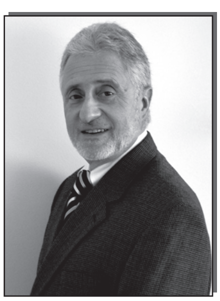
Continuous Pressure And Vacuum Filtration Technologies as Alternatives to Batch Filtration Operations

- Barry A. Perlmutter

This paper discusses the selection of the filtration process systems: continuous pressure and/ vacuum filtration through a process of laboratory and pilot testing. These tests enable problem analysis, technology selection and scale up which help in optimum filter selection.



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Introduction

Sherlock Holmes and Dr. John Watson are fictional characters of Sir Arthur Conan Doyle. Process engineers who live in the real-world can learn many things from the two of them for solving process filtration problems. This paper intertwines the detective techniques (mindfulness, astute observation, logical deduction and others) of Holmes and Watson with the problem solving skills required to select process filtration systems.

One example that Holmes proves time and again is that there is no benefit in jumping to conclusions. The paper discusses the bench-top laboratory tests that are conducted for problem analysis, technology selection and scale-up. The tests include pressure or vacuum, filter media, cake thickness, temperature and viscosity concerns, filter aids and similar process parameters. Testing will avoid "jumping to conclusions."

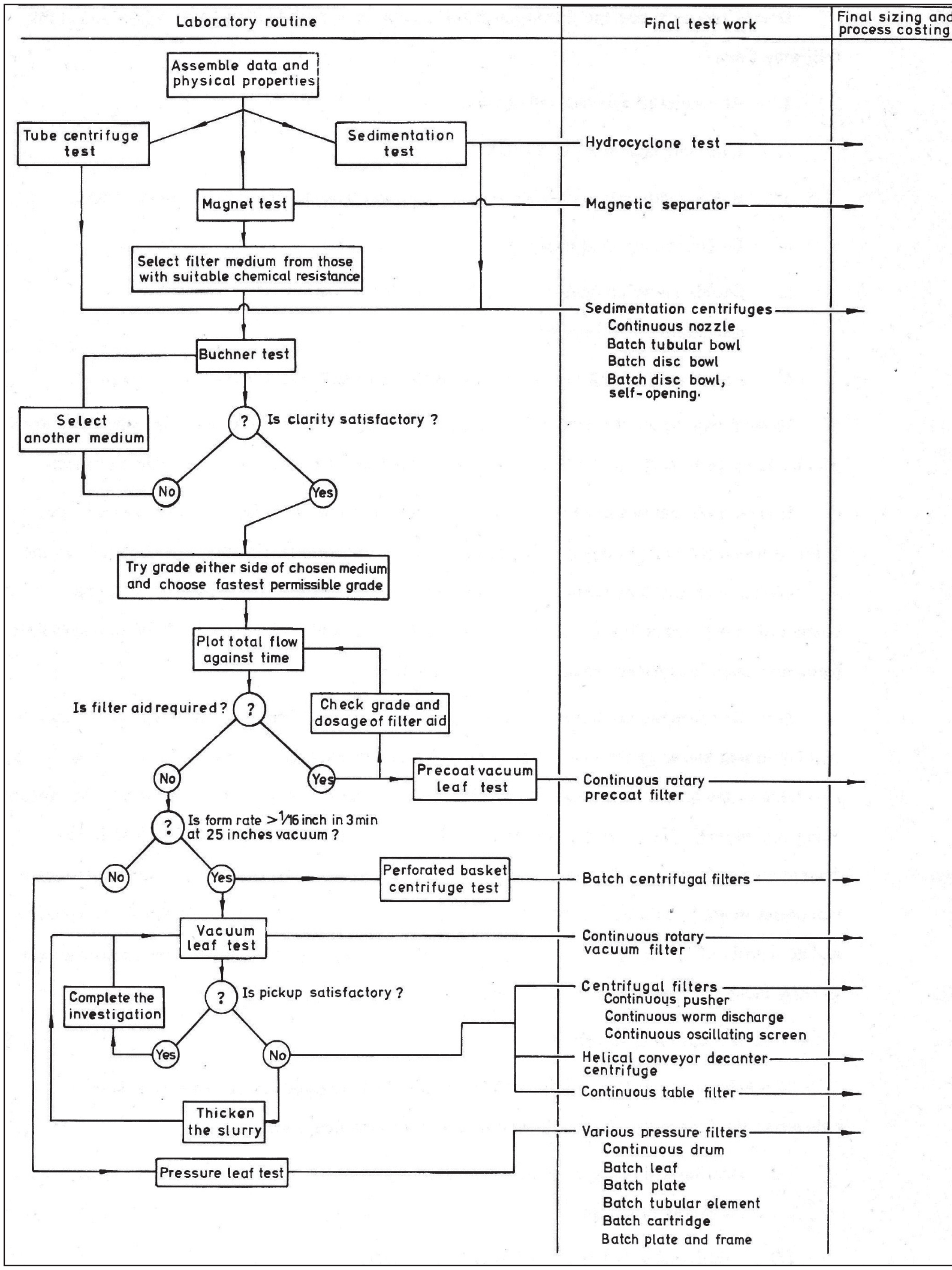
Two case history examples discussing slurry testing, process analysis and then process filtration selection for continuous pressure or vacuum filtration are covered. The case histories illustrate the methods followed from testing through decision-making.

The paper provides a general review of the problem-solving skills of Holmes and Watson such as the "occasional silence", "employing distancing" and "learning to tell the crucial from the incidental." These skills can be utilized by process engineers as a framework for "idea-generation" when analyzing an operating bottleneck issue or new process development problem. In all cases, by combining Holmes and Watson with accurate lab and pilot testing, the optimum filter selection can be realized.

Laboratory Testing and why there's no benefit to jumping to conclusions

According to Holmes and Watson, it is important to train yourself to be a better decision maker. For example, using checklists, formulas, structured procedures; those are your best bet. Figure 1 shows a typical Experimental Test Routine.

Fig 1: Davies' Experimental Test Routine



Overview of bench top testing for pressure and vacuum filtration

The BHS bench top testing is conducted using the BHS Pocket Leaf Filter, as shown in Figure 2. The test device is a BHS pocket leaf filter with a filter area of 20 cm^2 and a vacuum and pressure connection. 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 3. The steps in filtration testing are as follows:

First, it is necessary to clearly state the process description. This includes the slurry characteristics (particle size distribution, particle shape, density, etc.), washing of the cake (i.e. number of washes and wash ratios), drying / pre-drying of the cake (vacuum, pressure blowing, and mechanical pressing) as well as the upstream and downstream equipment. With this definition, the type of samples that need to be collected and analyzed can be determined.

Secondly, it is necessary to know what are the requirements for the operation such as solids/hour and cake quality (percent moisture, percent contaminants, etc.).

Thirdly, with the above in mind, the testing must determine the following objectives:

- Choice of a suitable filter cloth
- Vacuum or pressure filtration
- Wash ratios for the washing of the filter cake
- Drying techniques
- Cake thickness

Fig 2: BHS Pocket Leaf Filter

Fig 3: Data Collection Sheet for BHS Pocket Leaf Filter

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

Process Filtration Selection for Continuous pressure or Vacuum Filtration

According to Holmes and Watson, it is easy to succumb to certainty but every time you find yourself making a judgment upon observation, train yourself to stop and repeat. Then go back and restate from the beginning and in a different fashion and most importantly, out loud instead of silently, as this will save you from many errors in perception. Process engineers can benefit from discussing options with technology suppliers that can provide different filtration solutions.

Case History

Continuous pressure filtration as an alternative to batch filter press and batch plate filter operations

The current operation uses both a filter press as well as a batch manual horizontal plate filter. There were high operating costs, inefficient cake washing and drying.

Process testing was conducted at the site's laboratory and in the plant. For the bench-top lab testing, the BHS pressurized pocket-leaf filter (PLF) with 20 cm^2 of filter area. For the continuous pressure pilot testing, a pilot RPF with 0.18 m^2 of filter area is installed, as shown in Figure 4.

The objectives of the PLF testing are as follows:

- Filtration time vs. filter media
- Filtration time vs. slurry feed mass
- Filtration time vs. differential pressure
- Filtrate quality vs. filter media

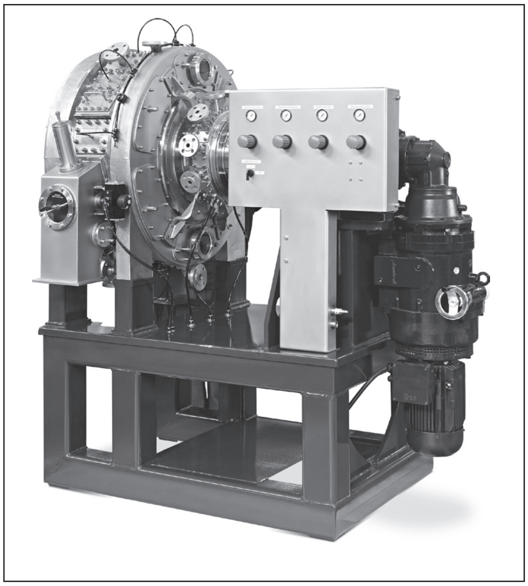


Fig 4: BHS Rotary Pressure Filter, RPF 0.18 M^2, Pilot Filter

- Cake solids wash time and quality
- Cake solids discharge characteristics
- Production Scale-Up and Process Guarantee.

The lab testing proved to be uniquely challenging both to feed the PLF as well as to maintain a pressure to keep the liquefied solvent. The plant engineers and BHS developed a confidential method to meet these challenges.

The PLF tests demonstrated that acceptable filtration and solids wash rates could be obtained for this product and acceptable solids levels were achieved for the mother liquor filtrate. Washing targets and drying quality parameters were also achieved.

Additional pilot plant tests with the BHS continuous pilot unit, RPF 0.18, were recommended to confirm the PLF lab tests. In these tests, BHS would be able to identify the necessary slurry solids percentage, cake solids thickness, solids wash time, solids drying time as well as cake discharge. Finally, the pilot testing will be the basis for the mechanical design of the RPF to ensure that the RPF can be designed for the process with a liquefied gas slurry.

While the actual data is confidential, the plant engineers and BHS process engineers gathered the following parameters from the pilot RPF 0.18 m^2 testwork.

Process Parameters:

- Slurry Feed Pressure:
- Slurry Feed Flow:
- Wash Pressure:
- Wash Flow:
- Dry Pressure:
- Drying Air Flow:

RPF Parameters:

- Drum Speed:
- Slurry feed rate, wash ratios and drying gas (rates and pressures):
- Cake blow back:
- Cloth blow back:
- Backpressure:
- Cake Thickness:
- Filter Cloth:

To fully evaluate the RPF performance, the site also compiled the following:

Slurry solids concentration

Filtrate quantity (mother liquor, wash, blow down, etc.)

Filtrate yield

Cake Moisture

Total Cake quantity

Scale-Up From RPF 0.18 M^2 Pilot Data

Calculate Specific Filter Performance from Pilot Testing = kg of dry solids/m^2/hour

Calculate Production Area Required from Filter Performance and Client
Required Production Rate

Using the drum speed, time for filtration, washing and drying and several other RPF factors, the specific filter area is calculated.

Pressure filtration and typical scale-up calculation-example only

- The scale-up is based on 224 g slurry with 1:1 composition = 112 g dry solids
- Filtration time (4 seconds); washing time (8 seconds); drying time (15 seconds); these times are from the lab testing and used to scale up to a production unit; the pilot RPF testwork confirmed the scale-up.

Drum revolutions: $$n = \frac{3600\frac{s}{h}}{(4+8+15)s} \cdot \frac{270°}{360°} \cdot 0,85 = 85\frac{revolutions}{h}$$

270°: active angle

0.85: factor for separating elements

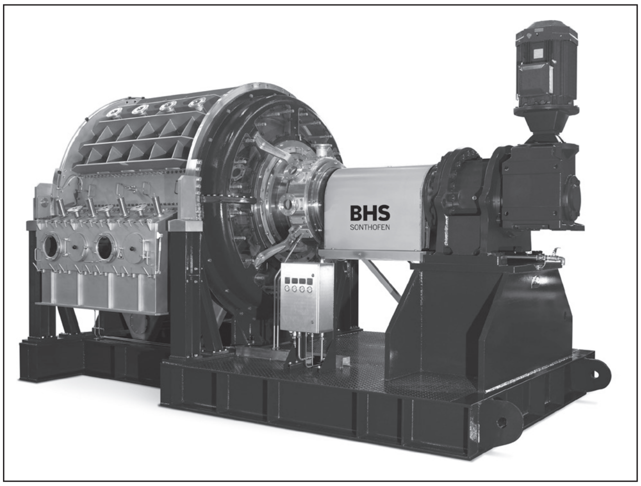


Fig 5: BHS Rotary Pressure Filter, RPF

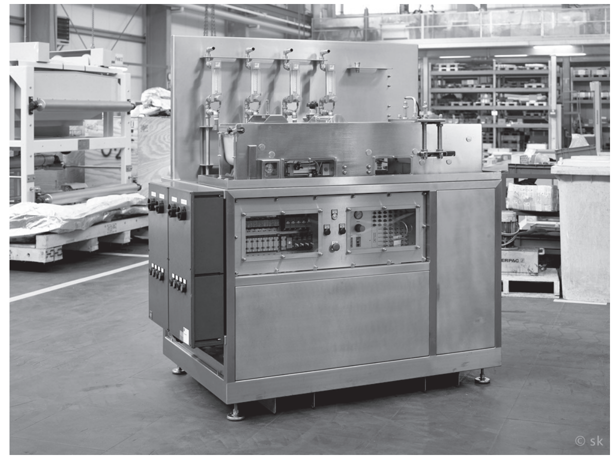


Fig 6: Pilot Vacuum Belt Filter in stainless steel

Specific filter performance: $Q = 500\frac{1}{m^2}\cdot 85\frac{1}{h}\cdot 112g = 4760\frac{kg\ dry\ solids}{m^2\cdot h}$

Required filter area: $$A = \frac{20000\frac{kgdrysolids}{h}}{4760\frac{kgdrysolids}{m^2 h}} = 4{,}2\ m^2$$

Selected filter: BHS Rotary Pressure Filter, type B16 with 5.4 m^2 is sufficient to operate 20,000 kg dry solids per hour. The full-scale unit is shown in Figure 5.

Case History

Continuous vacuum filtration as an alternative to batch centrifugation

Bench top laboratory tests are valuable in selecting a solid/liquid separation device. For this process, the initial lab tests suggested a continuous vacuum belt filter would achieve cake quality equal to or better than the current centrifuge with a major reduction in processing time. The footprint would be comparable to the current centrifuge and the unit would be suitable for conversion to a continuous process. After further discussions, the decision was to select a vacuum belt filter for pilot testing.

There are five objectives in running a pilot test filter:

1. To verify the time for formation of the cake and the initial saturation prior to dewatering of the cake
2. To evaluate the effect of cake thickness on the dewatering time
3. To investigate alternate ways to improve cake dryness (i.e. compression, gas blowing) that may eliminate the drying step
4. To evaluate the quality of the cake (dryness) and its effect on release from the filter media (Some initial tests would be required to make an initial selection , but 2-3 cloths may need to be tested in the pilot unit to verify release characteristics)
5. To evaluate wash ratio needed to remove solubles and color bodies.

The initial laboratory test data suggest that a full-scale continuous-indexing vacuum belt filter with from 0.5 to 1.5 m^2 of filter area would be suitable for the current process operations and reduce cycle time in half or better. The BHS 0.1 m^2 vacuum belt filter was selected for test, and would allow for a feed rate of 0.5 gpm (Figure 6).

Suggested testing order and condition changes:

1. Using a pocket filter and various samples of cloth, pull a vacuum of 20 inches Hg until no liquid is flowing. Invert the filter and observe the cake release. Describe it qualitatively (soupy, chunks, fine powder). Scrape out any remaining material and weight it separately from the material that was released. Select 2-3 cloths for the pilot testing from these tests. (optional) During the experiment measure how much time it takes for the cake surface to become dry and the dewatering time.
2. The estimated filtrate throughput for a 7 mm cake during cake formation and at the end of cake formation for vacuum filtration was measured. Since there are 10 zones, in the BHS filter, samples from the second or third zone would be taken to evaluate

the moisture after cake formation (dry surface). It may be necessary to stop the unit for this evaluation so it should only be done occasionally. Cake thickness can be checked at this time. The other zones can be sampled to determine the rate of dewatering after cake formation and wash ratio.

3. A wash ratio comparable to the centrifuge operation should be used for the previous tests. In the next series, the wash ratio could be varied to evaluate removal of solubles as well as the effect on cake stickiness.
4. While maintaining the same cloth indexing-time, the feed rate can be increased and decreased to vary the cake thickness.
5. Throughout these tests the visual quality of the cake, especially at the discharge should be evaluated.
6. The test unit has an optional compression zone that could be employed. It is also possible to evaluate gas blowing with and without compression.

The results of the testing illustrated that the BHS continuous-indexing vacuum belt filter would be able to produce a cake with better washing and drying compared with the existing centrifuge operation. The full-scale GMP unit is shown in Figure 7.

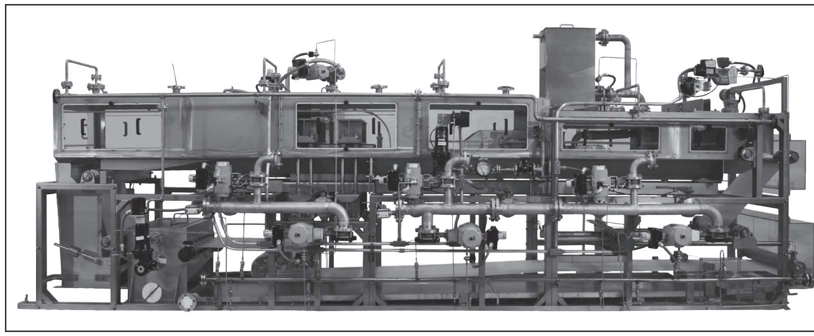


Fig 7: Full-Scale BHS Vacuum Belt Filter

Conclusion

Holmes and Watson provide a unique view of problem solving. The world of a process engineer is a distracting place and Holmes and Watson know that without the occasional silence, as in The Hound of the Baskervilles, there can be little hope for success. Engineers can benefit from conducting lab testing at the technology supplier's site to have time to think about the process issues, at hand. Finally, Holmes and Watson excel at "deduction from facts and deduction difficulties." All that matters are what the premises are (process definition, requirements and testing objectives) and how the testing "unwinds thecrucial from the incidental" (what is the critical process parameter) and finally ending up in the logical conclusion (optimum process filtration solution).

In summary, it is important to view the entire project from many different perspectives. These include knowing the process, observing the testing, deducing the solution only from what is observed (and nothing more) and learning from your colleagues and the technology supplier's successes and failures. It is always difficult to apply Holmes' logic but as Holmes' states "you know my methods, now apply them." Engineers must practice these habits such that even under stress to solve a process problem, these stressors will bring out the very best thought patterns that are needed.

References

1. All information about Holmes and Watson are taken from Maria Konnikova's *Mastermind-How to Think Like Sherlock Holmes* (Viking Penguin (USA) Inc. 2013).
2. Davies, E. (1965): Selection of Equipment of Solid/ Liquid Separations.