Dilute Stream Solid-Liquid Separations
Using Continuous Vacuum Filtration Technologies

Barry A. Perlmutter,
President & Managing Director
BHS-Filtration Inc.
9123-115 Monroe Road
Charlotte, North Carolina 28270
Presentation Overview

• BHS Background
• Vacuum Filtration
• Algae Lab & Pilot Tests
• Scale-Up & Production Design
• Pressure Filtration for Non-Algae Biomass
• Conclusions
BHS History-Worldwide

1563  Founded as a iron mining company
1888  Production of construction machines
1932  Production of gear units
1953  Production of filtration machinery
BHS History-Worldwide

1998  BHS-Filtration Inc., Charlotte, NC
2001  BHS-Tianjin, China
2002  Implementation of SAP Worldwide
2005  Record Sales for BHS Worldwide
2007  BHS-India, (Hyderabad)
2010  Expansions and Technology Upgrades
BHS-Filtration Inc.

Thin-Cake Solid-Liquid Separation,
Cake Washing & Drying Technologies

• Filtration & Process Laboratories
• Pilot Rental Filters for On-site Testing
• Process & Project Engineering
• PLC Control Systems & Turnkey Skids
• Start-Up & Mechanical Parts & Services
BHS Technologies
Thin-Cake Solid-Liquid Separation,
Cake Washing & Drying Technologies

• Pressure & Vacuum Filtration
• Batch & Continuous Operation
• High Solids to Clarification
• Maximum Cake Washing Efficiency
• Cake Pre-Drying
• Automatic Cake Discharge for Wet, Dry or Slurry
BHS-Technologies

Thin-Cake Solid-Liquid Separation, Cake Washing & Drying Technologies

Candle Filter: Clarification
Pressure Plate Filter: Clarification
Vacuum Belt Filter: High Solids, Continuous
Rotary Pressure Filter: High Solids, Continuous
Autopress Filter: Full Containment, Pharma
SOLID-LIQUID SEPARATION
CONTINUOUS VACUUM SYSTEMS
Vacuum Filtration

- Vacuum is mechanically simple
- Vacuum filters are continuous
- Cake thickness can be controlled
- Wide range of materials of construction
- Given that the cake thickness is controllable, residual cake moistures can be consistent
BHS Vacuum Belt Filter

Belt movement by pneumatic cylinders only
Schematic Presentation

Think of a Buchner Funnel and Vacuum Flask

Step 1: Slurry Feed and Cake Building
Step 2: Cake Washing
Step 3: Vacuum Drying

Now, think of several flasks.

Now, combine these to a continuous process.
The result is the BHS Continuous Indexing Vacuum Belt Filter.
BHS Continuous-Indexing Vacuum Belt Filter
BF 35/21.5 with 73 m² of Area
Typical Laboratory Testing to Determine the Optimum Vacuum Filtration Technology
BHS Laboratory Tests

BHS-Pocket Filter

20 cm² filter area
400 ml content
## BHS Laboratory Tests Data Using BHS Pocket Filter

### UNITS Run # 17

<table>
<thead>
<tr>
<th>Filter Media:</th>
<th>PP 2930</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspension:</td>
<td></td>
</tr>
<tr>
<td>Initial Volume</td>
<td>ml 8000</td>
</tr>
</tbody>
</table>

### Filling
- Volume of Slurry: ml
- Density of Slurry: %
- % Solids in Feed: 

### Filtration
- Vacuum: in hg 18.0
- Gas Flow Rate: ml
- Temperature: %
- Volume of Filtrate: ml 25.0
- Time for Filtration: min 1:00
- % Solids in Filtrate: 

### Drying
- Vacuum: ml
- Gas Flow Rate: psig
- Temperature: %
- Volume of Filtrate: ml
- Time for Drying: min 2:00
- % Solids in Filtrate: 

### Cake
- Weight: g 9.5
- Thickness: mm 5
- % Solids: 23.6
- Discharge OK?: Yes
- Cake rests on filter cloth?: No
BHS Laboratory Tests Data-Run # 17

Sample Volume (raw slurry equivalent) 8000 ml
Test Filter Area 20 cm²
  Filtration Time 60 seconds
  Cake Thickness 5 mm
  Cake weight 9.5 grams
  Cake Solids % 23.6

Filter Flux Rate = Sample Volume / (Test Filter Area * Filtration Time)

Filter Flux Rate (Raw Slurry Basis)
  = (Feed Volume) / (Filter Area x √Filtration Time)
  = 8.0 liters/ (20 cm² * √60 sec) * 10000 cm² / 1 m²
  = 516 liters / (m² * √sec)
BHS Pilot Tests with Vacuum Belt Filter Model LBF (0.1 m²)
BHS Pilot Tests with Vacuum Belt Filter Model LBF (0.1 m²)

Pressing/Blowing

Feed
BHS Pilot Tests with Vacuum Belt Filter Model LBF (0.1 m²)

Filtration Area (FA) = 2 zones x .01 m² = .02 m²

Correction Factor (CF) = $\sqrt{60 \text{ sec}/(60 + 2 \times 4 \text{ sec})} = 0.114 \sqrt{\text{sec/sec}}$

Expected Pilot Filter, LBF, Performance with Polymers and Sedimentation

\[
= \text{FA} \times \text{FFR} \times \text{CF} \\
= 0.02 \text{ m}^2 \times 516 \text{ liters} / (\text{m}^2 \times \sqrt{\text{sec}}) \times 0.114 \sqrt{\text{sec/sec}} \\
= 1.18 \text{ liters/sec or 70.6 l/min on a raw algae feed basis} \\
\text{or 186 gpm/m}^2 \text{ flux rate}
\]
BHS Pilot Tests with Vacuum Belt Filter Model LBF (0.1 m²) Feeding Box
BHS Pilot Tests with LBF (0.1 m²): Drying with Pressing, Blowing and Vacuum
BHS Pilot Tests with LBF (0.1 m²) Cake Discharge
BHS Scale-Up for Continuous Vacuum Filtration
BHS Scale-Up for Continuous Vacuum Filtration

• The Raw Slurry Feed is 30 gpm with 6% solids
• Based upon the pilot test flux rate, which was much lower than the laboratory tests due to elimination of chemical and mechanical pre-treatment, the ratios of filtration areas and drying areas are calculated.
The result is a BHS vacuum belt filter with a total area of 24 m² and eight (8) zones.

Zone arrangement
- Feed: Oscillating feed device / no vacuum
- Filtration: 3 Zones
- Drying: 3 Zones
- Pressing/Blowing/Vacuum: 1 Zone
- Spare Vacuum Before Discharge: 1 Zone
Vacuum Filtration P & ID

BHS VACUUM BELT FILTER
Typical Algae Vacuum Filtration - Drying Process
SOLID / LIQUID SEPARATION
CONTINUOUS VACUUM SYSTEMS:
OTHER APPLICATIONS
Vacuum Filtration for Lignin, Cellulose and Biomass with Eleven (11) Wash Stages and 24 m² of Filter Area
SOLID / LIQUID SEPARATION
CONTINUOUS PRESSURE SYSTEMS:
OTHER APPLICATIONS
Production Objectives for Biomass/Cellulose Wood Chips

• Production capacity:
  20 tons of dry solids / 24 hours
• Slurry composition:
  2 – 12 % solids per weight
• Washing: Three step, counter current
• Washing media: DI water
• Residual moisture: 50% Solids
Pressure Filtration

Specific total filter performance flux rate:

\[ Q = 90 \frac{1}{h} \cdot \frac{6g}{20cm^2} = 270 \frac{kg}{m^2h} \]

Required filter area:

\[ A = \frac{835 \frac{kg}{h}}{267 \frac{kg}{m^2h}} = 3.1 \ m^2 \]
Pressure Filtration

The result is a BHS rotary pressure filter with filter area of 3.2 m²

<table>
<thead>
<tr>
<th>Process Step</th>
<th>Degrees of Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filtration</td>
<td>57</td>
</tr>
<tr>
<td>Washing 1</td>
<td>57</td>
</tr>
<tr>
<td>Washing 2</td>
<td>57</td>
</tr>
<tr>
<td>Washing 3</td>
<td>57</td>
</tr>
<tr>
<td>Blow Drying</td>
<td>57</td>
</tr>
<tr>
<td>Cake Discharge and Cloth Cleaning</td>
<td>75</td>
</tr>
</tbody>
</table>
BHS Rotary Pressure Filter
Typical Operation

- Slurry Inlet
- Housing
- Sealing Element
- Drum
- Drying Gas Inlet
- Wash Inlet
- Outlets & Vents
- Solids Discharge
- Cloth Rinse
- Slurry Inlet

(BHS FILTRATION)
BHS Rotary Pressure Filter
Model B-16 Center Drive
Summary

- Algae filtration and drying is very unpredictable from 1.25 gpm/m² to 186 gpm/m²
- In another algae process testing, the flux rate was 21 gpm/m²
- Differences in feedstock parameters, chemical additions, and mechanical pretreatment can result in different process solutions.
- Thin-Cake vacuum operations have provided acceptable process results in combination with sedimentation and chemical treatment.
Summary

- Ultimately, there is no substitute for accurate and professional test work under realistic conditions.
- Laboratory and pilot testing is required.
- Close cooperation between the client and filtration vendor is necessary as small process changes can have significant impacts to the filtration and drying results.