Dilute Stream Solid-Liquid Separations Using Continuous Vacuum Filtration Technologies

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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

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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**

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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

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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**

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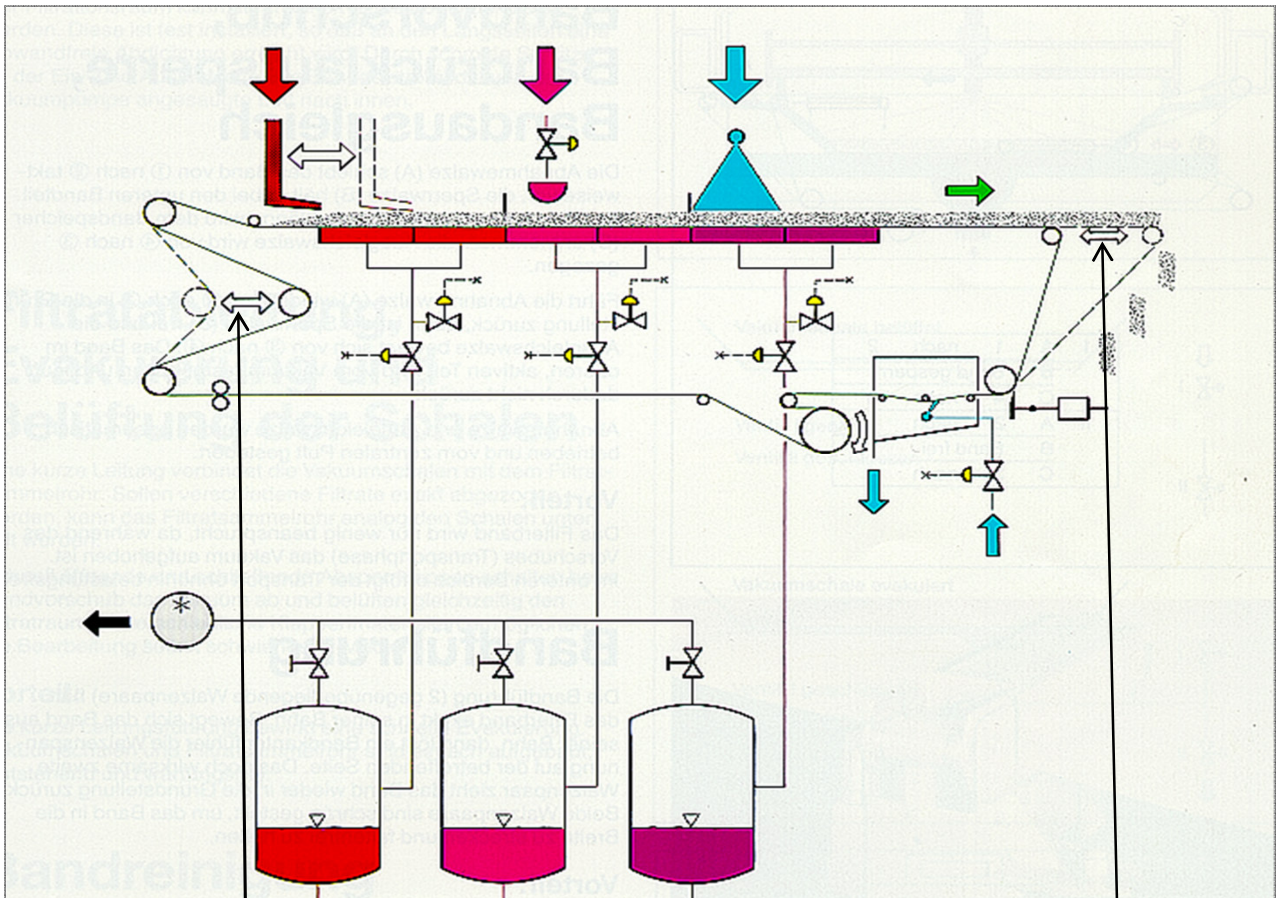
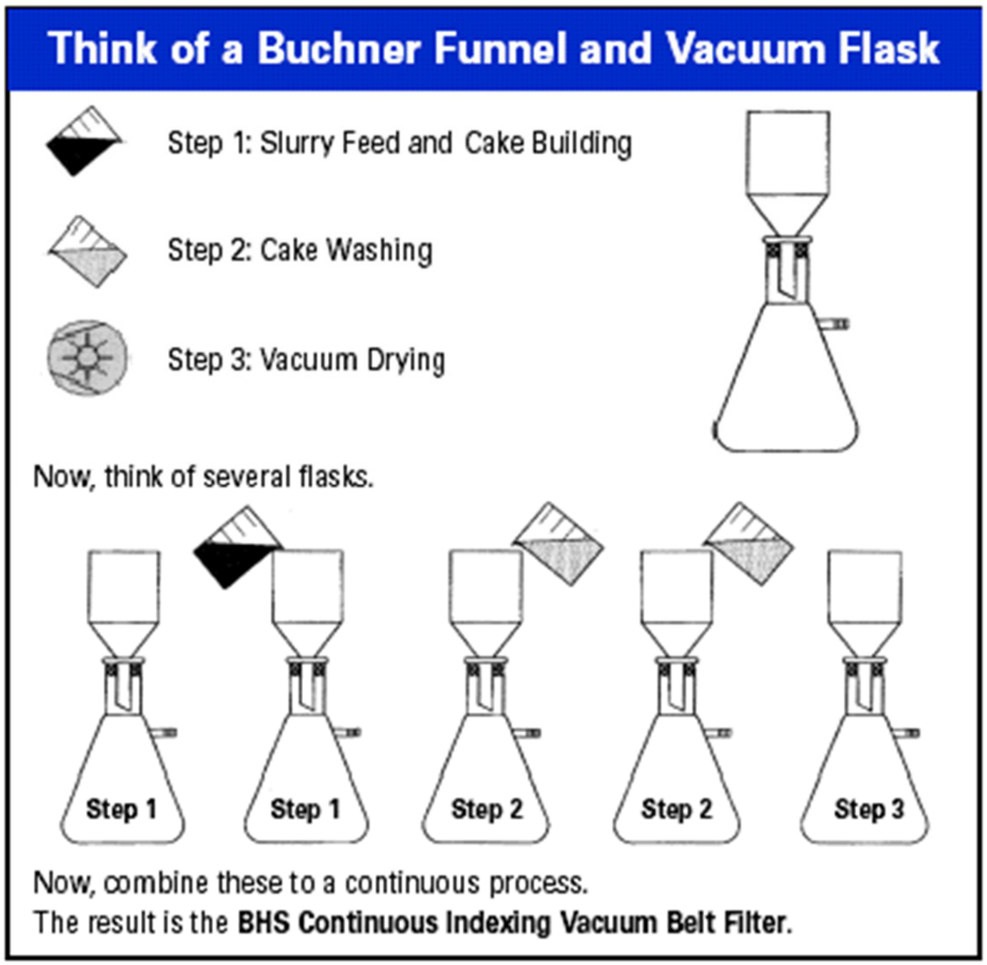
BHS Vacuum Belt Filter



Belt movement by pneumatic cylinders only

Schematic Presentation



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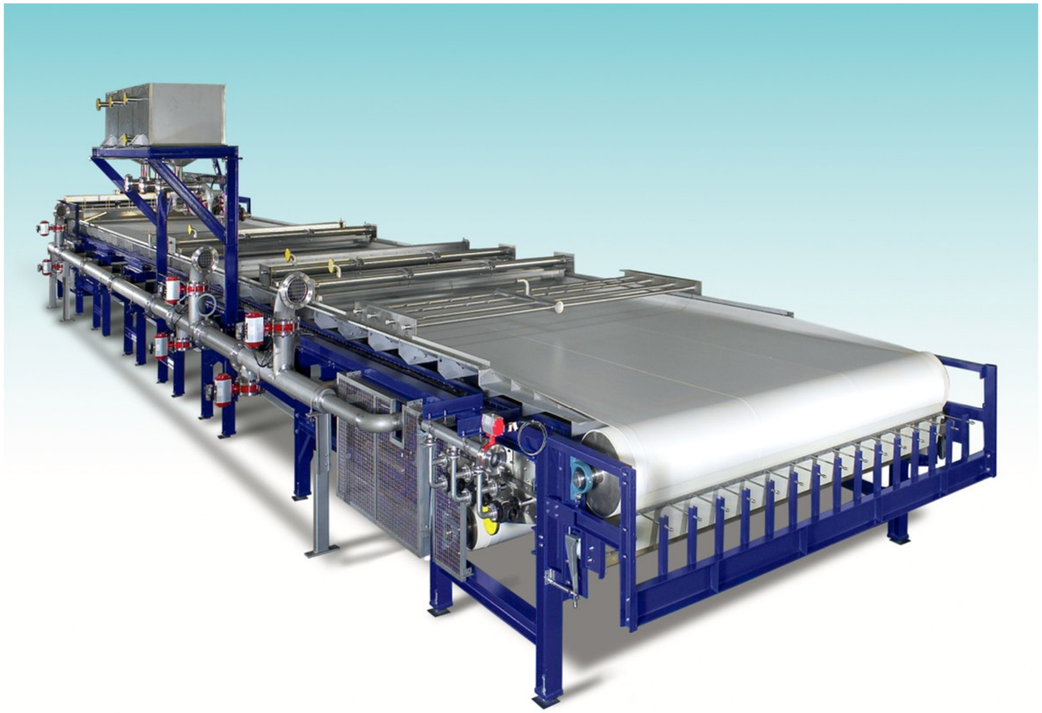
BHS Continuous-Indexing Vacuum Belt Filter BF 35/21.5 with 73 m^2 of Area



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Typical Laboratory Testing to Determine the Optimum Vacuum Filtration Technology

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BHS Laboratory Tests

BHS-Pocket Filter

20 cm² filter area

400 ml content

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BHS Laboratory Tests Data Using BHS Pocket Filter

		UNITS	Run # 17
	Filter Media :		PP 2930
	Suspension:		
	Initial Volume	ml	8000
Filling	Volume of Slurry	ml	
	Density of Slurry		
	% Solids in Feed		
Filtration	Vacuum	in hg	18.0
	Gas Flow Rate		
	Temperature		
	Volume of Filtrate	ml	25.0
	Time for Filtration	min	1:00
	% Solids in Filtrate		
Drying	Vacuum		
	Gas Flow Rate		
	Temperature		
	Volume of Filtrate		
	Time for Drying	min	2:00
	% Solids in Filtrate		
	Pressing Pressure	psig	
	Pressing Time	min.	
Cake	Weight	g	9.5
	Thickness	mm	5
	% Solids		23.6
	Discharge OK?		Yes
	Cake rests on filter cloth?		No

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BHS Laboratory Tests Data-Run # 17

Sample Volume (raw slurry equivalent)	8000 ml
Test Filter Area	20 cm^2
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 cm^2 * √60 sec) * 10000 cm^2 / 1 m^2

= 516 liters / (m^2 * √sec)

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

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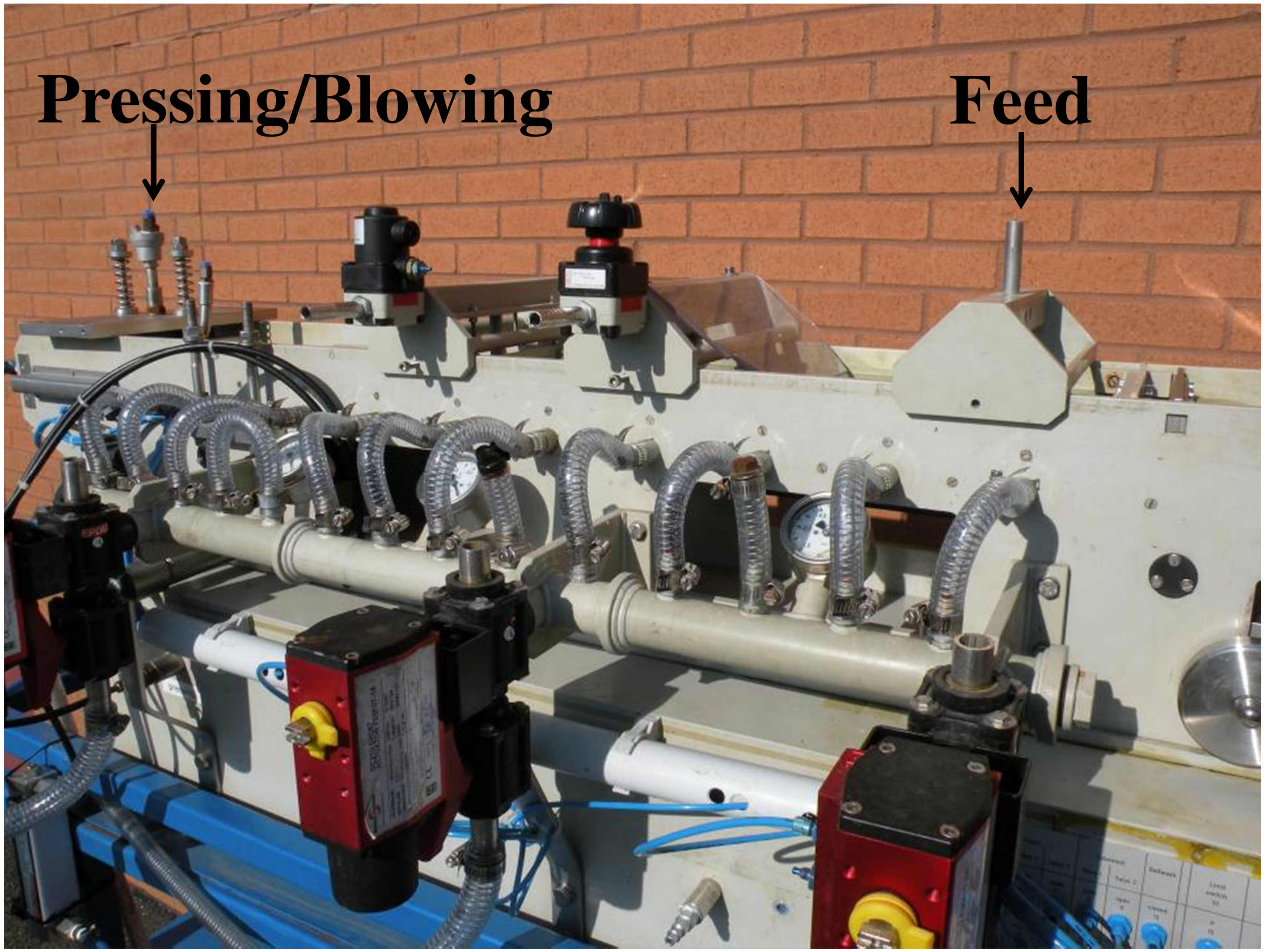
BHS Pilot Tests with Vacuum Belt Filter Model LBF (0.1 m²)



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BHS Pilot Tests with Vacuum Belt Filter Model LBF (0.1 m^2)

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

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

Expected Pilot Filter, LBF, Performance with Polymers and Sedimentation

= FA x FFR x CF

= 0.02 m^2 x 516 liters / (m^2 * $\sqrt{\text{sec}}$) x 0.114 $\sqrt{\text{sec}}$/sec

= 1.18 liters/sec or 70.6 l/min on a raw algae feed basis or 186 gpm/m^2 flux rate

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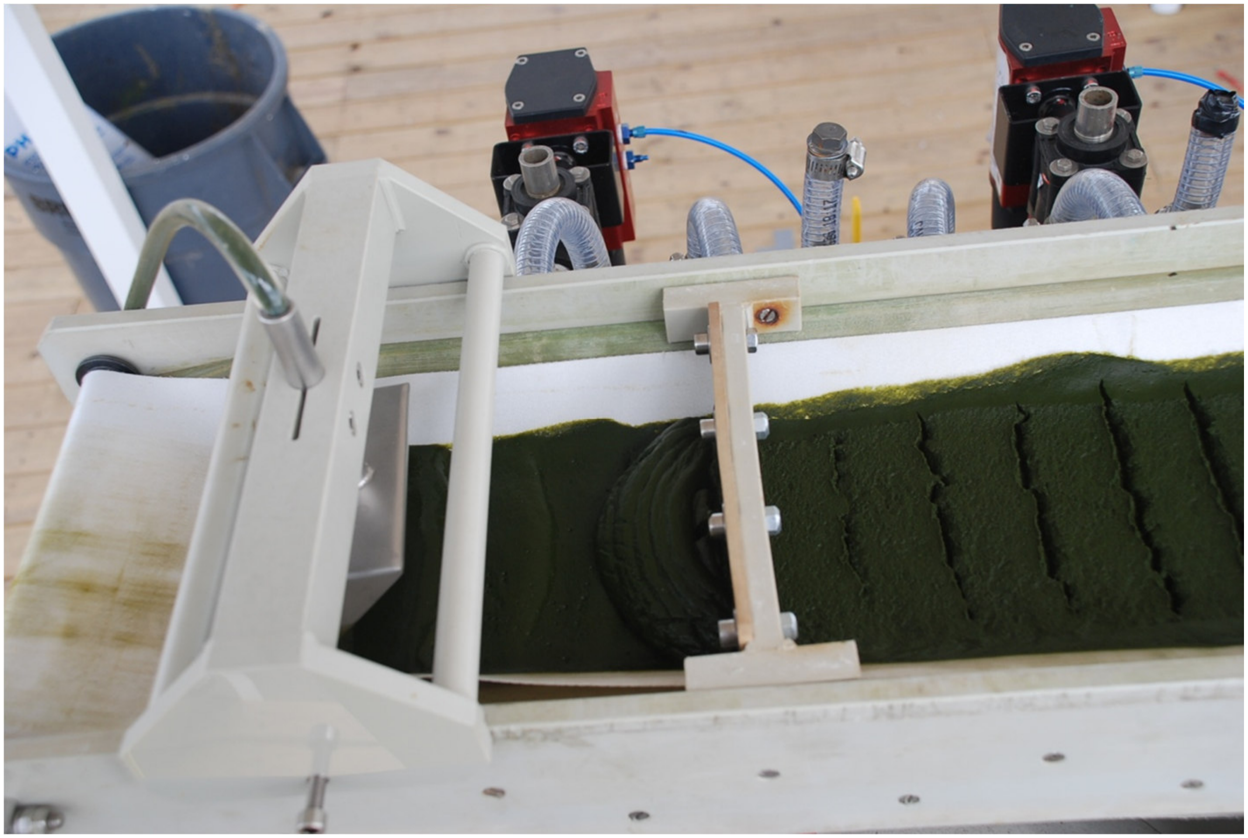
BHS Pilot Tests with Vacuum Belt Filter Model LBF (0.1 m²) Feeding Box



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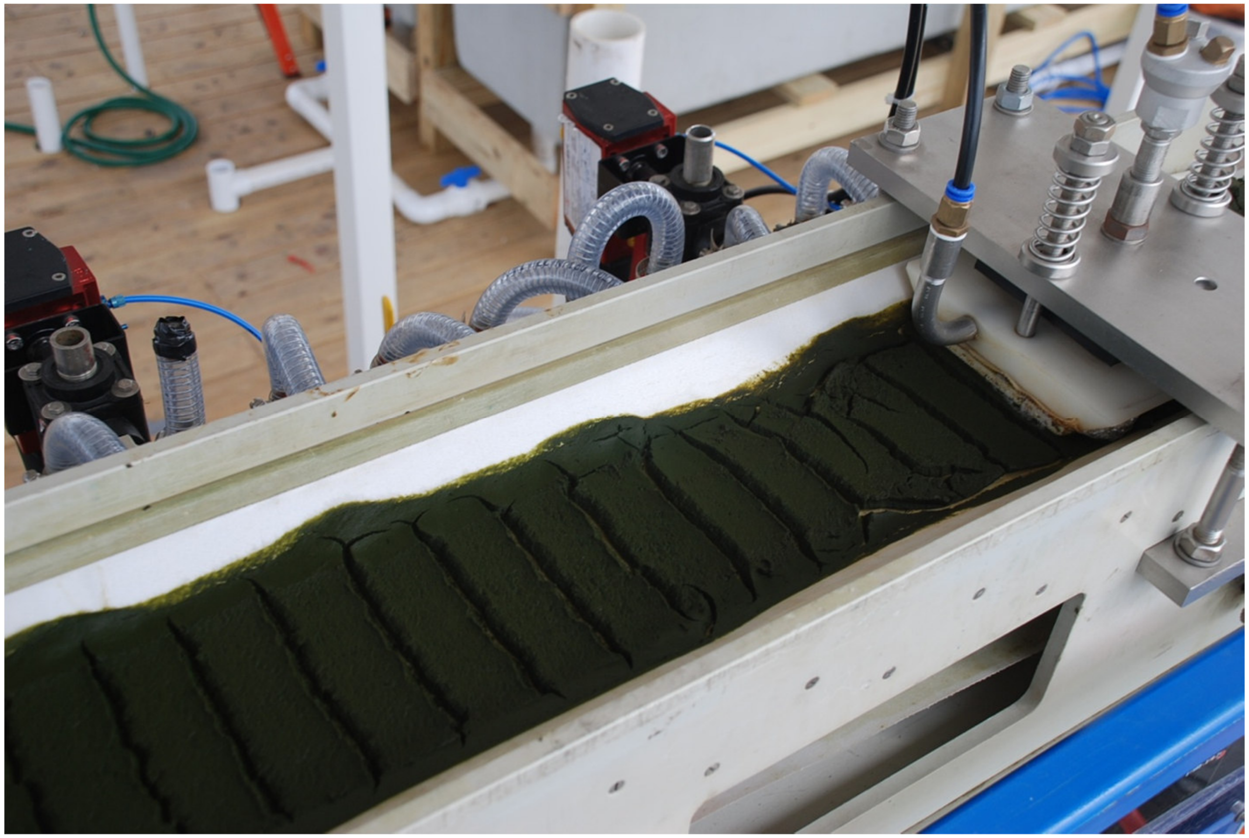
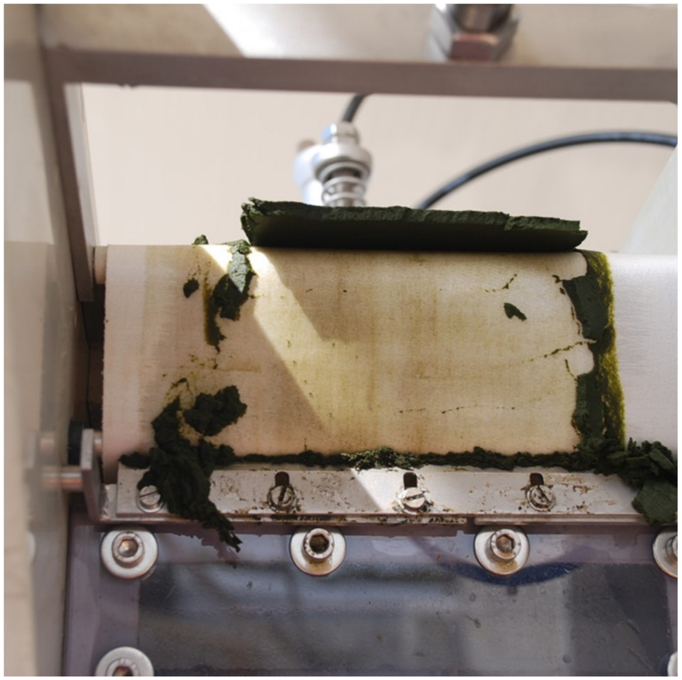
BHS Pilot Tests with LBF (0.1 m²): Drying with Pressing, Blowing and Vacuum



BHS Pilot Tests with LBF (0.1 m²) Cake Discharge



BHS Scale-Up for Continuous Vacuum Filtration

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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.**

BHS Scale-Up for Continuous Vacuum Filtration

- **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**

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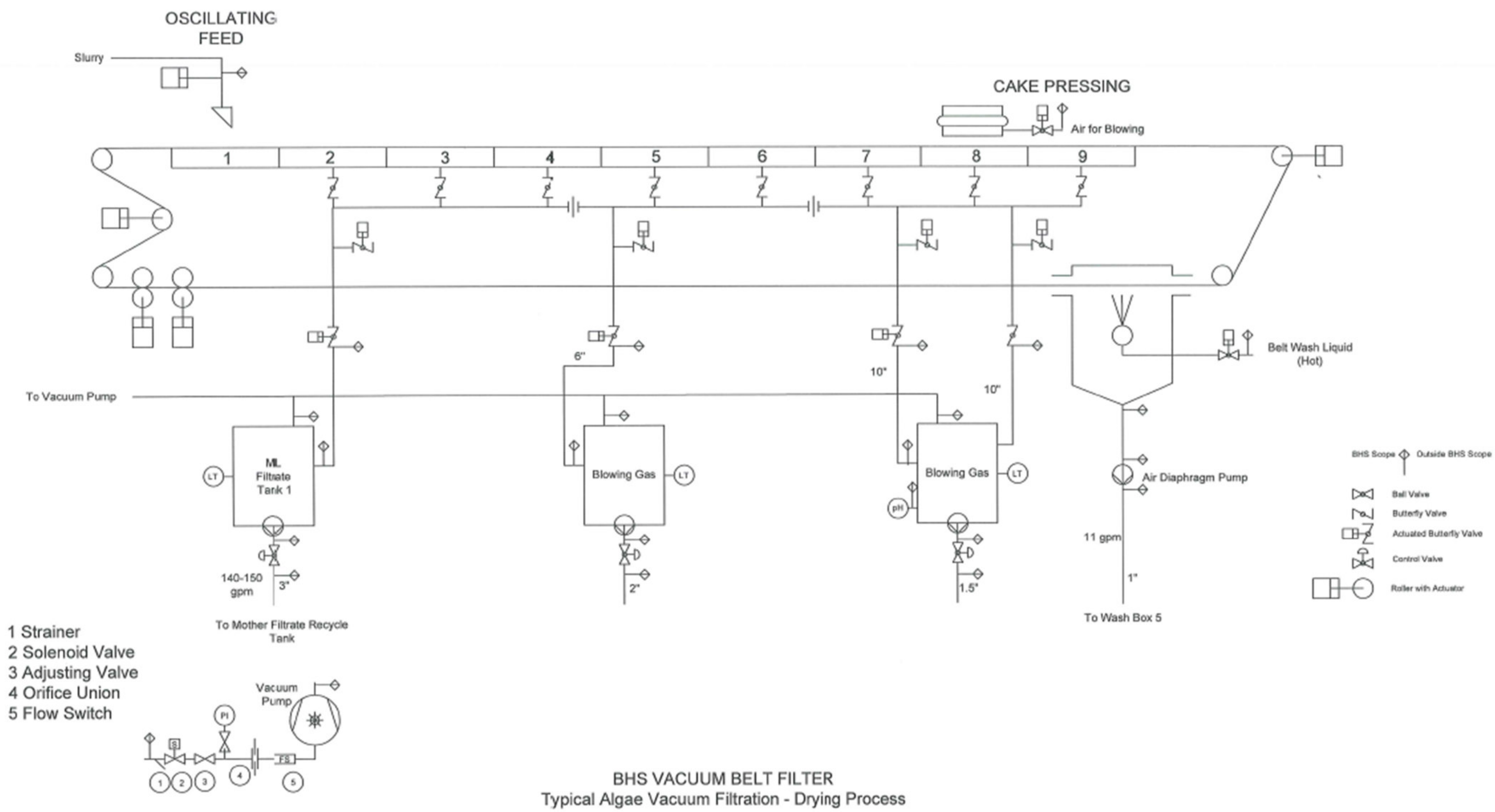
Vacuum Filtration P & ID



SOLID / LIQUID SEPARATION CONTINUOUS VACUUM SYSTEMS: OTHER APPLICATIONS

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Vacuum Filtration for Lignin, Cellulose and Biomass with Eleven (11) Wash Stages and 24 m^2 of Filter Area

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SOLID / LIQUID SEPARATION CONTINUOUS PRESSURE SYSTEMS: OTHER APPLICATIONS

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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

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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:

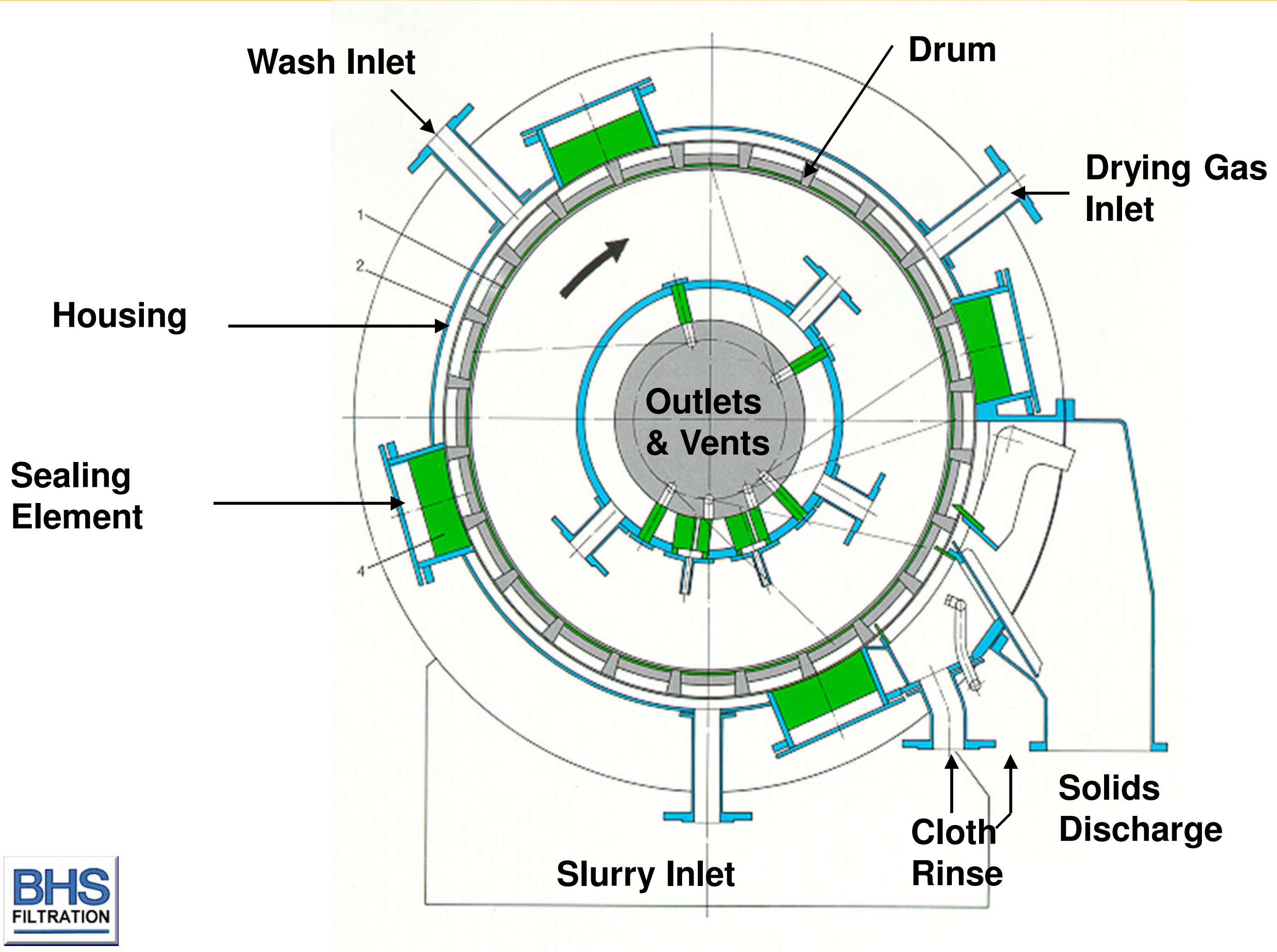
$$A = \frac{835\ \frac{kg}{h}}{267\ \frac{kg}{m^2h}} = 3.1\,m^2$$

Pressure Filtration

The result is a BHS rotary pressure filter with filter area of 3.2 m^2

Process Step	Degrees of Rotation
Filtration	57
Washing 1	57
Washing 2	57
Washing 3	57
Blow Drying	57
Cake Discharge and Cloth Cleaning	75

BHS Rotary Pressure Filter Typical Operation



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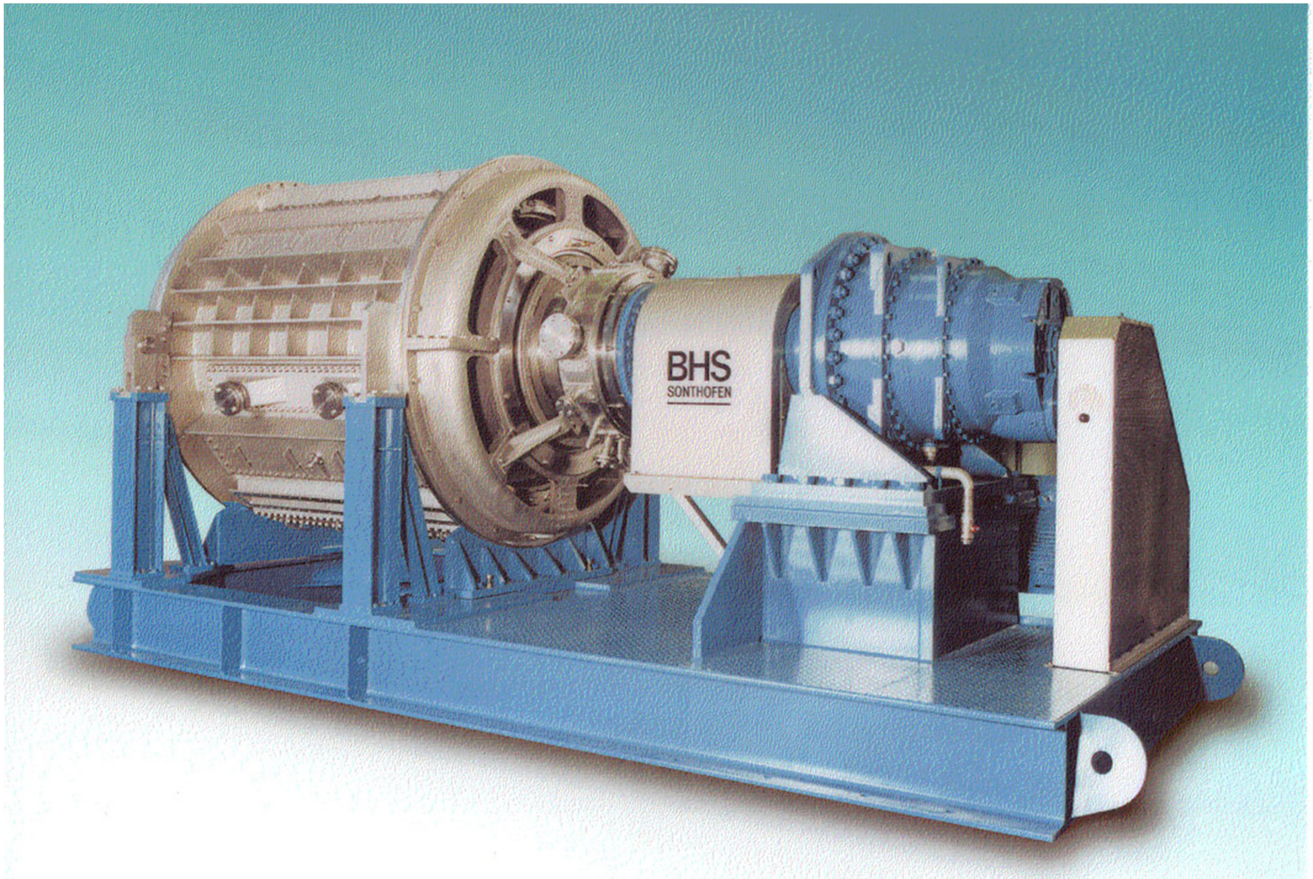
BHS Rotary Pressure Filter
Model B-16 Center Drive



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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.**

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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.**