CONTINUUM APPROACH
TO OPTIMIZING DOWNSTREAM FINAL DRYING WITH UPSTREAM SOLID-LIQUID FILTRATION, CAKE WASHING & DEWATERING

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ABSTRACT

This article will review the optimization of the selection of the final drying technology in conjunction with the upstream continuous solid-liquid filtration, cake washing, and dewatering technology selection. Most often when analyzing a new process development approach, engineers take a "silo" approach and look at each step independently. This article illustrates that by taking a holistic approach and looking at each step not individually but as a continuum, the process solution becomes much more efficient.

In the manufacturing of this specialty chemical, the crystals coming from the reactor in a methanol slurry must be filtered, washed and dewatered and then dried to a final moisture of less than 1.0 (<1.0 %). The standard approach would be to first look at the solid-liquid filtration step and optimize this step for the maximum washing and drying efficiency and then with this information optimize the downstream drying. The operating company, however, took a different approach and looked at the process as a continuum from solid-liquid filtration through cake washing and dewatering to final drying. The Continuum Approach" resulted in operational energy and nitrogen savings as well as lower capital and installation costs for a more efficient and reliable process.

INTRODUCTION

The operating company had several objectives in mind for this process:

- Maximum solid-liquid filtration performance
- Low wash ratios for minimum wash media consumption
- Lowest possible residual moisture in discharged filter cake
- Final moisture of <1.0%

The BHS technologies of continuous solid-liquid filtration as well as with the AVA drying technologies[1] are in the unique position to meet the above objectives.

The paper begins with a discussion of the BHS technology and testing of the Rotary Pressure Filter. It continues with a discussion of the AVA drying testing and technology. The optimization testing is then described. Finally, the results are presented illustrating an optimum process design.

BHS ROTARY PRESSURE FILTER (RPF)

The rotary pressure filter, shown in Figure 1, is a continuous pressure filter designed for thin cake to deep cake filtration with cake depths from 6 mm to 150 mm. The slowly rotating drum (6 – 60 rph), in Figure 2, is divided into segments (called cells) each with their own filter media (synthetic cloth or single or multilayer metal) and outlet for filtrate or gas. The outlets are manifolded internally to a service/control head where each stream can be directed to a specific plant piping scheme or collection tank. In this way, the mother liquor can be kept separate from the subsequent washing filtrates and drying gases. This allows for better process control as well as reuse and recovery of solvents and the gases. The service/control head, for this application, is pressure rated so the liquefied gas can be kept under pressure, acting as a liquid.

Figure 3 shows a typical operation as follows. The feed suspension enters each cell, under constant pressure, to form a filter cake. Internal divisions of the housing allow the cake to be processed in completely separate zones. Each zone can operate under different pressures depending upon the compressibility of the cake at each stage of filtration, washing and drying.

For example, pressure filtration is conducted up to a maximum differential pressure of 6 bar. Pressure filtration has the added benefit of eliminating post-precipitation of the solids if the process solvent is prone to flashing under vacuum filtration. In this case, the 6 bar pressure differential allows for a back-pressure of 2-bar or more, such that filtration can be at 4 bar and the gas can be a liquid.

A second benefit of the slow-rotating pressure filtration is the reproducible cake depth and the ability to control the residence time (by the speed of the drum). The slow rotation also results in much lower maintenance and energy costs.

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[1] *BHS acquired AVA GmbH in 2018. The AVA product range includes continuous and batch horizontal and vertical mixers and dryers. The combined BHS and AVA systems provide for turnkey projects for our clients as well as individual solutions; this article illustrates the marketplace benefits.*

Positive displacement washing or counter-current washing follows filtration. The design of the pressure cells, such that they have no free-space and are completely filled, eliminates the possibility of cake cracking or bypass, providing maximum washing efficiency. Multiple washing steps can be accomplished along with solvent exchanges, steaming and extraction.
The cake then undergoes a drying step by blowing ambient temperature or hot gas through the cake. The control of this drying step is influenced by gas flow, pressure, temperature as well as the cake depth and residence time.

Finally, the pre-dried cake is continuously discharged. The cake chute is pressurized which allows the cake to be fed directly into the downstream dryer without the use of rotary locks. This is an important benefit to keep the entire system pressurized. The cake discharge is assisted by a gas pulse.

After cake discharge, there is a cloth rinse step. This is controllable depending upon the product discharge, filter media and potential of cloth blinding. With the drum rotating, after the cloth rinse step, the cells are ready to be filled for filtration. A typical process flow is shown graphically in Figure 3.

ON-SITE PROCESS TESTWORK: POCKET LEAF FILTER (PLF) TESTWORK

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 is used as shown in Figure 4. For the continuous pilot testing, a pilot RPF with 0.18 m^2 of filter area is installed, as shown in Figure 5.

The objectives of the PLF testing are as follows:

- Filtration time vs. cake thickness
- Filtrate quality vs. filter media
- Cake solids wash time and quality
- Cake solids drying time and final moisture

CONCLUSION FROM THE LAB & PILOT TESTING AND SCALE-UP

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

The pilot tests confirmed the lab testing such that with a 14 micron cloth and a cake thickness of 25 mm, filtration times and filtrate quality were achieved. The wash ratios were very efficient, ranging from 0.7 to 1.2 kg Methanol/kg dry solids.

The moisture content of the cake varied between 11 – 30% depending upon the amount of nitrogen for blowing of the cake for drying. Based upon the initial thinking, the sizing of the Rotary Pressure Filter for moisture of 11% resulted in a filtration area of 2.88 m2, the RPF model, A-12 and nitrogen solvent recovery package to reduce the nitrogen usage. This is the important point which led to the optimization testing of the AVA dryer.

AVA VERTICAL BATCH DRYERS

The AVA vertical batch dryer, Figure 6, is made up of a conical vessel with a dished head and short cylindrical bottom part. The dryer consists of a conical mixing helix a centrally arranged shaft. Large radii of the welds and round bars allow for good cleanability and very close tolerances to the vessel walls. The helix is mounted in the dished head which avoids product-contacted shaft seals and eliminates possible product contamination.

Depending on the application, feed and cleaning nozzles, measuring instruments and vapor filters are also located on the vessel head. After the drying process the product is discharged via a large opening in the vessel bottom. The conical shape ensures maximum discharge of the solids - an essential aspect in the handling of bulk material.

Many solids are sensitive to mechanical stress and heat. The conical helix distributes the mechanical stress and heating uniformly in the product resulting in no hot-spots. This means that the dryer can be operated efficiently with the highest possible energy input without causing harmful stress peaks. Due to the large heating surface of the vessel jacket and the heated helix, optimum heat transfer is achieved for even and quick heating.

After the process, the product is discharged via a cleanable ball valve or knife-gate valve. To prevent cross-contamination, for example, CIP cleaning nozzles ensure that the entire interior and/or the vapor dust filter housing are operated when the machine is closed. The vertical batch dryer is well suited for the processing of other, high quality products, such as catalyst materials and metal powders.

PROCESS DRYING TESTING IN THE AVA TEST CENTER

The wet cake from the BHS Rotary Pressure Filter was tested on a vertical batch dryer in the AVA test center, Figure 7. This is where the benefits of the "continuum" approach really shine. The AVA testing started with three initial moistures at 11.6%, 17.5% and 30%. The results are as follows:

Initial moisture	Max. product temp.	Vacuum (mbar)	Drying time	Final moisture	Dryer Size
17.5%	65°C	100 - 300	45 min	<1.0%	2.4 m3
11.6%	95°C	5-120	35 min	<1.0%	1.9 m3
30 %	65°C	100 - 300	63 min	<1.0%	3 m3

The conclusion from the testing shows a small increase in the drying time and dryer sizing from a cake moisture of 30% moisture as compared with 11.6%. The final powder is shown in Figure 8.

CONTINUUM APPROACH & SUMMARY

With the data from BHS and AVA, the overall sizing was reviewed. Initially, with a traditional approach, the client needed 2.88 m2 of filter area plus a nitrogen-solvent recovery package for a cake of 11% moisture with the downstream dryer of 1.9 m3.

However, with the "Continuum Approach", the filter sizing can be reduced to 1.44 m2 of filter area with much less nitrogen consumption to produce a wet cake of 30% moisture. The downstream dryer increases to 3.0 m3 with only an increase in drying time to about 60 minutes which is within the client's batch time.

In summary, the "Continuum Approach" resulted in savings of energy and nitrogen plus capital savings of a smaller filter area and a small increase in the dryer capacity.

As operating companies develop new and unique chemical processes, there are many choices for filtration, cake washing, dewatering and drying. Engineers must evaluate all outcomes to make an informed and successful decision. Technical evaluation and, as shown, laboratory and pilot testing are critical for a successful decision and project. The take-away is that close collaboration between the operating company and the vendor will allow for creative problem-solving and process solutions to achieve the desired quality and production requirements.

Figure 1: BHS Rotary Pressure Filter (RPF)

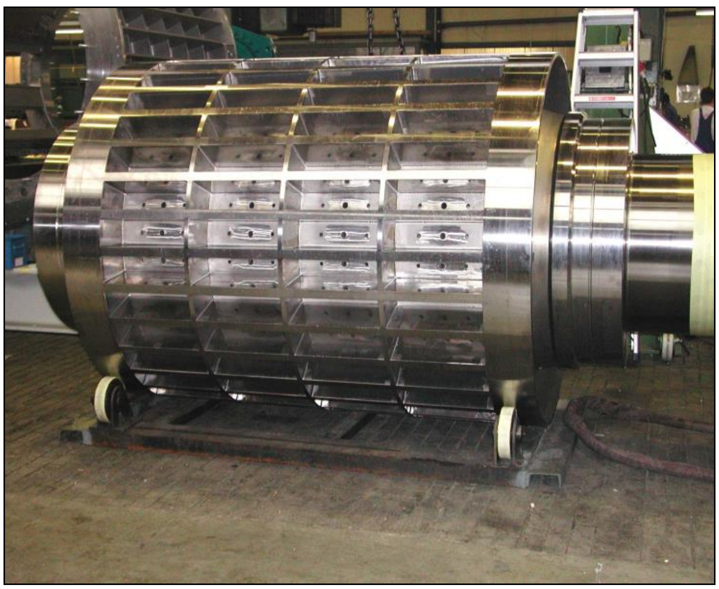

FIGURE 2: Rotary Pressure Filter Drum and Cells

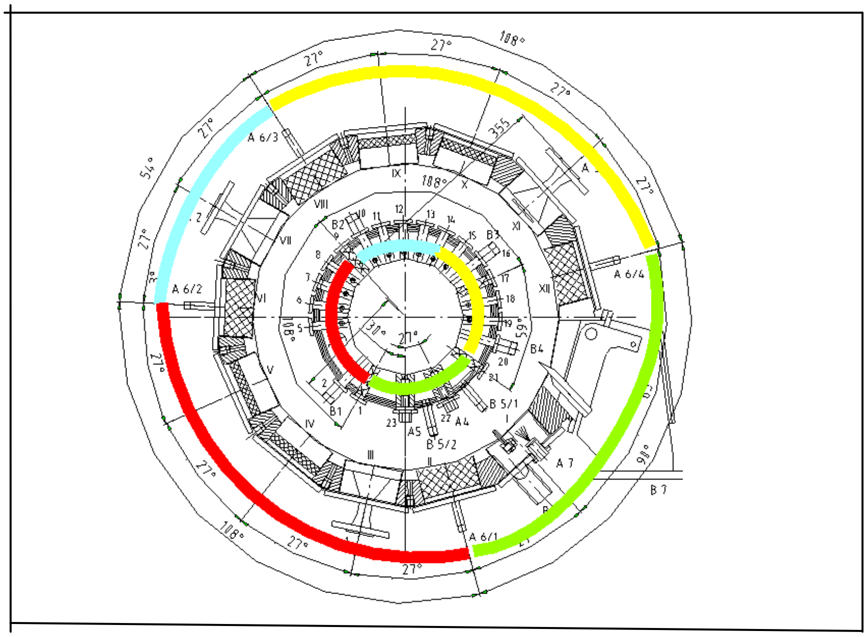

Figure 3: Rotary Pressure Filter Process Flow

FILTRATION (RED)
CAKE WASHING (BLUE)
DRYING (YELLOW)
CAKE DISCHARGE & CLOTH RINSE (GREEN)

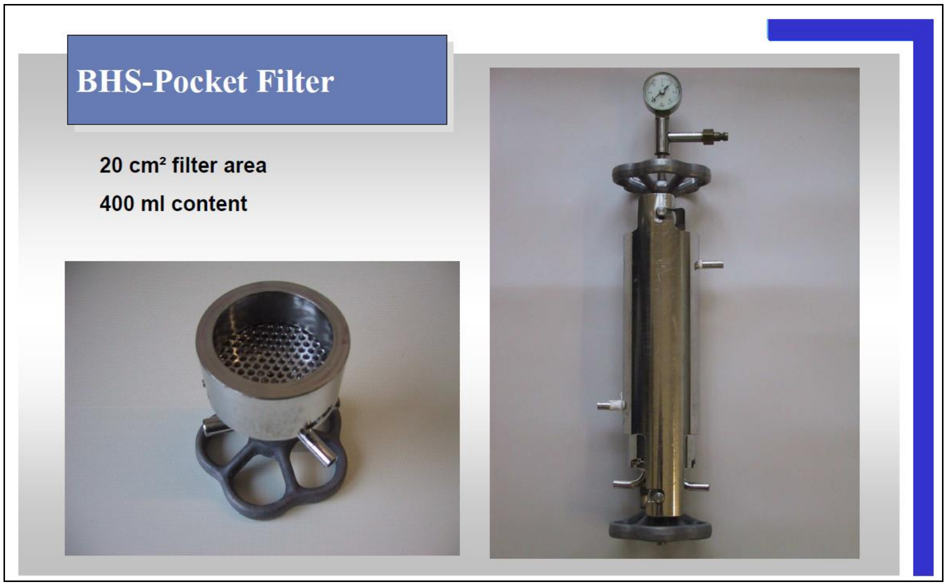

Figure 4: BHS Pocket Leaf Filter (PLF)

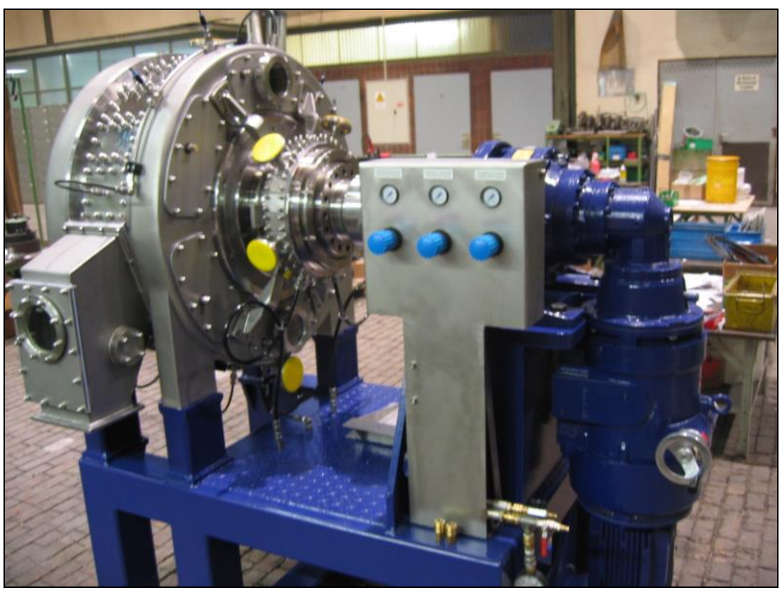

Figure 5: Rotary Pressure Filter Pilot Unit, 0.18 m2

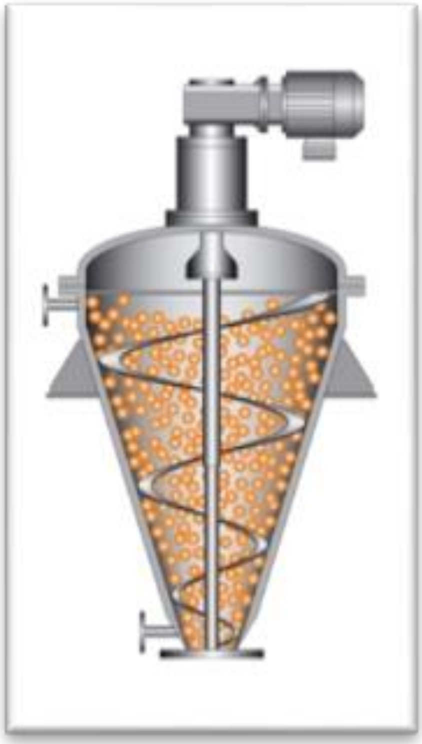

Figure 6: AVA Vertical Helix Dryer

Figure 7: AVA Vertical Helix Dryer in test center

Figure 8: Final Powder from AVA Vertical Helix Dryer

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BHS-Sonthofen Inc. and AVA-GmbH are wholly-owned subsidiaries of BHS-Sonthofen GmbH and part of the BHS group of companies. The BHS filtration technologies provide for thin-cake (3 mm - 25 mm) filtration, cake washing and dewatering based upon pressure or vacuum, for batch or continuous operations from high solids slurries (up to 50% solids) to clarification applications with solids to 1% and less (trace amounts). The AVA technologies provide for turbulent mixing, reacting and drying of wet cakes as well as powders and process slurries. The vertical and horizontal technologies are vacuum or atmospheric, batch and continuous, for final drying to "bone-dry" powders.

Filtration and drying tests are conducted on-site or in the BHS test labs in Charlotte, North Carolina or AVA test center in Herrsching (Munich), Germany. The BHS drying test center will be available in 3Q 2019. For further information, please visit our websites at www.bhs-filtration.com or https://www.ava-huep.com/en/.