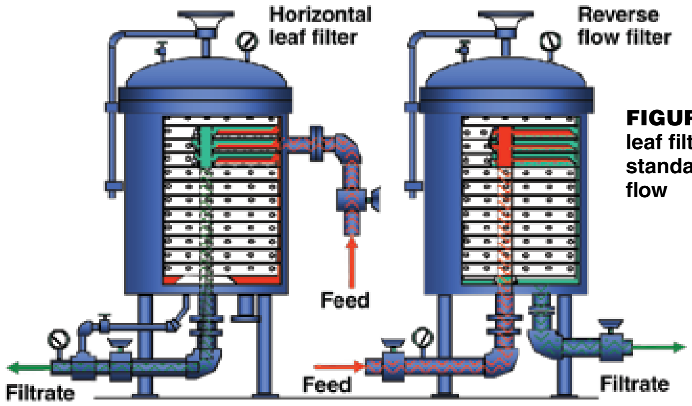

FIGURE 4. Horizontal leaf filters operate with standard or reverse flow

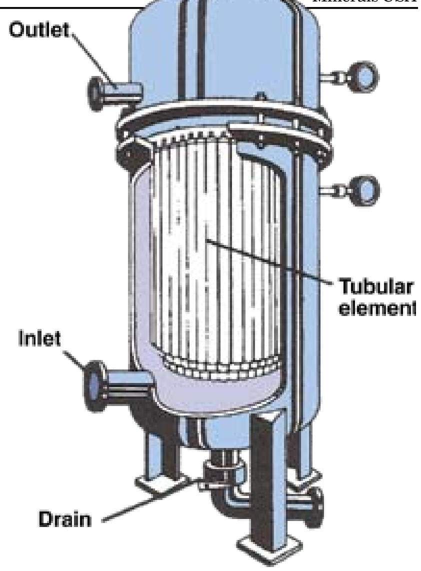

FIGURE 5. Tubular filter elements can be cleaned by back washing to discharge the filter cake as a slurry

spacer rings between filter plates. The filtered liquid fills the tank and discharges through the outlet nozzle in the bottom of the tank. Since the unfiltered liquid feeds directly to the filter plate bundle, there is no unfiltered tank heel, and no separate bottom filter plate is needed. The filter tank is only in contact with clean filtered liquid, so the operator does not have to clean the tank as in the standard type. The reverse-flow filter-plate bundle is cleaned and redressed in a similar way to the standard, horizontal plate filter by removing the filter bundle from the tank, dissembling the plates, removing the media and cake and redressing with clean media.

Both types of horizontal plate filters are batch type, manually cleaned and labor intensive filters. The filter cake is always contained on top of the filter media and within the compression rings between the plates for maximum filter-cake stability. If process flow stops for one reason or another, the cake stays in place. To resume filtration, a simple recirculation step is added to reestablish the filter cake, and then production continues without detrimental effects in most cases.

Horizontal plate filters are preferred by small production chemical plants, pharmaceutical, fine chemical, beverage, and other processors who want fine reliable filtration with maximum filter-cake stability and clean-ability of the filter internals.

Tubular filters

Another self-cleaning type filter is the tubular filter consisting of a pressure vessel and filter elements that are tubular (Figure 5). The tubes are covered with cloth, felt or wire mesh. At the end of the filter cycle, these tubular filters discharge the filter cake by either blowing back to pop the filter cake off the tubular element or backwashing to discharge the filter cake in a slurry form. The limitation of tubular filters is the filter cake capacity.

Pressure leaf filters

This type of filter can have a vertical or horizontal tank. Horizontal-tank pressure-leaf filters come in two different styles. The stationary tank design (Figure 6) has a leaf bundle that pulls out and away from the tank to expose the leaves for discharge of the filter cake. The stationary leaf-bundle design has a front head that remains stationary with the filter bundle attached, and the tank pulls away to allow discharge of the cake. Additional operating features like rotating plates and internal screw conveyors for cake discharge are offered by some filter manufacturers.

Vertical-tank pressure-leaf filters (Figure 7) with vertical plates have internal spray headers for wet cake discharge or quick-opening bottom-drop doors with pneumatic vibrators for dry cake discharge. They are used in the fine chemicals and food-and-beverage industries.

Rotary drum filters

Rotary drum filters (Figure 8) are the only truly continuous filter. The filter itself is located on the outer surface of a drum that is under vacuum inside. In a single full rotation of the drum, this system precoats the filter, performs the filtration, washes the filter cake (to recover the mother liquor), and dries and discharges the cake. Filtrate passes through to the center of the drum to where it is recovered. The filtration cycle starts all over again in the next full turn of the drum. Rotary drum systems are used for primary filtration when there are large amounts of solids.

Belt filters

Another continuous-type filter is the belt filter, which has essentially the same operation as the rotary drum filter, but uses a continuous cloth band instead of a drum. The continuous cloth band travels into the bottom of a trough that is continuously fed the slurry to be filtered. Suction is applied to the cloth, causing the liquid to be filtered as it passes through. The filtered solids remain on the cloth and are dried as the cloth travels out of the slurry, and the filter cake is discharged. At this point the cloth is washed by a spray system to clean the cloth for the next cycle. Continuous belt filters are typically used in the paper and fibers industries.

Nutsche filters

Some pharmaceutical and fine chemicals processes use a single plate or "Nutsche" type filter. Manual Nutsche filters (Figure 9) consist of a vertical pressure vessel with a single filter plate in the bottom of the tank or a removable basket with a filter plate in the bottom of the basket. Nutsche filters are used to remove and process high bulk-type solids resulting from a reaction where the filter cake is the product.

High bulk solids are porous and allow deep filter-cake beds to form, filtering without filter aids. Processing steps include filling, filtering (either, vacuum or pressure), reslurrying, displacement wash, drying of the filter cake and cake discharge. Cake discharge options include scooping out

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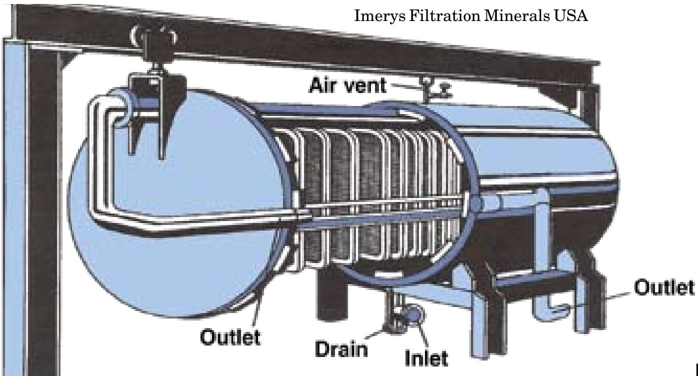

FIGURE 6A. Horizontal-tank, leaf filters have a leaf bundle that can be pulled out for cake discharge

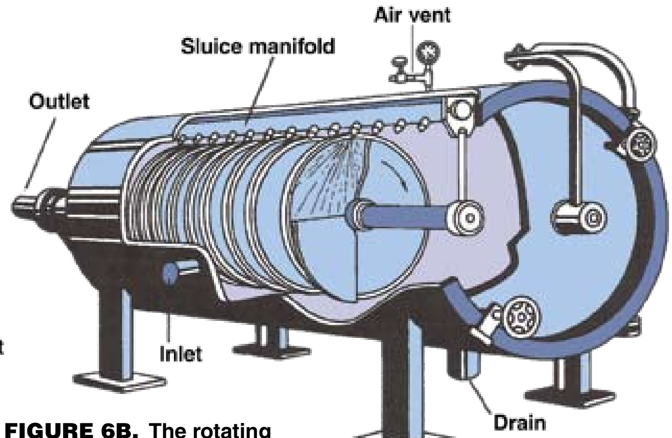

FIGURE 6B. The rotating plates of this horizontal-tank, leaf filter are cleaned by sluicing from above

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the cake, removing the basket, bottom drop door, tilting the tank, or dissolving the cake with a solvent through a bottom outlet.

The automatic Nutsche filter (Figure 9b) includes an internal agitator or impeller, which is used for reslurrying, compressing the filter cake, smoothing the filter cake, reslurrying the cake during cake washing or extracting and ultimately discharging the filter cake. Dissolving the filter cake in a solvent is also possible.

Inline cartridge or bag filters

Last but not least are the inline or final filters to remove trace solids, usually either a cartridge or a bag type filter (Figure 10). Cleaning is easy for both types. The cartridge type uses a replaceable or throw away cartridge. The bag filters have a removable felt or cloth bag where the solids are contained. To clean bag filters, remove the bag and either throw it away or wash to remove all solids and replace the bag inside the tank.

THE MECHANICS OF LIQUID FILTRATION

Liquid filtration is accomplished by separating solids from the process stream at a media interface where filter cake containing the solids is deposited and maintained open-to-flow by filter aids. The tank is the house for the filter plates, which support the media and the cake, which perform the filtration.

There are three filtration techniques to consider as you design the filter station for your process (Figure 11). In some cases, such as for crystalline, easy-to-filter solids, a filter medium alone (cartridge or bag filters) may be sufficient for the filtration process. More-difficult-to-filter solids may require precoating, body feed and filtration aids to perform the task at hand. As discussed previously, laboratory test results will help you determine if the filter media alone will produce the desired results or if precoating is required.

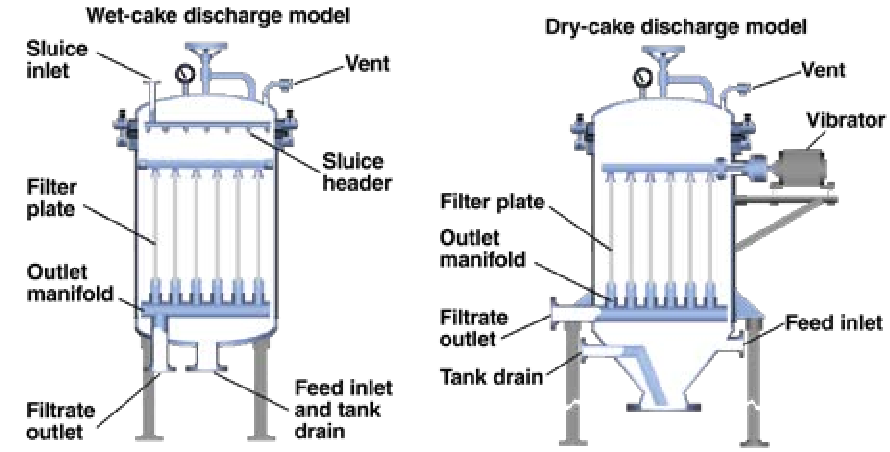


FIGURE 7. Vertical tank leaf filters have vertical plates inside a pressure vessel. Filter cake is either discharged wet with a spray from above (left), or dry (right)

Filtration system designs

Filtering without precoat. In certain applications, due to the nature of the suspended solids, filtration can be performed without a precoat. This situation is considered the exception to the rule of filtration. The filter setup consists of a feed tank, feed pump, filter and piping.

Filtering with precoat tank only. Some applications require only a precoat, so the flow diagram will include a precoat tank with mixer, a pump, the filter and the interconnecting piping with associated valves.

Filter with precoat and bodyfeed. This application requires both a precoat and a bodyfeed tank. Typical filter station setups, shown in Figure 12, will include precoat and bodyfeed slurry tanks, piping, valving, gages and pumps for the filter aids.

For all situations, pressure gauges are installed on the inlet and outlet. The difference in the readings of these two gages (inlet and outlet) is the differential pressure. Close monitoring of differential pressure is necessary to prevent damage to the filter elements by over pressuring. Filter plates are specified for a differential pressure rating, such as 50, 75, or 100 psid. For higher differential pressure ratings, plates have thicker and more heavy duty construction.

Monitoring the cake loading in the filter is important to prevent permanent damage to the filter elements by “bridging” or overloading the filter cake in between the plate elements. Do not exceed the cake capacity rating for the filter, but do leave space for washing and blowing down.

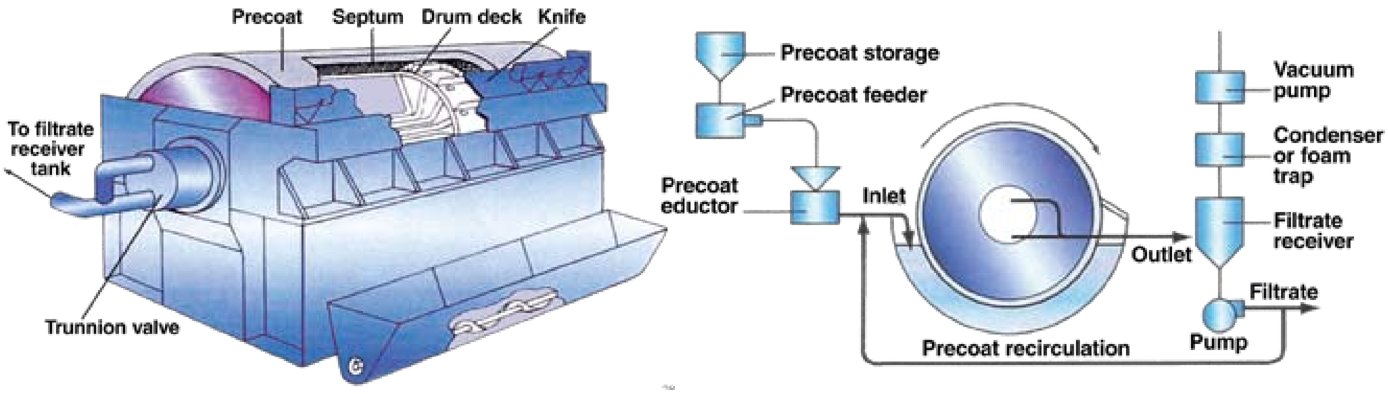


FIGURE 8. Rotary drum filters continuously perform precoating, filtration and cake washing, drying and discharging for each revolution of the drum. The cutaway diagram on the left shows the mechanical components. The flowsheet on the right shows the feeding and recycling of the precoat

The effects of overpressuring and overloading cause the most permanent damage to filter elements. This damage bends and warps the filter plates causing problems with filter sealing and performance. Breaks and tears in the filter media lead to bleed-through and lack of filtrate clarity. Problems are compounded when the filter is difficult to clean.

For the filter station that has a precoat tank, the general rule-of-thumb is that the precoat tank should hold about 1.25 times the holding volume of the filter. This ratio allows sufficient volume to fill the filter and the additional volume needed for the interconnecting piping. If the resulting volume of the precoat tank is too large, it is possible to have a precoat tank of about one third or one half of the total volume of the filter. In that case, provisions are made to fill the filter tank and the precoat tank prior to circulating the precoat, so that both tanks are full of liquid.

Precoating

Clean liquid is used for precoating and is either the same liquid, or one that is compatible with the process feed. The reason for this is that with a clean liquid only the precoat material is deposited on the filter media and there is no contamination from the suspended solids in the feed that would actually defeat the purpose of the precoat.

The precoat tank must have internal baffles to avoid vortexing that will make the precoat pump cavitate by sucking air. The tank should have a properly sized, top-mounted mixer. Consult the local mixer representative or distributor to ensure that the mixer is properly sized, taking into consideration the specific gravity of the liquid, the solids concentration and the abrasive nature of the filter aids. One word of caution about precoat mixing: avoid using air or gas lines inserted into the precoat slurry for mixing, which would introduce air into the filter cake. The air or gas bubbles trapped inside the filter cake, have a tendency to pop, disturbing the filter cake and affecting the clarity of the filtrate.

The amount of precoat material required will depend on the laboratory findings, but normally the rule is to use 0.15 to 0.2 lb for each square foot of filter area. The flowrate required for feeding the precoat material is related to the filter area. A rate of about 1.0 gal/min/ft^2 generally gives an even distribution across the plate. The precoat layer should be thick enough to produce the desired results without taking up too much of the cake space available between the filter elements. Select the precoat material that allows the maximum flow in the process with the minimum resistance to flow and pressure drop.

The precoat system needs a good reliable pump, preferably an open-impeller type centrifugal pump. The pump is to carry the precoat as quick as possible with a low pressure drop. Deposit the precoat layer quickly and evenly, but do not compact this layer to cause a high pressure drop and low process flowrate. When precoating the filter, fill the precoat tank and the filter first, thereby allowing the clean liquid to circulate through the filter plates establishing the process flow. Fill the filter with the air vent fully opened to allow displacement of all the air out of the filter tank, avoiding air pockets inside the filter. Avoid any backflow from getting into the filter tank by having a check valve on the filter outlet piping. Also, avoid having any outlet piping at a higher level than the filter tank without a check valve to prevent back flow that will disrupt the filter cake on the filter elements.

Sometimes, depending on the suspended-solid's particle sizes, a double precoat of a fine and then a coarser grade of filter aid is recommended. The recommended procedure is to apply first the finer grade of precoat and then the coarser grade on top. This technique provides a depth-filtration type effect. Your local filter aid representative will help you with this procedure and tell you what distribution to use. Generally the distribution is 60% of the finer grade and 40% of the coarser, but this ratio could vary according to your actual requirements.

When the filter is full and the precoat liquid is circulating from the precoat tank to the filter back to the precoat tank, turn the mixer on and start adding the precoat filter aid material to get it on the filter elements quickly and evenly. Continue this recirculation until the liquid returning to the precoat tank is clear, which should take approximately 10 to 15 minutes. During this procedure the differential pressure across the filter will go from 0 psid to not more than 10 psid.

Bodyfeeding

If the nature of the solids being filtered tends to blind over the precoat, then once the precoat is formed on the filter media, a bodyfeed is used to introduce additional filter aid to the feed to keep the filter cake porous. While the precoat rate is according to the filter area at about 1–1.5 gal/min/ft^2, the bodyfeed rate is according to the percent by weight of suspended solids. This bodyfeed ratio is determined in the laboratory test, and the local filter-aid representative will offer some guidelines to follow for determining the optimum rate. When in doubt or when there is no laboratory test data, a good starting point is to use a ratio of 1:1 (one part filter aid for each part of suspended solids). The initial results will help determine if this ratio should be increased or decreased. The more crystalline the solids are, the less bodyfeed is required. Sometimes the ratio may be as low as 1:5 (filter aid to suspended solids). If the solids are gelatinous in nature, a higher ratio may be required, such as 2:1. Practice and experience will help with the bodyfeed process specification.

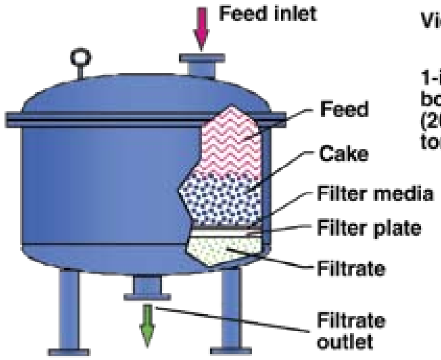


FIGURE 9A. A single-plate Nutsche filter is designed to process large volumes of solids that are easy to filter

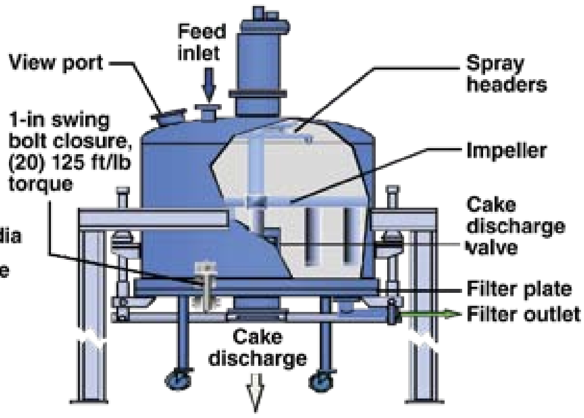


FIGURE 9B. The automatic Nutsche filter includes an internal agitator or impeller

Sometimes, the bodyfeed is added directly to the feed tank, so a separate bodyfeed tank is not required. Also, sometimes the precoat tank is used as the bodyfeed tank. In such case, the precoat tank remains full after precoating, and the bodyfeed material is added. Since the admix requires the mixer to stay on while the bodyfeed is injected, a low speed mixer is used to prevent the erosive nature of the filter aid from reducing its particle size thus affecting the filtration. The bodyfeed pump is a proportioning type pump, a slurry feed pump or a metering pump.

Filtration

Once the filter is precoated, the filtration process starts. Smooth switching of the valves from the precoat step to the filter step is very important. Always open valves that are to open and then close the valves that are to close to prevent any upsets to the filter cake and the filtration process. If bodyfeed is used, the bodyfeed mix is prepared before hand, during the precoat step. The bodyfeed tank mixer and the bodyfeed pump is turned on to start introducing the bodyfeed into the feed to the filter. The inital flow from the filter is sometimes sent to the precoat tank to ensure that the level is up and ready for the next cycle. Filtration continues with the filtrate going to the holding tank or wherever the process requires. The pressure drop will gradually rise up to the maximum allowable pressure or to a point where the outlet flow decreases, so to continue running the filter is not economical. Again, close attention to the valve sequencing is necessary at the end of this step.

For vertical leaf filters, one more warning comes to mind here. If at any time the filter is stopped, such as while waiting for the next batch to come, it is very important to maintain flow through the filter. Some operators have the idea that if the filter is kept under pressure by closing off the inlet and outlet valves on the filter, maintaining pressure inside the filter is the way to wait for the next batch. This procedure is wrong. The cake on the filter leaves will fall off, slide off and eventually the filter cake is lost in part or in total.

The correct way to wait in between batches is to maintain flow through the filter cake by circulating from the filter outlet back to the inlet. This closed loop circulation is necessary to keep the filter cake on the filter plates and undisturbed. This circulation is achieved by either using a separate circulating pump or providing additional piping to use the feed pump to keep this circulation going. Once the filter is ready to resume filtering, the valves are switched to continue filtering.

After filtration is complete, depending on the process requirements, sometimes a cake wash step is used to extract the mother liquor from the cake with wash liquid or solvent. This cake wash will take 10 or 15 minutes at most, depending on the resistance to flow in the cake. Now the filter is ready for blow down and cleaning.

Filter cleaning

Depending on the filter features, the filter is cleaned either manually or by the self cleaning features of the filter. For the manually cleaned filters, blow the filter down with air or gas to empty liquids from the filter. Once the filter tank is empty, release the pressure in the filter by opening the vent, leave the drain open, open the filter cover closure and remove the filter elements for manually cleaning and replacing the filter media for the next cycle.

In the case of a self cleaning filter, this step is done either by washing the filter cake off the filter elements using the internal spray or sluice feature or by drying the filter cake with air or gas, opening the filter and using the air vibrator to vibrate the cake off the filter elements. In either case, air or gas is used to drain the filter of the unfiltered liquid left in the tank at the end of the filter cycle. This unfiltered "heel" is returned to the feed tank or to a separate holding tank for that purpose.

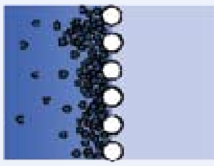
In the case of the wet-cake discharge filter, open the filter drain and the air vent and then open the sluice/spray valve. The internal spray will wash the filter cake off the filter elements and down the drain. This process should take approximately 5 to 10 minutes. The filter is then ready for the next cycle and in the standby mode.

In the case of the dry-cake discharge filter, the valve sequence is handled with care to avoid any premature cake drop that will affect the dry-cake discharge process. Open the air blow-down valve, gradually close the feed inlet valve and turn off the feed pump. Blow air or gas through the filter with the outlet valve and drain valve partly closed to keep from losing pressure in the filter suddenly. Drain the filter of the unfiltered heel and once empty, close the drain valve, Gregg-Taylor Associates

FIGURE 10. Shown here are a typical bag filter housing, a selection of synthetic cloth and felt bags, and baskets that hold the bags in the housing

THREE FILTRATION TECHNIQUES

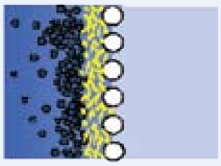
Media only



When you have:
- Crystalline, easily filtered solids
- Very low solids concentration
- Particle size about the same as media opening

Use:
- Bags, cartridge, plate or leaf filters

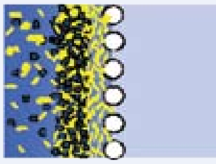
Media + precoat



When you have:
- No slimy solids
- Up to 5% solids
- Fine retention needs

Use cake filtration:
- Plate or leaf filter

Media + precoat + body feed



When you have:
- Slimy, difficult to filter solids
- Up to 5% solids
- Fine retention needs

Use cake filtration:
- Plate or leaf filter

FIGURE 11. To perform a liquid filtration process, there are three different techniques to consider when designing the filter station. The technique used will depend on the nature of the solids being filtered

leave the outlet valve partially open and let the air pressure in the filter build up. Once the pressure reaches 30 to 40 psig, quickly open the outlet valve and partially close it again when the air pressure drops to 10 psig. Repeat this procedure for about 10 to 15 minutes in order to dry the filter cake by blowing out as much moisture as possible. Once this cake drying step is concluded, relieve the pressure in the filter, open the drain valve and the air vent, close the air blow down valve and open the filter tank bottom in the vertical tank or the tank closure in the horizontal tank.

Either retract the tank or pull out the leaf bundle exposing the filter leaf bundle with the filter cake and activate the air vibrator to shake the cake off the filter leaves. The discharged filter cake will then fall into a tote bin below the filter to contain the cake. The filter cake discharge is completed. If the filter has an internal washing feature, it is used at this time to wash the filter internals of any residual filter cake or solids.

Running an air vibrator in the filter is always recommended when filling the filter in the beginning of the precoat step to help loosen any precoat material left on the filter media and thus ensure that the filter leaves are clean for a new cycle.

Filter cake options

Disposal or further handling of the filter cake varies depending on the application. In some applications where the products filtered are very valuable, washing of the filter cake is prescribed to recover as much of the mother liquor as possible to reduce residual product in the filter cake for further processing. This application applies to the plate-type batch filters as well as the Nutsche filters and even to the pressure leaf filters. The washing in place of the filter cake with a solvent is commonly done at the end of the cycle. The solvent or wash liquid is introduced and pumped through the filter cake or pushed through the filter cake with air or gas to displace the mother liquor out of the cake. This procedure is done taking into consideration the pressure drop or resistance to flow at the end of the filter cycle. Generally, as the mother liquor is displaced, the pressure drop is reduced. This displacement procedure normally should take about 10 minutes or slightly more depending on the initial pressure drop and resistance to flow through the filter cake. Laboratory testing is helpful in defining this washing step.

Disposing of the filter cake in some applications can pose problems, depending on the toxicity of the resulting filter cake. In the case of the plate filters, the filter cake is on top of the filter paper. As the filter is cleaned, the filter paper is removed from the filter plate, folded up and disposed into a waste receptacle or sent to be incinerated.

In the pressure leaf filters with a wet cake discharge the resulting slurried cake is sent to either a waste sump or transported off site for ultimate disposal. The cake from filters with dry cake discharge is typically held in the waste tote for transportation off site or sent for further processing either at the plant or another location that may recover certain wanted products from the processed, spent filter-cake waste. Sometimes the non-toxic spent cake is used for landfill or soil conditioning or even animal feed.

TROUBLESHOOTING

Some of the more common situations or problems that affect the performance of a filter are now covered to assist you in the troubleshooting process.

Bleedthrough

This situation is identified by different names like cloudy filtrate or particle migration. Sometimes these situations are caused by tears or pinholes in the filter media, or poorly cleaned filter elements with residual cake from the previous cycle that prevents good seals. Channeling due to erosion of the filter cake by the incoming liquid not being properly baffled to prevent disturbing the cake is another cause of the problem. If possible, the filter needs inspection once it is precoated or prior to the cleaning step to determine if the cause of the channeling or bleedthrough is due to pinholes or tears. You can readily see the holes in the cake or the disturbed flow path across the cake where this short circuit has occurred to cause the bleedthrough. Poorly cleaned filter elements leave particles inside the filter element structure that eventually are released by the flow once the differential pressure equalizes.

Short cycle

The filter cycle is cut short due to a sudden increase in pressure drop, by blinding or plugging and loss of clarity. A sudden increase in pressure drop indicates that the filter cake is blinded due to not enough bodyfeed, a poor precoat or an incorrect choice of filter aid. This problem is identified and resolved in the laboratory by running a bench-scale filter test to determine if an increase or change in bodyfeed or precoat is required to improve cycle time.

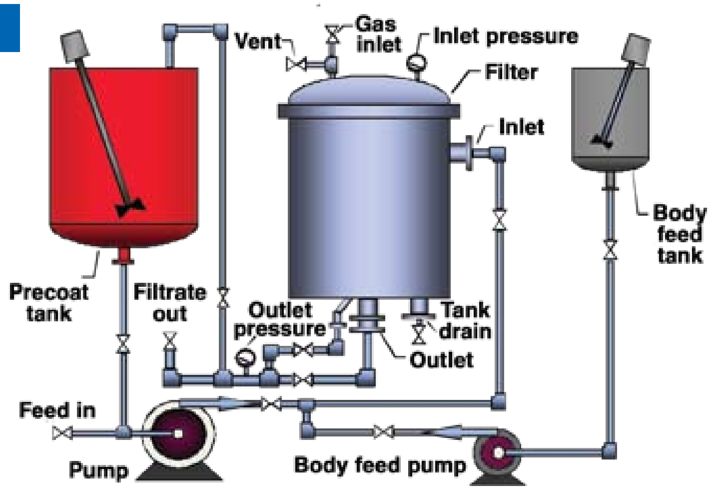


FIGURE 12A. Shown here is a typical filter station with the associated piping and valves. Pressure gages at the inlet and outlet of the filter are needed to measure the pressure drop

Premature cake drop

This problem affects the dry cake discharge of the filter. A sudden change in flow or improper valve sequencing can cause the cake to drop prematurely leaving gaps in the filter cake. When there are gaps in the filter cake, drying of the cake is affected since the air or gas will short circuit through the crack or missing filter cake. When the filter cake does not dry properly, the cake is wet and mushy and will not discharge, leaving cake on the filter elements that interferes with the next precoat cycle. This leftover cake problem compounds poor cleaning, and the problem snowballs from there requiring opening of the filter and removing the filter elements to manually clean them by pressure washing.

Process changes

In one instance that I recall, a process was developed by simulating a reaction in the laboratory. The plant was built — including the required process equipment — based on the laboratory results. Prior to starting the plant, the raw material for the reaction in the process was changed without running more tests in the laboratory. The different raw material produced more suspended solids of different characteristics than those originally tested. The results were disastrous, rendering the process equipment incapable of handling the added solids load and complications from these extra solids. So once again, the importance of laboratory testing is stressed.

PREVENTATIVE MAINTENANCE PROGRAMS

Preventative maintenance in any filter operation, no matter how simple and uncomplicated the operation, is a very important subject. A well executed preventive-maintenance program ensures a long productive life for any filtration equipment, just like that required for other process equipment. In the following section some of the more common recommendations are discussed.

Filter paper media

The installation of the filter paper onto the plate filters should be done with care to prevent wrinkles, ballooning, tears and folding of the paper. Wrinkles are usually caused by swelling of the filter paper and once compressed between the filter plates, the paper has no place to expand, so wrinkles form in the paper sheet. This problem is avoided by prewetting the filter paper just prior to installing on the filter plates.

Ballooning is caused either by the swelling or by air entrapped under the paper due to filling the filter too fast. If this problem occurs, reduce the flow during the filter fill, thus allowing the air inside the filter plate to evacuate more slowly and completely. Check with the manufacturer of the filter about proper venting recommendations during the filling of the filter. The air entrapped inside the filter plate and under the filter paper tries to push up, and causes the paper to balloon with the trapped air bubbles. These bubbles will flatten as flow starts and pressure rises during filtering and will cause the precoat or cake formed on the filter paper to crack. This crack allows solid particles to break or pass through the filter paper as they did during the initial flow through the filter to form the first precoat layer for coating of the filter paper. Sometimes the bubble under the media breaks causing tears on the filter paper. Also, tears in the filter paper are caused by broken under supports, nicks or imperfections on the metal sealing surfaces in the filter plates. When this problem occurs, inspect the filter paper during the cleaning of the filter and the metal surfaces of the filter plates for any irregularities to determine the cause for cake disturbance.

Folding of the filter paper is due to assembling and redressing the filter plates bundle too fast. Care should be taken to ensure that all the filter papers are lying flat and evenly on the filter plates. A quick visual inspection should show the edges of the paper extending beyond the plates.

Filter-cloth covers or bags

In filters with cloth covers or cloth bags inspection of the filter cloth is routinely done to look for tears, pin holes or frayed areas that are the cause of problems in the filter performance. Tears on the cloth can occur due to friction or moving parts rubbing against the cloth. Tears, pin holes and fraying of the cloth is also caused by the erosive action of the filter aid. Sometimes the impacting force of the internal sluice or washing jets of the filter cleaning system causes tears or fraying. This damage is prevented by having protecting caps on the filter cloth covers or bags, thus reinforcing the impact areas.

Inspection of the cloth covers or bags for blinded areas, due to improper washing by the internal spray or sluice system, is necessary on a systematic basis. Also, some blinding occurs due to the build up of solids in the weave

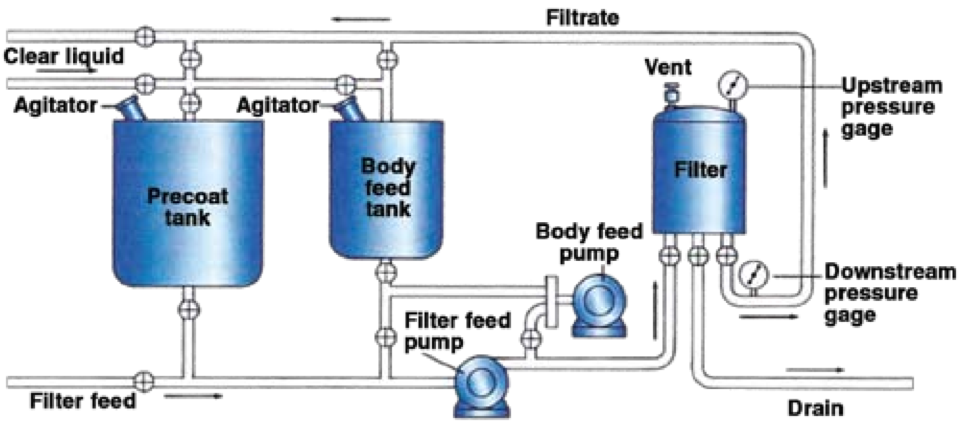


FIGURE 12B. Another view of the piping arrangement for a filter system. Centrifugal pumps are used for the feed and precoat, while diaphragm pumps are used for body feed

or threads of the cloth, which is corrected by periodic washing of the cloth bags or covers in industrial washing machines with detergent. Sometimes the cloth material is subject to chemical attack over a long period of use. Changes in the texture of the cloth or stiffness or discoloration of the cloth such as yellowing or browning indicate chemical attack of the cloth.

Handling cloth-covered filter elements with much care is important while installing or removing the filter elements from the filter. Do not drag the cloth-covered filter element on the floor. Do not stack or store the cloth-covered filter elements in a way that shifting or rubbing can occur, and which could damage the cloth covers. Some cloth materials are affected by direct sunlight. Always store cloth covers, cloth bags or cloth-covered filter elements away or protected from direct sunlight. The effects of sunlight exposure are change in color or yellowing and brittleness of the cloth to the point that the cloth itself disintegrates.

Wire mesh media

In filters with wire-mesh-covered filter elements, inspect for pinholes, tears, fraying, erosion worn areas and broken or loose welds. As stated above for cloth media, possible causes of these potential problems are the same for wire-mesh-covered filter elements. Look for broken under-supports that will cause pinholes and tears on the wire mesh. Friction or rubbing with metal parts can also cause tears, frayed areas and holes. One possible cause of holes in the wire mesh is the erosive action of filter aid, which can act like a sandblast shot wearing away spots or areas on the wire mesh. This wear is evident by closely inspecting the wire mesh for wires worn thin to the point of developing holes. Some of the holes are pinholes while others are areas where the wires are missing altogether with the telltale worn wire hanging around the opening. Another problem to inspect for is broken or loose welds of the wire mesh on the filter elements. Repair the broken welds by welding, spot welding or temporary soldering. Soldering offers a quick temporary repair, but needs follow-up with a proper clean up of the affected area and welding. Sometimes a piece of the same wire mesh is spot welded in place to cover torn spots or holes in the wire mesh.

Since the wire mesh for mesh-covered filter elements are considered permanent, sometimes filter aid particles or solids particles are imbedded inside the filter element structure and under the wire mesh. A simple high pressure wash may not loosen these built-up areas, so ultrasonic or special cleaning is necessary to return the filter elements to like-new conditions. Consult outside sources that perform these types of special cleaning services either on a one time basis or on a routine maintenance schedule.

Gaskets, seals and O-rings

Other potential problem areas for inspection on a regular preventive maintenance program are O-rings, filter element's outlet couplings, gaskets, seals and packing glands. Check the O-rings for tears, nicks or flattened areas that can cause leaks during filtration. When installing the filter elements in the filter, lubricate the O-rings with a process-liquid-compatible lubricant to prevent damage to the sealing surfaces. Check the filter element outlet couplings to inspect for irregularities on the sealing machined surfaces or for being "out of round." All gaskets in the filter require periodic inspection for tears, nicks or breaks that can cause potential leaks during the operation of the filter.

Lubrication

Lubrication of moving parts is also an important part of the proper preventive maintenance program of any filter. Good lubrication ensures the trouble free operation of the filter.

Mechanical service

Cross–tighten and cross-loosen bolts when servicing tank covers. Use torque wrenches to achieve the correct tension for securing pressure vessels and avoid stripping threads on the bolts. Avoid any undue stress or forceful operation of the filter to prevent unnecessary wear and tear on the filter parts.

FINAL REMARKS

Good training for your production staff is time well spent to produce filtered products that meet specifications cost effectively and keep equipment operating efficiently.

Remember your best source for help to achieve the successful operation of the filter, trouble and problem free, is your filter equipment manufacturer or a filter consultant. Help and assistance is only a phone call or an email away. ■

Edited by Gerald Ondrey

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