COMBINATION FILTRATION OF PRESSURE, VACUUM AND CLARIFICATION TECHNOLOGIES FOR OPTIMUM PROCESS SOLUTIONS

(INCLUDING DATA IN APPENDIX A)

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INTRODUCTION

Filtration experts, over the years, have discussed combination filtration and debated its definition. In the realm of cartridge filtration, simply defined, a combination filter is one that does at least one other processing job at the same time as filtering a suspension. For example, this could be carbon canister which removes both suspended and dissolved components. In water applications, a combination filter removes bacteria, sediment, chlorine taste and odor, and scale. In lubrication oil filtration, combination filtration refers to full-flow and by-pass flow filtration. Finally, for small scale process filtration, combination filtration is installing bag and cartridge filtration systems in series.

There is, however, a new definition of combination filtration that transcends the standard approach and will assist process engineers with trouble shooting and "idea-generation." The approach relies upon the slurry analysis and testing to uncover the "process symptom" and then develop a process solution called "combination mechanical slurry conditioning and filtration." This article discusses slurry testing and process analysis and then illustrates seven (7) case history example installations showing "combination mechanical slurry conditioning and filtration" including data in Appendix A.

TESTING TO DETERMINE "COMBINATION MECHANICAL SLURRY CONDITIONING AND FILTRATION"

Overview of Bench Top Testing in the BHS Laboratory

The BHS bench top testing is conducted using the BHS Pocket Leaf Filter, as shown in Figure 1. 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.

Typical Example of "Combination Mechanical Slurry Conditioning and Filtration" from Bench Top Testing in the BHS Laboratory

The typical testing program is shown in Figure 3. The results and summary of the testing illustrated that the most effective approach for the process filtration is a two stage process.

The primary filtration is by candle filters on a continuous basis. These filters are able to retain particles down to 0.5 microns and discharge these solids as a concentrated sludge/slurry. In order to reduce utilities, no drying or washing is necessary in the larger candle filters.

The concentrated slurry will then be filtered on a secondary pressure plate filter to recover the remaining solvent and discharge the dry solids. The secondary filtration is a batch process which will incorporate filtration, counter current washing, drying, and dry cake discharge. The overall result is a very dependable process with high quality filtrate and minimal utility air and water usage. Each of these processes for the primary and secondary filtration has been tested to confirm that the overall design requirements can be met.

COMBINATION FILTRATION TECHNOLOGIES OF PRESSURE, VACUUM AND CLARIFICATION

There are, without doubt, many technologies that can be applied in combination, including the use of chemicals such as flocculants and coagulants, and which would be the subject of a filtration-chemical handbook/textbook. These already exist in the marketplace. However, from a practical viewpoint, for the basis of this article, a brief description of five (5) types of filtration technologies is presented below based upon general operating conditions at chemical plants.

High-Solids Slurries: Continuous Pressure Operation

The Rotary Pressure Filter technology provides for thin-cake, continuous production in a single unit. Filtration is conducted via pressure of up to 90 psig. Positive displacement washing or counter-current washing follows filtration. Of course, multiple washing steps as well as solvent exchanges, steaming and extraction can also be accomplished. Finally, the cake is dried by blowing hot or ambient-temperature 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.

As for the operation, each process zone (typically 5 - 7 zones) is isolated by a separating element. The pressure in the specific zone can be adjusted to meet the process parameters. The separating elements are sealed to the rotating drum via a gas membrane pressure seal. This drum is sealed to the outer housing by drum packing. The drive system with self-sealed roller bearings provides for high stability and low stress on the drive.

High-Solids Slurries: Continuous Vacuum Operation

High-solids slurries can be defined as up to 50 – 55% solids in the slurry feed. In some cases, for high solids applications, the slurries can be better handled using vacuum filtration rather than pressure filtration. An example of a continuous, thin-cake technology is a Continuous – Indexing Vacuum Belt Filter. This technology consists of fixed vacuum trays, continuously feeding slurry system and indexing or step-wise movement of the filter media. The filter media is indexed by pneumatic cylinders located on the exterior of the unit. The pneumatic operation and fixed trays eliminates a motor and variable speed drive, there are no rails/rollers, and no rubber carrier belt.

Low-Solids Slurries for Clarification & Recovery: Batch Pressure Operation

Candle Filters and Pressure Plate Filters are installed for clarification and recovery applications from liquids with low solids content. These units offer full containment, fines removal in the 0.5 micron and finer range, and can be fully automated. The candle filters are vertical candles while the pressure plate filters are horizontal plates. The major difference between the two units depends on the cake structure that is formed. Some cakes are better handled in the horizontal and some in the vertical. Cake discharge is automatic either by gentle gas expansion of the filter sock in a candle filter or via plate vibration with gas-assist for the pressure plate filter.

Low-Solids Slurries for Clarification & Recovery:
Conventional versus Contained Filter Presses

Conventional filter presses are open design with a series of vertically mounted plates. The Filter cloth is hung over each plate, extending from top to bottom, and is held in place by eyelets that fit over the cloth-pins on top of the plates. The plates are compressed by hydraulic closing pressure. Cake discharge can be manual or automatic.

Contained filter presses consist of circular filter plates that are sealed in a movable housing. The housing is sealed to 150 psig and full vacuum. The housing is then contained in an outer enclosure. The filter plate design allows for forward and reverse flow operations and can be automatically cleaned to less than 1 ppm residual cross contamination. Process steps can be pressure or vacuum and cake discharge is automatic using scraper knives.

CASE HISTORY EXAMPLES SHOWING "COMBINATION MECHANICAL SLURRY CONDITIONING AND FILTRATION"

The next sections review various actual installations showing the benefits of "combination mechanical slurry conditioning and filtration." These examples are included to illustrate creative idea-generation when examining a process problem.

Continuous Vacuum Filtration Followed by Candle Filtration

In this case, shown in Figure 4, the slurry contained a high solids loading but with a very small particle size distribution. Continuous vacuum filtration solved the first part of the process. The cake is very sticky with a cake thickness of 5 – 6 mm. The mother filtrate contained small, very fine solids. These solids were filtered, washed, and concentrated in candle filters and then sent back to the process.

Secondly, as the solids are sticky, the cloth wash contains solids. These solids, as above, are filtered and concentrated also in candle filters and then sent back to the process.

Candle Filtration Followed by Continuous Vacuum Filtration

In this case, shown in Figure 5, the candle filters operate to mechanically condition the slurry through thickening and concentrating up to 10% solids. The resulting slurry can then be economically and technically processed on a vacuum belt filter by vacuum filtration, cake washing and drying. The drying can be by vacuum, compression, blowing with hot or ambient-temperature gas or steaming. Applications for this approach occur in chemical plants as well as in coal gasification plants.

Candle Filtration Followed by Pressure Plate Filtration

This is the case described in the testing section "Typical Example of "Combination Mechanical Slurry Conditioning and Filtration" and shown in Figure 3. The process flow is shown in Figure 6.

Continuous Vacuum Filtration Followed by Contained Filter Press Filtration

In this process, there are three process reaction steps occurring which are being processed by only two types of filtration technologies. Figure 7 illustrates the process flow.

The first reaction requires vacuum filtration, cake washing and drying by vacuum only; the crystals are fragile and cannot be mechanically pressed. The continuous-indexing vacuum belt filter can have the pressing device installed but not operated.

The second step has more robust crystals and requires a lower moisture specification. The cake from the second reaction and is then processed on the same vacuum belt filter but, in this case, the cake is mechanically compressed with blowing for final drying.

The cake from the second step undergoes further processing, but, in this case, pressure filtration is the optimum solution. Due to the nature of the chemicals and solvents, a contained filter press for pressure filtration, cake washing and drying, by both blowing and vacuum is accomplished.

Continuous Pressure Filtration Followed by Candle Filtration

For this commodity chemical, with rates up to 60 tons of dry solids/hour, the initial mother liquor contains fines in the 1 – 5 micron size range. The process decision is to accept fines in the mother liquor rather than have a reduced rate with a tighter filter cloth. The fines are then recovered in the candle filters which can either produce a dry cake or concentrated slurry. The flow diagram is shown in Figure 8.

Continuous Vacuum Filtration (Two Variations)

In this case, similar to one of the previous examples, it was more efficient to use the same vacuum belt filter with two different variations and to conduct the initial cake washing in a separate agitated reslurry tank. Figure 9 shows this process.

Candle Filtration Followed by Conventional Filter Press

In some applications, a conventional filter press is the correct technology but the initial slurry feed is the problem. For these applications, mechanically conditioning of the slurry by concentrating candle filters is the optimum approach. The concentrating candle filters will increase the solids concentration in the slurry as well as reduce the volume of slurry that is to be treated by the filter press. Specialty chemical, chlor-alkali and coal gasification plants are typical examples. Figure 10 shows this flow process; Appendix A contains data from testing for an installation.

SUMMARY

This article discussed a new definition of combination filtration that will provide process engineers a framework for "idea-generation" when analyzing an operating bottleneck. The approach relies upon the slurry analysis and testing to uncover the "process symptom" and then develop a process solution called "combination mechanical slurry conditioning and filtration." This article illustrated that the installation and combined use of filtration technologies, while higher in capital cost, will result in a more reliable operating process at the plant. In all cases, however, only through accurate lab and pilot testing, will the optimum filter selection be realized.

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Barry A. Perlmutter is currently President and Managing Director of BHS-Filtration Inc., a subsidiary of BHS-Sonthofen GmbH. BHS is a manufacturer of thin-cake filtration, washing and drying technologies. Barry has over 30 years of engineering and technical business marketing experience in the field of solid-liquid separation including filtration and centrifugation and process drying. He has published and lectured extensively worldwide on the theory and applications for the chemical, pharmaceutical and energy / environmental industries and has been responsible for introducing and creating growth for many European companies and technologies into the marketplace. He received a BS degree in Chemistry (Albany State, (NY) University), MS degree from the School of Engineering, Washington University, St. Louis and an MBA from the University of Illinois. Barry served on the Board of Directors of the American Filtration and Separations Society (AFS) and is a member of several internationally recognized societies.

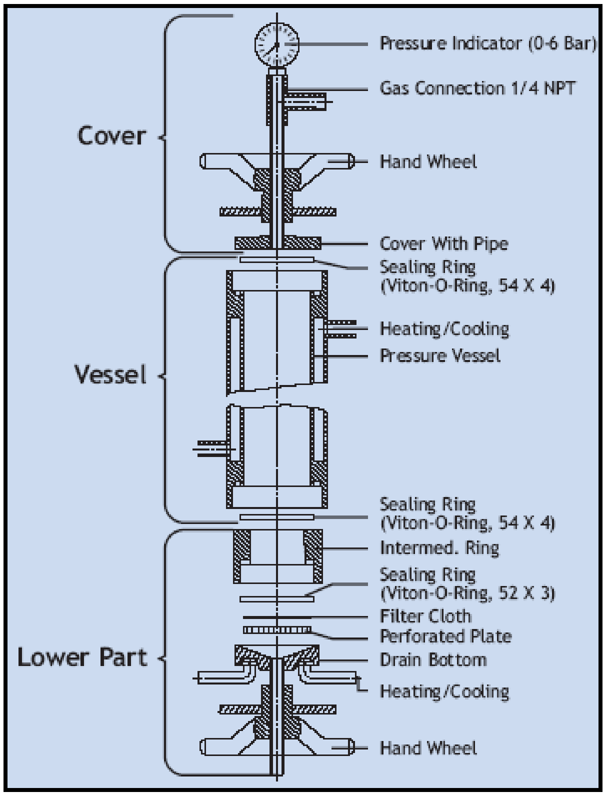


Figure 1: BHS Pocket Leaf Filter (PLF)

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	
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 for BHS Pocket Leaf Filter (PLF)

1. Test Purposes

The purposes of these tests were to:

1.1 Determine required filter area for the primary filtration.
1.2 Evaluate filtrate quality of both primary and secondary filtration.
1.3 Determine filter aid requirement for secondary filtration.
1.4 Evaluate washing efficiency and minimize amine loss in filter cake.

2. Test Methods

The BHS-Filtration Pocket Leaf Filter, jacketed with a 400 ml capacity and with 20 cm^2 filter area, was used to gather data and make observations on this product.

The following information was gathered during this test:

Primary Filtration Test Methods:

2.1 Variable speed peristaltic pump was used to conduct primary filtration tests.
2.2 Filtration Rate vs. Differential Pressure
2.3 Filtrate Quality vs. Filter Media

Secondary Filtration Test Methods:

2.4 Filtration pressure for secondary filtration tests was provided by compressed air.
2.5 Filtration Rate vs. Filter-Aid Concentration
2.6 Filtrate Quality vs. Filter-Aid Concentration
2.7 Filtration Rate vs. Filter Media
2.8 Filtrate Quality vs. Filter Media
2.9 Filter Cake Residual Amine (Filtrate Conductivity) vs. Volume Wash Water
2.10 Filter Cake Residual Moisture vs. Drying Air Usage

Figure 3: Typical Testing Program

Vacuum Belt Filter → Cake Discharge

$$\begin{array}{ccc} \text{Vacuum Belt Filter} & \longrightarrow & \text{Cake Discharge} \\ \downarrow & & \downarrow \\ \text{Mother Liquor} & & \text{Cloth Wash} \\ \downarrow & & \downarrow \\ \text{Concentrating Candle Filters} & & \text{Concentrating Candle Filters} \end{array}$$

Figure 4: Continuous Vacuum Filtration Followed by Candle Filtration

$$\begin{array}{ccc} \text{Concentrating Candle Filters} & \longrightarrow & \text{Vacuum Belt Filter} \\ & & \downarrow \\ & & \text{Cake Discharge} \end{array}$$

Figure 5: Concentrating Candle Filters Followed by Continuous Vacuum Filtration

$$\begin{array}{ccc} \text{Concentrating Candle Filters} & \longrightarrow & \text{Pressure Plate Filter} \\ & & \downarrow \\ & & \text{Cake Discharge} \end{array}$$

Figure 6: Concentrating Candle Filters Followed by Pressure Plate Batch Filtration

Vacuum Belt Filter (Drying without pressing) → Cake Discharge

Vacuum Belt Filter (Drying with pressing) → Cake Discharge

Contained Filter Press (Drying with blowing and vacuum)

↓

Cake Discharge

**Figure 7: Continuous Vacuum Filtration (Two Variations)
Followed by Contained filter Press**

Continuous Rotary Pressure Filter → Cake Discharge

↓

Mother Liquor → Dry Cake Candle Filters

↓

Concentrating Candle Filters

Figure 8: Continuous Rotary Pressure Filtration Followed by Candle Filtration

Vacuum Belt Filter → Cake Discharge → Reslurry Washing

Vacuum Belt Filter (Drying with blowing and pressing) → Cake Discharge

Figure 9: Continuous Vacuum Filtration (Two Variations)

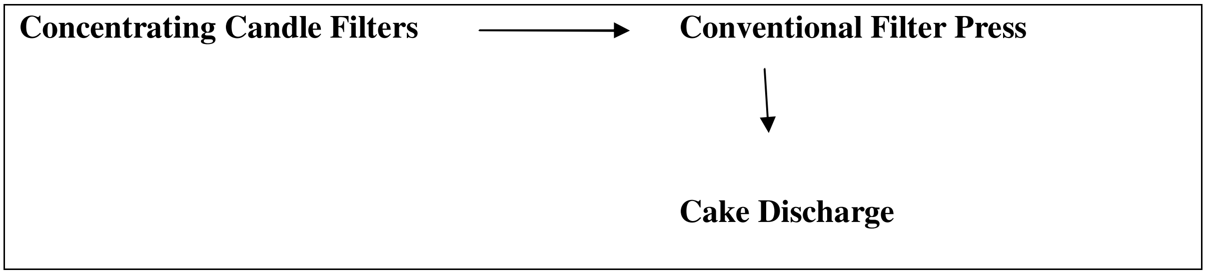


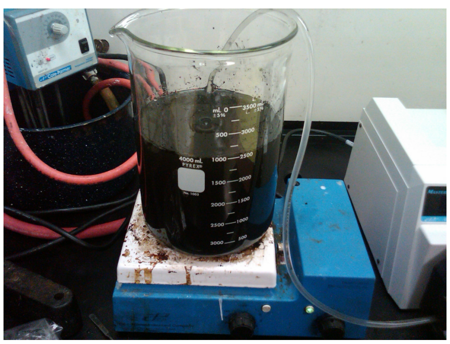
Figure 10: Concentrating Candle Filters Followed by Conventional Filter Press Batch Filtration

APPENDIX A:
DATA FOR CONCENTRATING CANDLE FILTERS FOLLOWED BY CONVENTIONAL FILTER PRESS BATCH FILTRATION

Result: Reduction of Treated Flow Rate to 300 gallons/3-hour-cycle at 10% solids from 800 gpm at 200 ppm solids

Pocket Leaf Filtration (PLF) tests were conducted to determine the filter flux for a fines clarification application. The filter flux of 0.50 – 0.60 gpm/ft^2 of filter area gives cycle times of approximately 4 hours. A filter cycle is defined by the time it takes to build a differential pressure of 25 psi across the filter membrane. For a capacity of 800 gpm, the required filter area is approximately 1,455 ft^2 (135 m^2).

Fines Slurry at 200 PPM

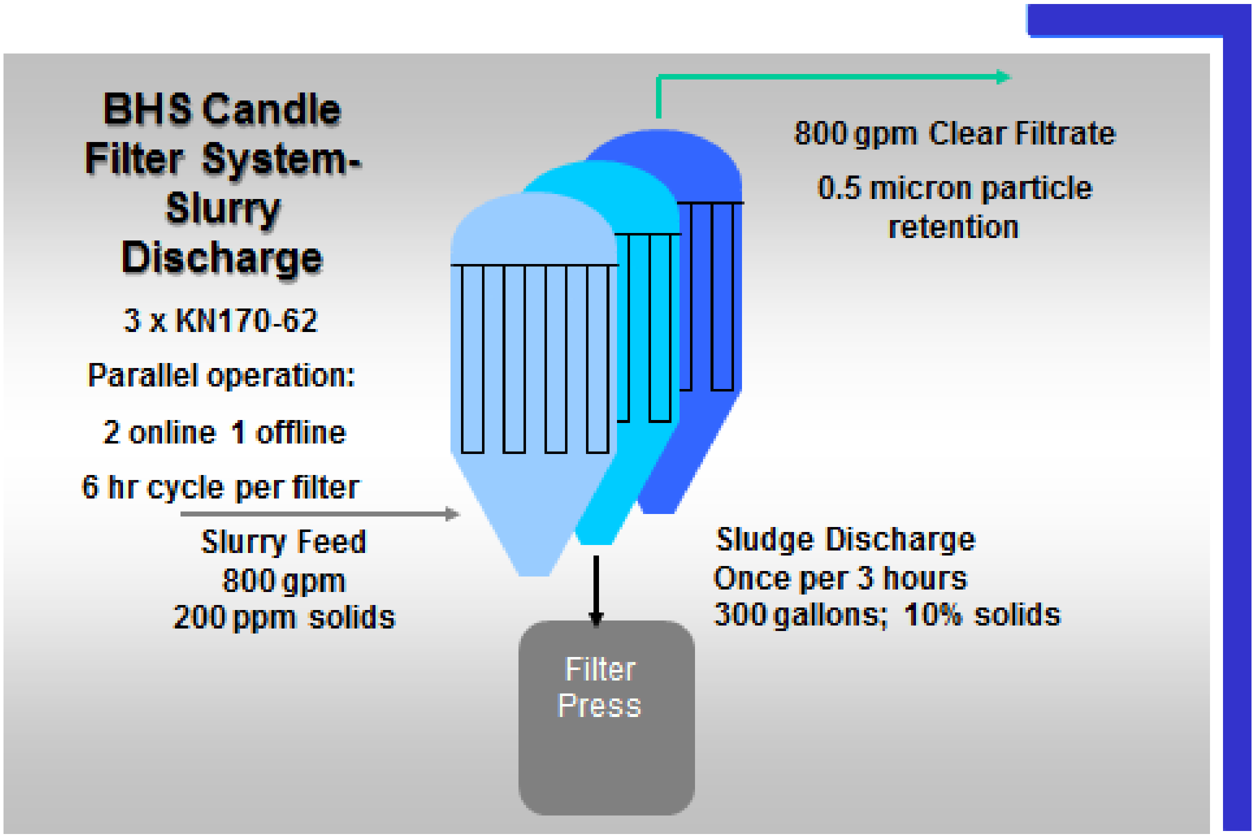


BHS Pocket Leaf Filter

Clarified Water (0.5 um)

RECOMMENDATIONS

For continuous operations, redundancy is recommended for maintenance purposes. This also allows for higher solids capacity in upset conditions. For this flow rate, the most cost efficient design would be three (3) BHS candle filters-concentrated slurry discharge each sized for 50% capacity with 62 m^2 of filter area per filter.


BHS Candle
Filter System-
Slurry
Discharge
3 x KN170-62
Parallel operation:
2 online 1 offline
6 hr cycle per filter
Slurry Feed
800 gpm
200 ppm solids
800 gpm Clear Filtrate
0.5 micron particle
retention
Sludge Discharge
Once per 3 hours
300 gallons; 10% solids
Filter
Press

BHS Thin-Cake Pressure and Vacuum Filtration Technologies
For Batch/Continuous Operations
From High Solids to Clarification Applications

BHS-Sonthofen GmbH, founded in 1563, is a leader in technology and innovation. BHS specializes in thin-cake (3 mm - 180 mm) filtration, cake washing and drying technologies.

BHS serves three major market segments as follows:

- Chemical: Fine, Specialty, Agricultural
- Pharmaceutical: Bulk and Final Products
- Energy / Environmental: Refinery, Power Plants, Wastewater, Mining

BHS-Filtration Inc.

BHS is organized both locally and globally. BHS-Filtration Inc., a subsidiary of BHS-Sonthofen GmbH is responsible for North America and Mexico.

Product Technologies & Capabilities

The BHS technologies and expertise are thin-cake (3 mm – 180 mm) filtration, cake washing and drying. The five-patented BHS technologies are as follows:

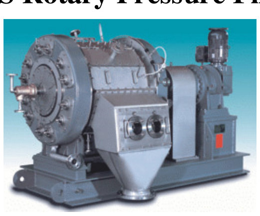
- Rotary Pressure Filter
- Vacuum Belt Filter
- Candle Filter
- Pressure Plate Filters
- Autopress, an Automated/Contained Specialized Filter Press

These technologies are installed for pressure or vacuum filtration, for batch or continuous operations from high solids slurries (up to 60% solids) to clarification applications with solids to less than 1% and trace amounts.

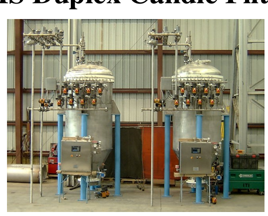
Process Lab Testing & On-Site Pilot Testing

BHS conducts preliminary tests in our worldwide laboratories or at your facility. On-site tests with pilot rental units continue the process. Finally, BHS completes the project with a complete technical solution and performance guarantees. Contact us today.

BHS Rotary Pressure Filter



BHS Duplex Candle Filter



BHS Vacuum Belt Filter