A REVIEW OF THE ROTARY PRESSURE FILTER FOR THE FILTRATION OF A LIQUEFIED GAS SLURRY

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ABSTRACT

In the manufacturing of this specialty chemical, the pilot plant examined the process to determine the most effective method for filtration to develop a production process. A study was undertaken, by plant engineering and development, to examine the use of a rotary pressure filter to develop the overall process operations for product quality and production rates.

This paper reviews the basics of two alternatives: rotary pressure filter and pressurized drum filters. The technologies are reviewed for the filtration of a liquefied gas slurry.

The article continues with the discussion of the process testing in the laboratory and in the field to evaluate the Rotary Pressure Filter. The lab testing used a BHS pressurized pocket leaf filter with 20 cm^2 of filter area while the fieldwork was conducted on a Rotary Pressure Filter with a filter area of 0.18 m^2.

The paper discusses test procedures, data collection, filter media selection and other process parameters. Scale-up data includes process conditions and production rates.

The paper conclusion is two-fold: a review of the unique specifications of the rotary pressure filter required for the process to meet production rates, product quality and site environmental and safety concerns. Finally, the paper demonstrates the creative process solution that is developed with close collaboration between the operating company and the vendor.

Acknowledgements: The author would like to thank Brian Moore, BHS Application Sales Engineer and Bruce Glines, BHS Senior Process Engineer for their help and assistance with this article.

LIQUEFIED GAS SLURRY

A liquefied gas is a clean, colorless gas that is easy to liquefy and transport. It is gaseous at normal temperature and pressure, but changes to a liquid when subjected to modest pressure or cooling. This easy liquefaction makes it easy to transport and store. This and other properties of certain liquefied gases, including a high oxygen content, lack of sulfur or other noxious compounds, and ultra clean make these versatile and promising process solvents. The most important point is to keep these gases, under pressure, so they behave as a liquid during filtration, cake washing and drying. The plant engineers reviewed the Rotary Pressure Filter and the Pressurized Drum Filter as two possible alternative solutions.

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.

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.

PRESSURIZED DRUM FILTER (P-DF)

The other alternative to the RPF is the pressurized drum filter (P-DF) which is a rotating drum inside a pressure vessel. The unit consists of a filter drum, slurry trough, agitator, wash bars and a "pressure let-down rotary valve. The process begins by closing the pressure vessel manually with bolts and nuts, pressurizing the vessel with compressed gas, the rotary valve is also pressurized for sealing and the filter trough is filled via the suspension feed pipe and the agitator is started to keep the solids in suspension.

During the evaluation stage, the plant engineers reviewed the P-DF operation, as described above, and determined that the gas usage for the pressure vessel and rotary valve was very excessive. This is not required in the RPF.

Secondly, the RPF housing does not require the manual process of closing and sealing which saves man-hours and time as well as eliminates a possible leak path of the liquefied gas.

Finally, in the RPF, the solids fill the cell via a centrifugal feed pump which eliminates the need for a filter trough, agitator and feed pipe. It was for these points as well as the additional safety relief valves required, the back pressure to maintain the gas as a liquid and other points that the decision was to begin the test work for the RPF.

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. filter media
Filtration time vs. slurry feed mass
Filtration time vs. differential pressure
Filtrate quality vs. filter media
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 gas as a liquefied solvent. The plant engineers and BHS developed a confidential method to meet these challenges.

CONCLUSION AND PATH FORWARD STEPS FROM THE PLF TESTING

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 parameters were also achieved.

Additional pilot plant tests with the BHS continuous pilot unit, RPF 0.18, are 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.

DISCUSSION OF THE RPF 0.18 M^2 PILOT TESTWORK AND SCALE-UP

While the actual data is confidential, the plant engineers and BHS process engineers gathered the following parameters:

Process Parameters:

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

RPF Parameters:

- Drum Speed:
- Separating elements:
- 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

TYPICAL SCALE-UP CALCULATION - EXAMPLE ONLY

The scale-up is based on 224 g slurry with 1:1 composition = 112 g dry solids:

Drum revolutions:

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

270°: active angle
0.85: factor for separating elements

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:

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

Selected filter: BHS-Rotary Pressure Filter, type B16 with 5.4 m² is sufficient to operate 20,000 kg dry solids per hour.

DESCRIPTION AND SPECIFICATIONS OF THE RPF

The RPF design has several unique features for this application to ensure that the liquifeid gas remains as a liquid and secondly to ensure the safe operation of the unit.

- Direct-coupled drive for completely stable drum rotation, shown Figure 6.
- Closed and pressurized housing and bearing shields, shown in Figure 7.
- Secondary containment of the control head
- Pressurized control head
- Pressurized discharge housing

SUMMARY

As operating companies develop new and unique chemical processes, there are many choices for filtration, cake washing 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 filtration solutions to achieve the desired quality and production requirements.

Figure 1: RPF Filter

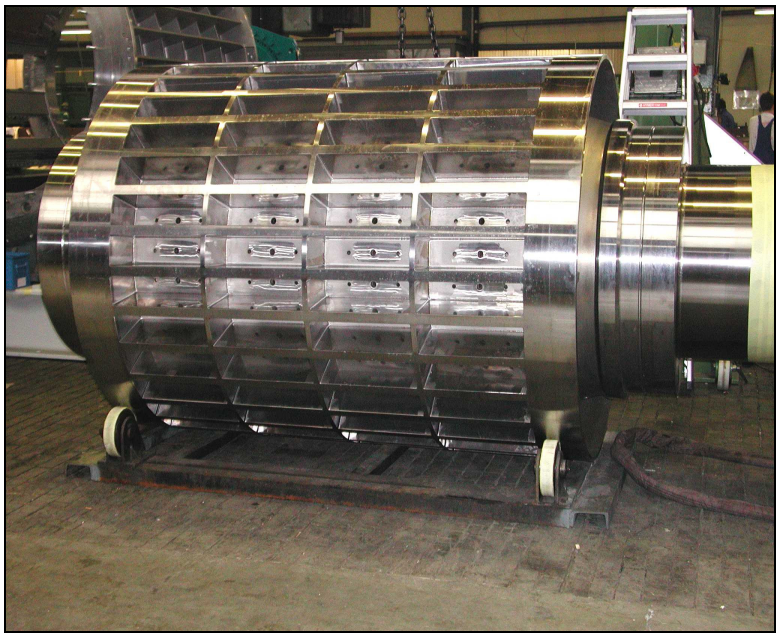


FIGURE 2: RPF DRUM AND CELLS

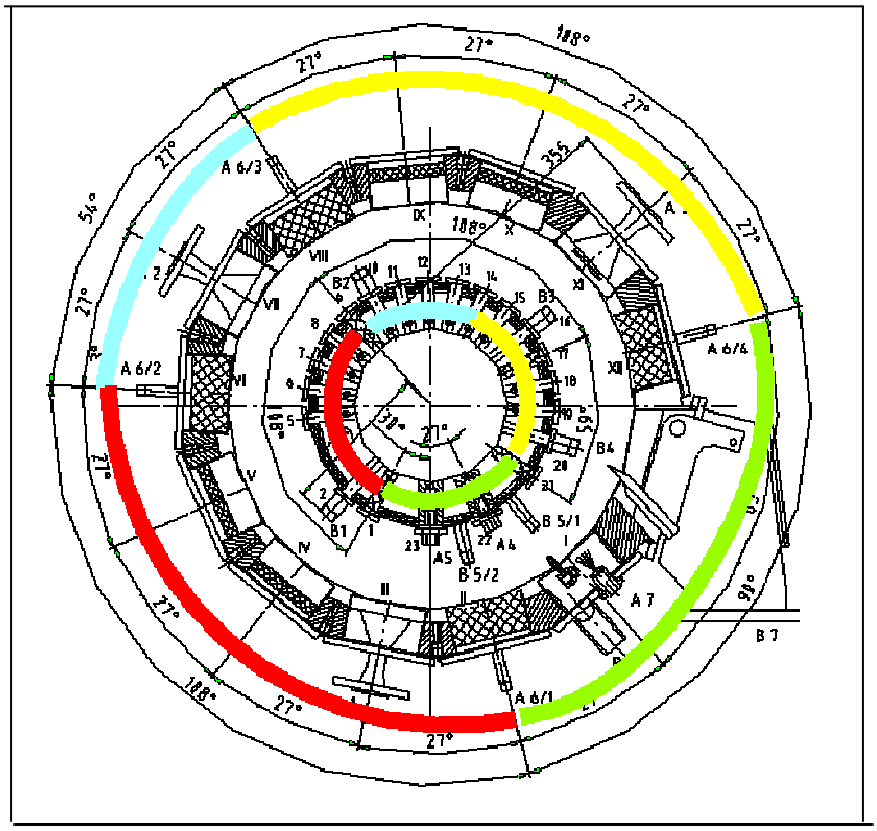


FIGURE 3: PROCESS FLOW

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

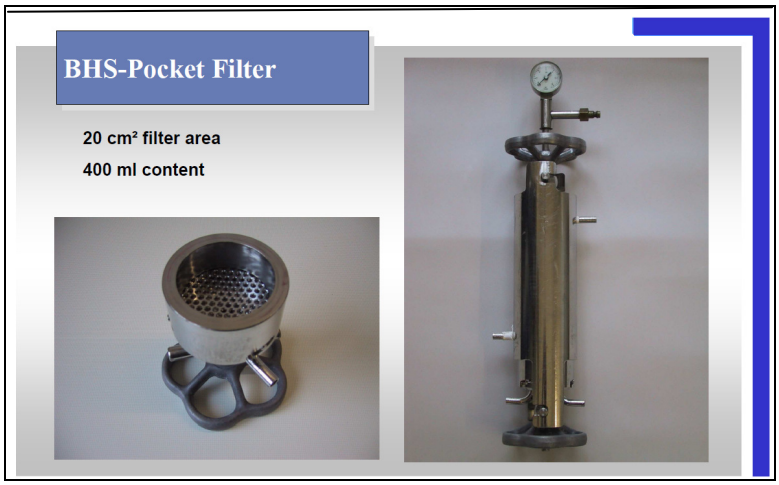


FIGURE 4: BHS POCKET LEAF FILTER (PLF)

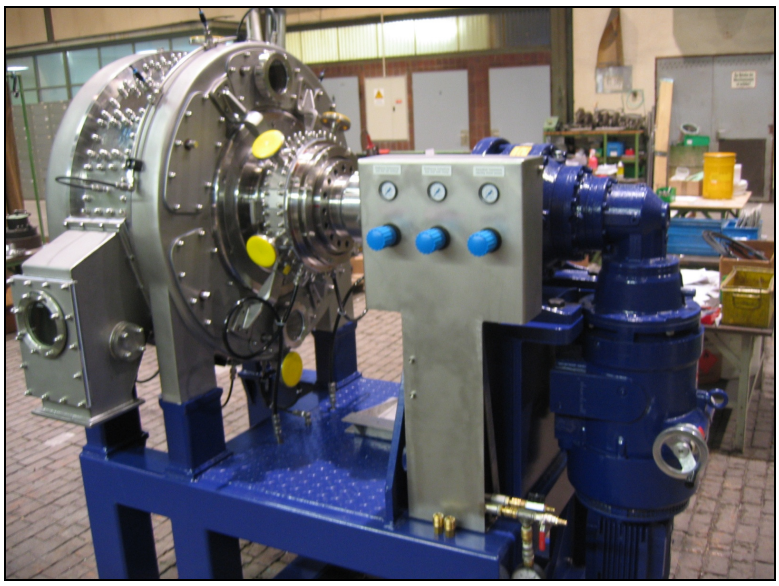


FIGURE 5: RPF 0.18 M^2 PILOT FILTER

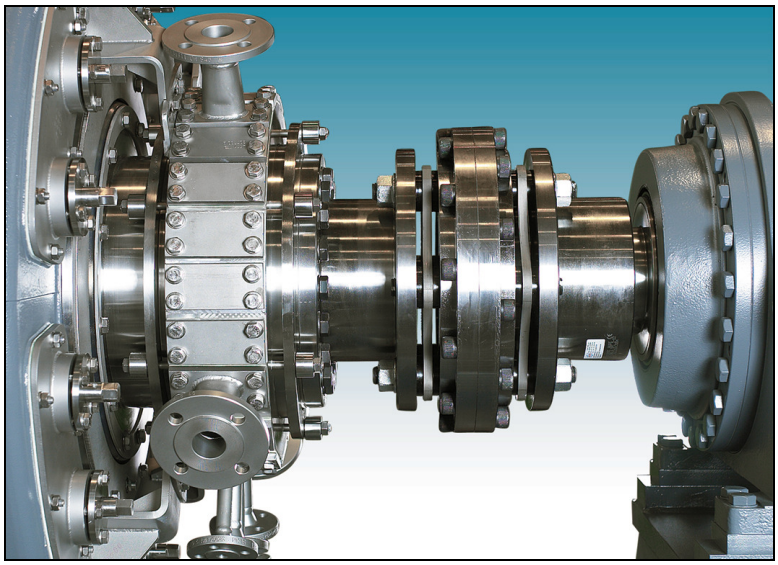


FIGURE 6: RPF DIRECT-COUPLED DRIVE

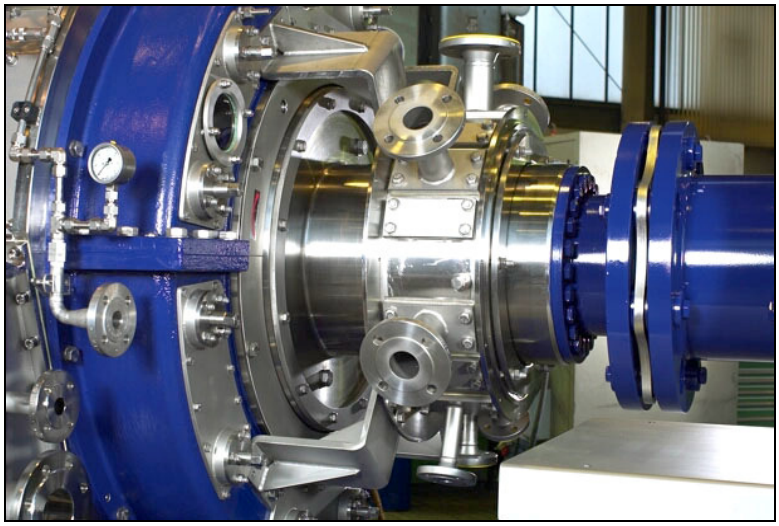


FIGURE 7: RPF PRESSURIZED HOUSING AND BEARING SHIELDS

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

BHS-Sonthofen GmbH, founded in 1607, is a leader in technology and innovation. Among other areas of mechanical process engineering, 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, and Others
- Pharmaceutical: Bulk and Final Products
- Energy / Environmental: Refinery, Power Plants, Bioenergy, and Wastewater

Specialized Applications & Centres of Excellence:
For specialized applications, BHS is organized globally with centres of excellence. These centres include, for example, aromatic acids, cellulose derivates, pharmaceuticals, dewatering of gypsum, refinery and bio-energy applications.

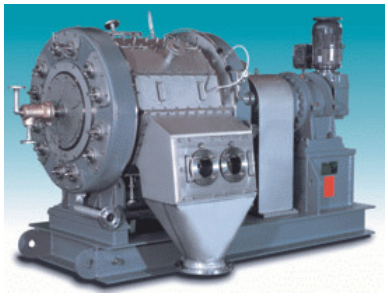
Product Technologies & Capabilities
The BHS technologies and expertise are thin-cake (3 mm – 180 mm) filtration, cake washing and drying. The five-patented BHS technologies are as follows:

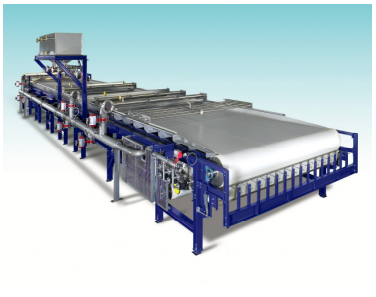
- Rotary Pressure Filter
- Vacuum Belt Filter: Continuous-Indexing & Rubber Belt
- Candle Filter
- Pressure Plate Filter
- Autopress, an Automated/Contained Specialized Filter Press

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 0.5%.

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. Contact us today.

BHS Rotary Pressure Filter



BHS Duplex Candle Filter

BHS Vacuum Belt Filter