

## Back to Basics

# Selection of Filters for the Separation Process

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Selecting the right type of liquid/solid separating equipment is not a simple task as the range of equipment is very large. For these reasons it is useful for an engineer confronted with a separation problem to conduct the basic evaluations of the possible or probable solutions and above all establish which routes not to follow. This article will help to conduct basic testwork and then to select the most optimum separation equipment.

## Basic Principles of Liquid / Solid Separating Equipment

To separate liquids from solids or solids from liquids there are only two mechanisms available

- Separation: Either the solids have a tendency to go one way and the liquid the other way
- Filtration: One must find a pore sizes smaller than the solids which one wishes to capture

### Laboratory tests

Although there is a theoretical possibility that one could arrive at the right equipment of the right size based on nothing more than an analysis of the solid and liquid,

the chances that this is going to happen are poor. Therefore, basic laboratory tests are essential with representative slurry (suspension) samples. If it is at all possible one should aim at carrying the initial laboratory tests on site and as close to the source as possible. Even if that means working under difficult conditions and without the normal laboratory facilities. A representative sample, tested with some basic equipment on a crate is much more valuable than a non-representative sample tested in the best-equipped laboratory.

### Observation of the Slurry

However, do not rush into tests

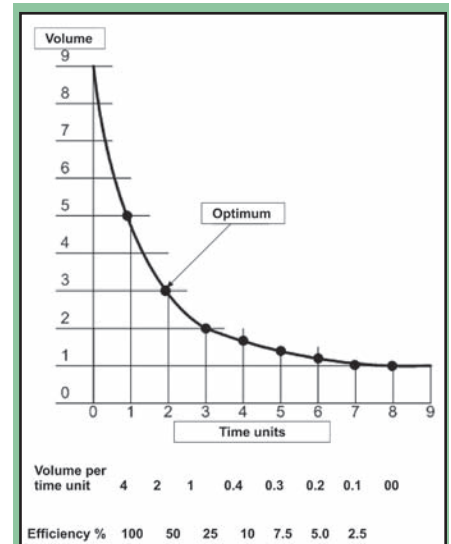


Figure 1: General filtration curve showing as filtration continues, the cake grows thicker and denser, while the efficiency decreases

immediately, but rather pour some of the suspension into a glass beaker and observe what it does and what happens to it. Observe if the suspension has a tendency to separate naturally and if so, how? Are some solids settling rapidly, but the rest stays in suspension? Is there a tendency to foam? Do the solids look as if they are coagulating and give a more 'granular' appearance than at first. Do the particles form clusters, so that what one actually filters is not the particle itself but the loosely held together structure of crystals? This latter phenomenon often occurs with

needle shaped crystal. This initial observation may provide clues into how the suspension will handle.

### Basic Principles of Filtration

To some extent one would expect that a high pressure driving force would be beneficial for liquid removal, but the effect is limited because some cakes are compressible. In these cases, then, vacuum filtration would be more efficient.

With a compressible cake, the act of forcing liquid through the already collected solids (the cake) result in these solids being pressed together forming a dense matt. This dense matt, which requires a greater force to penetrate, thus produces a denser matt, which requires even higher forces which produce an even denser matt and so on. This problem multiplies exponentially with the thickness of the cake layer.

Figure 1 illustrates this phenomenon. Normally one can expect a 'best overall efficiency' if the cake thickness is kept well below its theoretical maximum and the

driving force is not the maximum available. This is true in general, but especially so in those cases where the solids have to be washed, extracted or subsequently impregnated.

### Overview of Bench Top Testing for Pressure or Vacuum Filtration

Pressure or vacuum testing is best conducted using the BHS Pocket Leaf Filter. The testing will analyze cake depths, operating pressures, filter media, washing and drying efficiencies and qualitative cake discharge. The data collection sheets are shown in Figure 2. Based upon the results of the testing, the selection of the types of filtration equipment to meet the process requirements is the next step.

### Filter Systems

The choice of filter systems is infinitely great and has the further problem that all filters rely on only one principle, 'find a pore size smaller than the particle which you must catch and apply enough force

Customer:		Test Number:
Date:		Run #
	Filter Media Suspension	
Filling	Volume of Slurry Density of Slurry % Solids in Feed Temperature	
Filtration	Vacuum or Pressure Volume of Filtrate Time for Filtration % Solids in Filtrate	
Wash 1	Wash Material Pressure Volume of Filtrate Time for Filtration	
Wash 2	Wash Material Pressure Volume of Filtrate Time for Filtration	
Wash 3	Wash Material Pressure Volume of Filtrate Time for Filtration	
Drying	Pressure Temperature Flow Rate Time for Drying Pressing Pressure	
Cake	Weight Thickness %Residual Moisture Dry Cake Weight Cake Discharge OK?	

Figure 2: Data Collection Sheet

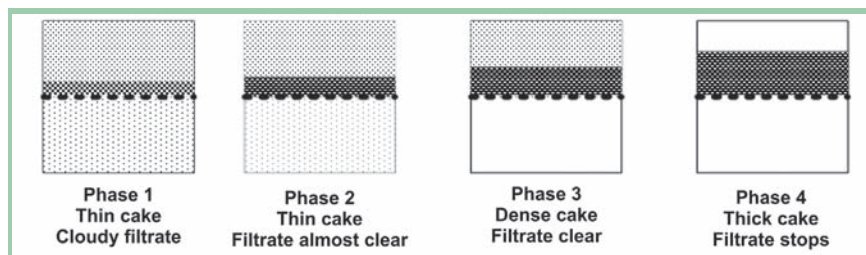


Figure 3A: Filter Cake Formation

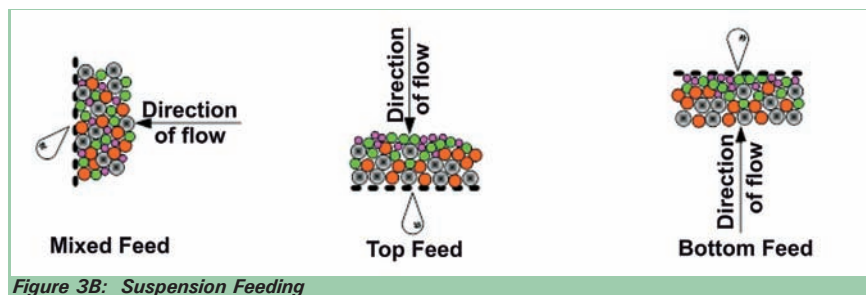


Figure 3B: Suspension Feeding

to get the liquid through it'. This is probably the reason why certain industries have one type of filter whereas another industry having substantially the same filtration problem will have a totally different one.

**Cake Versus Non-Cake Filters**

There is no agreement on the terms 'cake filter' and 'non-cake filter' but it is a useful distinction, although it is recognized that all filters produce 'a' cake, be it thick or thin. However, there are processes where it is essential that the solids are recovered as a solid cake (ie cake filters) whereas other processes require the solids to be discharged as a slurry with some of the mother liquor. (ie non-cake filters). In addition, most cake filters can offer cake-washing facilities, whereas most non-cake filters cannot. This distinction will therefore be used.

**Filter Cake Formation**

To understand filtration one must understand how the cake is built up and structured, because in all filters a significant part of the filtration takes place with the filter cake acting as the filter medium. This applies equally to batch filters as to continuous filters because all filters have basically the same phases, as shown in Figure 3 A.

**1st Phase:** suspension flows through the clean filter medium, some solids stay behind

**2nd Phase:** suspension continues to flow but now through the partially coated medium and thus at either reduced rate or higher pressure differential, more solids stick

**3rd Phase:** suspension now meets

a medium with very much reduced apertures and has to flow through the cake solids. Most solids will now be caught, filtrate is cleaner, flow reduces further and cake starts to consolidate

**4th Phase:** solids have built up on the medium until there is so much resistance that filtration has virtually stopped. In case of batch filters this means stopping the filter, discharging the cake, backwashing or otherwise cleaning the medium and restarting, whereas in continuous filters the cake is continuously discharged and the medium cleaned, once the fourth phase has been reached.

**Suspension Feeding**

A further very important matter impacting cake formation is the way in which the feed is introduced to the filter. Three basic systems exist, shown in Figure 3B.

**1. Mixed flow filtration.** The feed as a homogeneous mixture enters the filter and meets the filter medium, either or not covered by cake. There is no tendency for cake stratification or for preferential liquid flow. This condition pertains to all filters with vertical filter areas as well as to centrifugal filters.

**2. Top feed filtration.** The feed flows onto a horizontal filter area (usually, by gravity) where it can be given some time to settle out and thereby form a stratified cake.

**3. Bottom feed filtration.** The liquid phase of the feed gets sucked

through the filter medium, taking the solids with it, which impinge on the medium. Obviously the very fine solids will preferentially be carried in the stream and thus tend to build a layer of very fine, blinding solids onto the cloth.

**Preliminary Selection of Filters**

Figure 4 shows a preliminary selection process and Figures 4 A and 4 B show the most important characteristics of each group of equipment.

If the vacuum test obtained the right quality of filtrate and cake, then for both batch and continuous vacuum filters one has the choice between bottom fed and top fed machines.

If the vacuum tests were basically encouraging but the rate of filtration was rather slow or the filtrate a little too cloudy, one can consider pre-coat filtration, which is only possible with bottom, fed vacuum filters, or alternatively use flocculants or body feed which can be used in either type. Because vacuum filters are normally simpler and more economical than either pressure filters or centrifugal filters there is every sense in

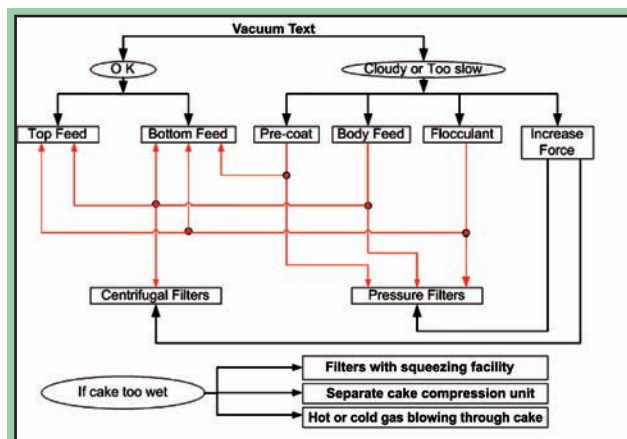


Figure 4: Preselection Process

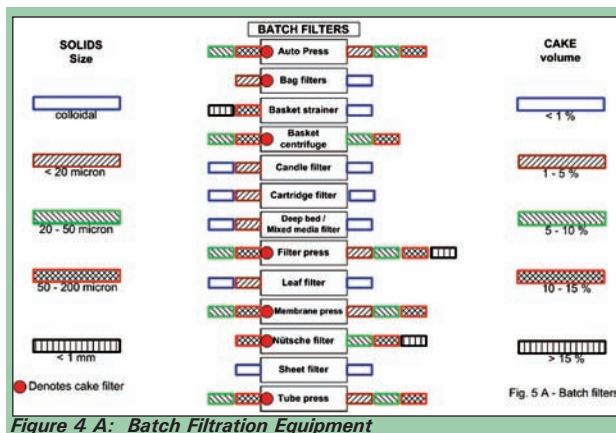


Figure 4 A: Batch Filtration Equipment

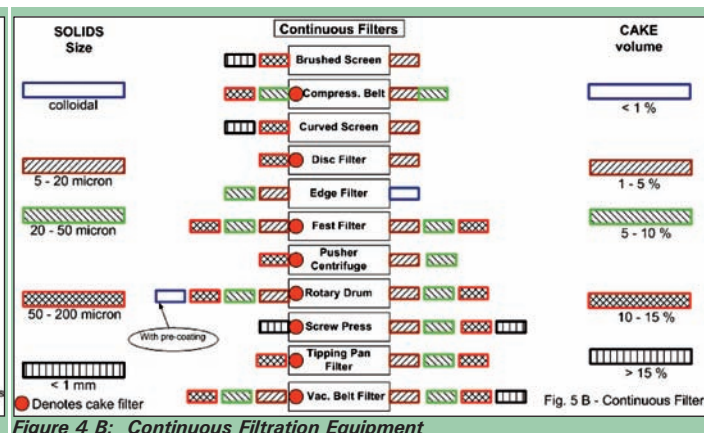


Figure 4 B: Continuous Filtration Equipment

pursuing vacuum filters, but of course one has to be realistic. If one can make a vacuum filter work by adding body feed and flocculants, incorporating compression rollers, heating elements and steam hoods then one is clearly not looking at a practicable solution.

So, if vacuum is not satisfactory one has to resort to higher filtration forces, ie pressure filtration or centrifugal filtration, again with the option to use flocculants, pre-coat or body feed, although the former two normally do not work in centrifugal machines.

If basically everything is acceptable but the cake is too wet, one must consider machines with inherent cake compression facility or alternatively feed the cake into a separate dryer, which is often easier and cheaper.

### Pilot Tests

Once the equipment selection is completed based upon laboratory tests, pilot tests are the next step. When planning for pilot tests, it is important to allow for the product, time, economics, space and manpower. Pilot tests are valuable, often even essential, but

should be planned as if it is a full-scale installation. If not the results will be meaningless and expensive information.

### Conclusion

Filtration and separation are affected by many variables. For example, in terms of the particles, the amount of solids, size, shape, particle density, compressibility of the solids, zeta potential and other ionic forces, agglomeration of the particles due to internal bonding and forces, etc all impact the filtration flux rate. Two particles of the same size, may behave differently if one is flat in shape while the other is irregularly shaped.

In terms of the liquid, there are also characteristics that impact the filtration rates such as temperature, viscosity, density, pH, components of the liquid, chemical additions (flocculants, coagulants, etc.), polar/non-polar constituents, the interaction of the solids and liquids, etc. Once again, a small change in the liquid can have a dramatic impact on the rates.

As can be seen, many variables must be examined during filtration studies. This article discussed

techniques to conduct laboratory tests and then how these results can be transferred to production systems. The process engineer through the development of an optimum test plan can analyze the resultant cakes and slurries to maximize his or her process. In the future, if the actual results differ from the tested results, then, with a good baseline of tests, the engineer can analyze the differences and develop the necessary corrective actions for a successful result and process. ■



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