Design of Membrane Filtration Systems for Biotechnology Process Applications

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Who is GEA Filtration?
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GEA Filtration

mg Technologies
Frankfurt, Germany

mg Engineering

mg Chemical

Lurgi AG

Lurgi Lentjes AG

GEA AG
Bochum, Germany

Zimmer AG

Process Divisions

Mech. Separation

Process Components

Process Engineering

Refrigeration

Dairy Farm Systems

Thermal Divisions

Strategic Business Units
Food & Dairy Drying Technology
Chemical Drying technology
Pharma Equipments
Evaporation Technology
Membrane Filtration
Barr Rosin
Dairy, Food & Juice Liquid Processing
Brewery & Beverage
Personal & Health Care
Spare Parts & Service

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What is Biotechnology?

“All lines of work by which products are produced from raw materials with the aid of living things.”

As defined by Karl Ereky, 1917
Biotech Market Segments

**Bio-food**
- Wine & Beer
- Lactic acid
- Citric acid
- Flavors & fragrances

**Nutraceuticals**
- Food supplements
- Health Foods

**Bio-pharmaceuticals**
- Antibiotics
- Proteins & peptides
- Vaccines
- Vitamins

**Bio-chemicals**
- Enzymes
- Ethanol
- Insecticides & Pesticides
- Poly-lactates
Biotechnology Process

Upstream Processing
- Media Preparation
- Fermentation
- Cell Rupture

Cell Harvesting / Clarification
- Precoat Filters
- Microfiltration
- Ultrafiltration
- Diafiltration
- Centrifugation

Downstream Processing / Purification
- Concentration
- Ultrafiltration
- Diafiltration
- Nanofiltration
- Chromatography

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- Clarification of Fermentation Broths to recover active compounds
- Cell Harvesting to concentrate and recover whole cells containing product
- Enzymes
- APIs (Active Pharmaceutical Ingredients)
- Proteins and Amino Acids
What is a Membrane Filtration System?
Sections of a Membrane Filtration System (Simplified)

Membrane Stages

Permeate

Concentrate

Feed Tank

Feed

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Membrane Configurations

- Conventional Configurations
  - Polymeric Membranes
    - Spiral
    - Tubular & Hollow Fiber
    - Plate & Frame
  - Inorganic Membranes
    - Tubular

- Specialized and / or Proprietary Configurations
Spiral-Wound Membrane Element
Tubular Polymeric Membrane Elements and Modules

Pictures Courtesy of Koch Membrane Systems

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Ceramic Membrane Elements and Modules

Pictures Courtesy of TAMI

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Scepter Membrane Elements and Modules

Pictures Courtesy of Graver Technologies

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A Few Important Terms & Concepts
**Important Terms**

- **Feed or Product**
  - Initial material into system on feed side of membrane

- **Retentate or Concentrate**
  - The fraction of the feed which is rejected by the membrane.

- **Permeate**
  - The fraction of the feed which passes through the membrane
Important Terms

- **Flux**
  - rate of permeate flow per unit area per unit time
  - “lmh” - liters/square meter/hour
  - “gfd” - gallons/square foot/day

- **Cross-Flow Rate**
  - flow rate of feed material through feed channel or feed side of a membrane element or module
  - determines feed flow characteristics which impacts performance parameters
Important Terms

- **Concentration Factor ("CF")**
  - feed volume (or flow rate) divided by the concentrate volume (or flow rate)

- **% Rejection**
  - $100 \times (1 - \frac{\text{permeate}_i}{\text{retentate}_i})$
Important Terms

- **Pressure Drop ("ΔP")**
  - Difference between the inlet and outlet feed-side pressures

- **Transmembrane Pressure ("TMP")**
  - Difference between feed & permeate pressure
  - Driving force for all membrane filtration processes

- **Osmotic Pressure ("Π")**
  - Function of MW and component concentration
  - Counter-pressure which TMP must overcome
Membrane Filtration System
Design Considerations
Steps in the Design Process

- Review of Application
- Review of System Design Criteria
- Pilot Testing
- Engineering and Design
Key Factors of System Design

- Stability of Product
- Shear Sensitivity
- Volume of Product to be Processed
- Up and Down Stream Operation Steps
Review of System Design Criteria

- Materials of Construction
- Design Specifications
  - Food industry Standards
  - Dairy Standards
  - Pharmaceutical / Biotechnology Standards
- Specialized Requirements
  - XP system

“Food Grade”
3A
GMP Compliance
Examples of Validation Documentation (if required)

- Bill of Materials
- Certificates of Compliance and Conformance
- Component Calibration Verification
- Material Test Reports
- Factory Acceptance Test (FAT)
- Weld logs, weld maps, etc.
Steps in the Design Process

- **Pilot Testing**
  - Test on representative feed(s)
  - Validate membrane type and configuration
  - Compilation and review of data

- **Membrane Configuration Selection**
  - Selection between spiral, ceramic, hollow fiber, cassette, others
Membrane Design Factors
- Type and Material of Membrane
- Configuration and Construction of Membrane
- Housing and Module Design

System Design Criteria
- Operating Parameters
  - T, P, Flux, CF, DP, TMP, etc.
- Mode of Operation
  - Feed and bleed, batch, etc.
- System Design
  - Stages-in-series, array, etc...
- Control Scheme
Integration of System Design with Plant Process

- Coordination with upstream operations, i.e. fermenters
- Coordination with downstream operations, i.e. extraction, chromatographic separation, formulation
With proper design and successful integration in the plant’s process, a membrane filtration system can become a key and integral process step within the recovery operation of a biotechnology processor.
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