Dairy Products 301

Fundamental of Filtration

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Agenda

- Introduction
- System Design Principals - Operating Membrane Systems
- Major Applications in dairy Processing

General

Tetra Pak Filtration Solutions

A merger of three businesses and four decades of expertise

1981

Tetra Pak Filtration Systems
Aarhus, Denmark

2012

FE Engineering
Champlin, MN, USA

2013

DSS
Silkeborg, Denmark

Today

Tetra Pak Filtration Solutions
- Two sites: Silkeborg, DK, & Brooklyn Park, MN, USA
- One global portfolio

Main focus areas:
- Dairy
- Food and Beverage
- Water

Filtration Office Locations

Brooklyn Park/ Winsted Minnesota, US

Aarhus, Denmark

We’re dedicated to membrane filtration!

Life cycle support – innovation, implementation, and services

PROJECTS

- Project managers
- Mechanical & design engineers
- Automation engineers
- Commissioning engineers with a dairy background

SALES SUPPORT

- Chemical engineers
- Food & dairy and bioprocess technologists
- Engineering BA
- Mechanical engineers

R&D

- Food and dairy technologists
- Chemical engineers
- Mechanical engineers

Strong team of membrane filtration specialists

SERVICES

- Upgrades specialists
- Membrane replacement specialists
- Spare parts specialists
- Trainers

Dairy Products 301

System Design Principals

Ultrafiltration and Microfiltration

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Terms and Definitions

- The terms “**membrane”, “element” and “module”** are often used interchangeably
- **Membrane”** specifically refers to the membrane surface itself
- A “**module” or, “element”,** is the prepared package which encloses the membrane
- **Vessel** – Housing that holds the module or element
- **Loop** – Set of vessels within a system.
- **Feed** – The initial liquid which enters a Membrane System
- **Concentrate/Retentate** – The fraction of the feed which is retained, rejected or concentrated
- **Permeate** – The fraction of the feed which passes through the membrane surface
- **Diafiltration (DF)** – Washing step that involves adding water to the retentate as it is being filtered to reduce product viscosity and remove even more lactose and minerals.
- **Concentration Factor (CF)** – Is the feed flow divided by the concentrate flow.
- **Flux** – The rate at which permeate passes through the membrane surface; in relation to area and time, LMH Expressed as L/m²/hr
- **Cross-flow** – Velocity of the product flowing parallel to the membrane surface

General

System Design Principals

Flux

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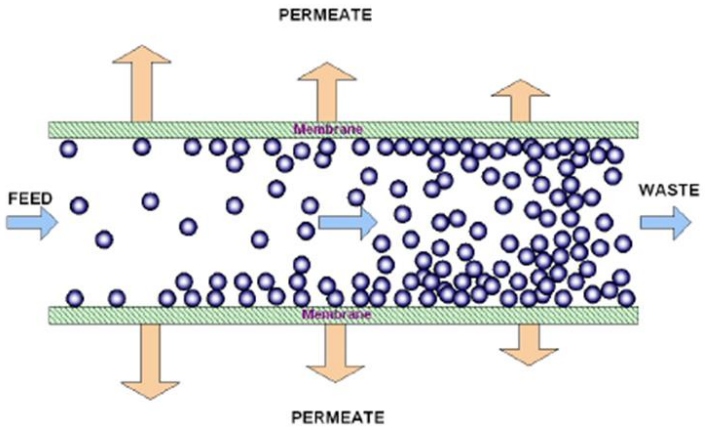
Flux or permeation rate

- Definition – The amount of liquid passing through a unit membrane are per unit of time
- Expressed as Liters/square meter/hour (LMH) or Gallons/square foot/day (GFD)
  - **Example:** 15 liters in one hour permeates through 10 meters^2 installed membrane area = 1.5 LMH
- Determines them amount of membrane area needed for a specific application
- Flux is based on application knowledge and can be affected by:
  - Temperature
  - Solids
  - Viscosity
  - Pressure
  - Membrane Vexar
  - Membrane Molecular Weight Cutoff

- Viscosity ↑ , Permeation ↓
  - Temperature ↑, viscosity ↓ = Flux ↑
  - Total Solids ↑, viscosity ↑ = Flux ↓
  - Fat ↑, viscosity ↑ = Flux ↓
  - Protein ↑, viscosity ↑ = Flux ↓



General

System Design Principals

Boost Pressure

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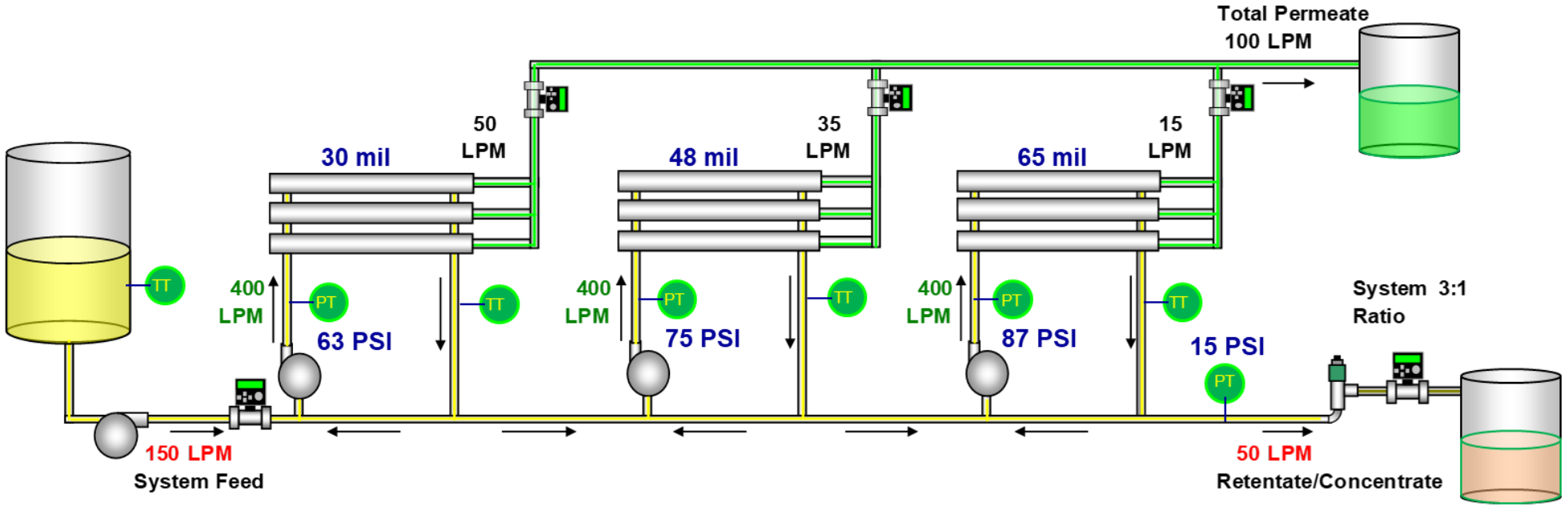
Boost pressure = Cross Flow Velocity/Turbulence



Membrane cross flow velocity:

- Stage/Loop pump used to create boost pressure
- Creating turbulence – Why is it needed?
- Keep surface clean - minimize “Cake Layer or fouling layer”

General

Membrane system operation – Boost Pressure

Membrane cross flow velocity:
Creating turbulence – Why is it needed?
Keep surface clean - minimize “Cake Layer”

Boost Pressure Ranges based on Vexar Size

30 mil vexar – 12-15 psi per element

48 mil vexar – 15-18 psi per element

65 mil vexar – 18-20 psi per element

80 mil vexar – 20-23 psi per element

It is important to have the proper pressure drop across each membrane element to minimize fouling during production and promote proper cleaning during CIP.

System Design Principals

Stage/Loop Flow

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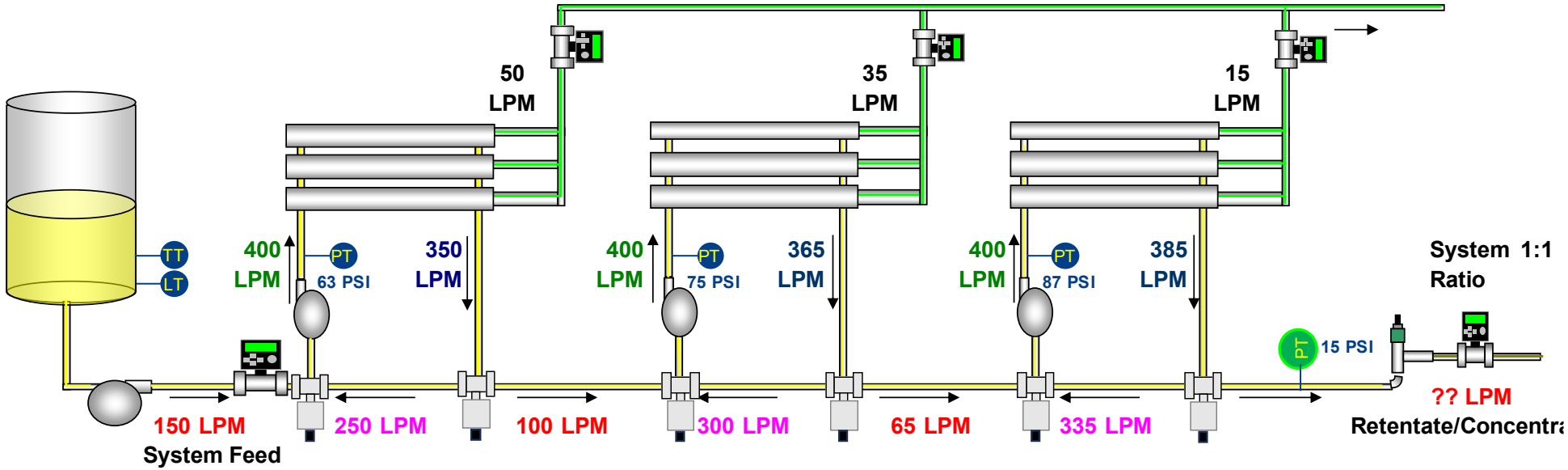
Stage/Loop Flows



- Boost Pressure dictates stage/loop flows and flow per vessel
- Total stage/loop flow divided by the number of housings/vessels equals flow per housing/vessel
- As viscosity increases stage/loop flows drop even at the same boost pressure

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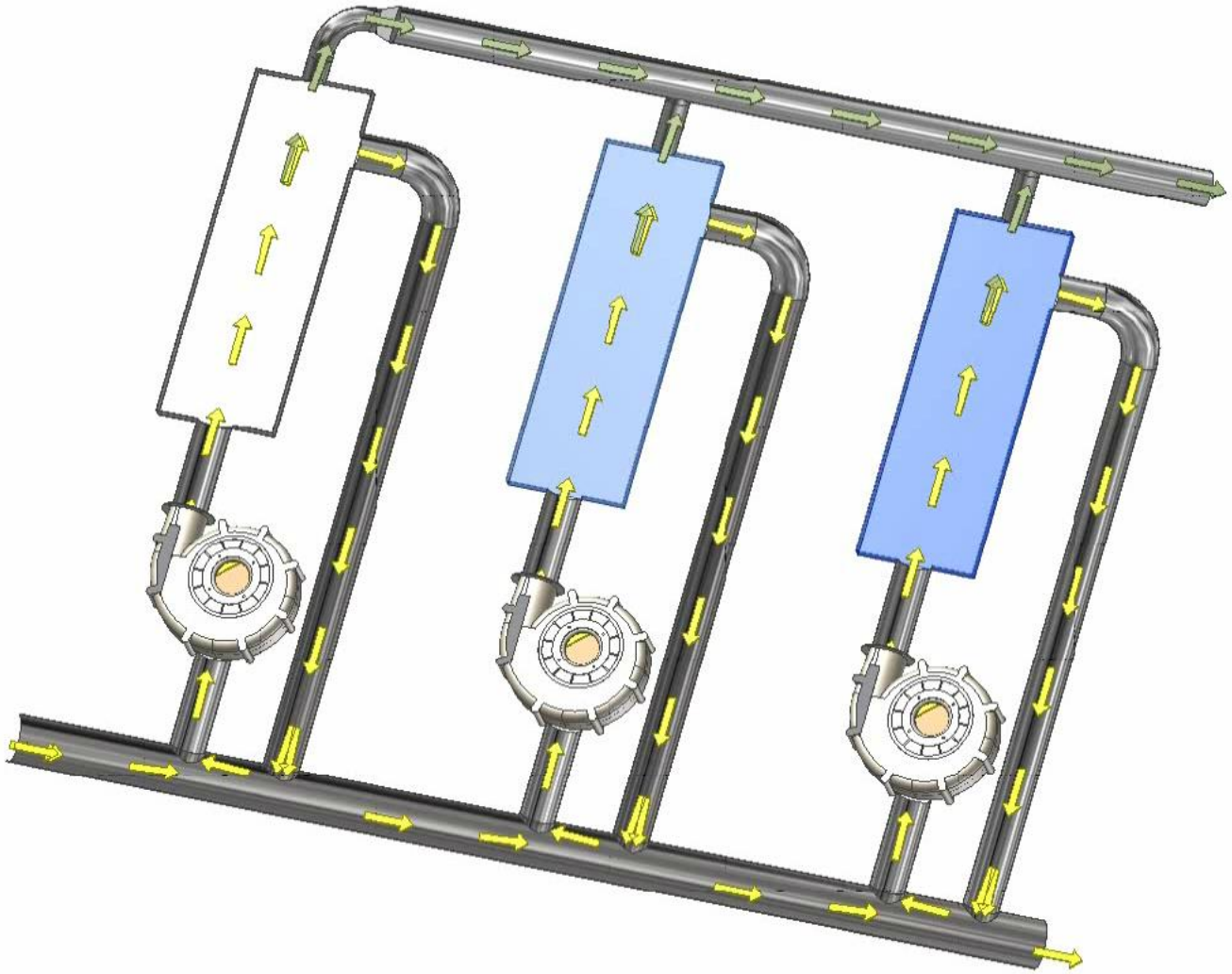
Example of flow in a membrane loop



Loop/Stage Flow Recommendations

Flow per Vessel – “Rules of Thumb”

UF/MF Recirc Rate (gpm) – 15 psi per element					
	30	48	65	80	100
3.8	35	50	65	80	100
6.3	85	114	140	175	225
8	115	135	160	200	250

RO/NF Recirc Rate (gpm) 15 psi per element					
	31	47	65	80	100
3.8	30	40	50	60	NA
6.3	NA	NA	NA	NA	NA
8	100	125	150	NA	NA

System Design Principals

Stage/Loop Valving

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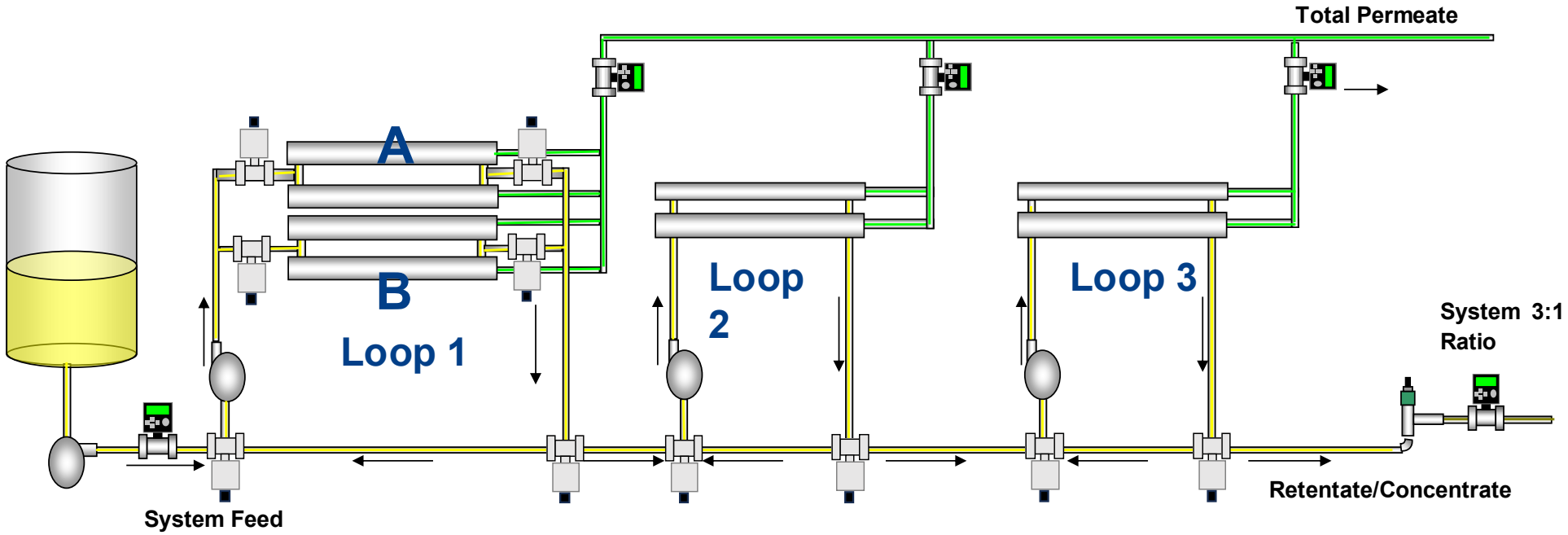
UF / MF Systems - Loop & Bank Isolation



- System Control – Stage valves: Loop isolation
- System Control – Stage valves: Bank isolation
- Maintain Proper Baseline Pressures for during production for process control
- Used in CIP to manage recirculation and flushing steps

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System Design Principals

Diafiltration

Concentration Factor

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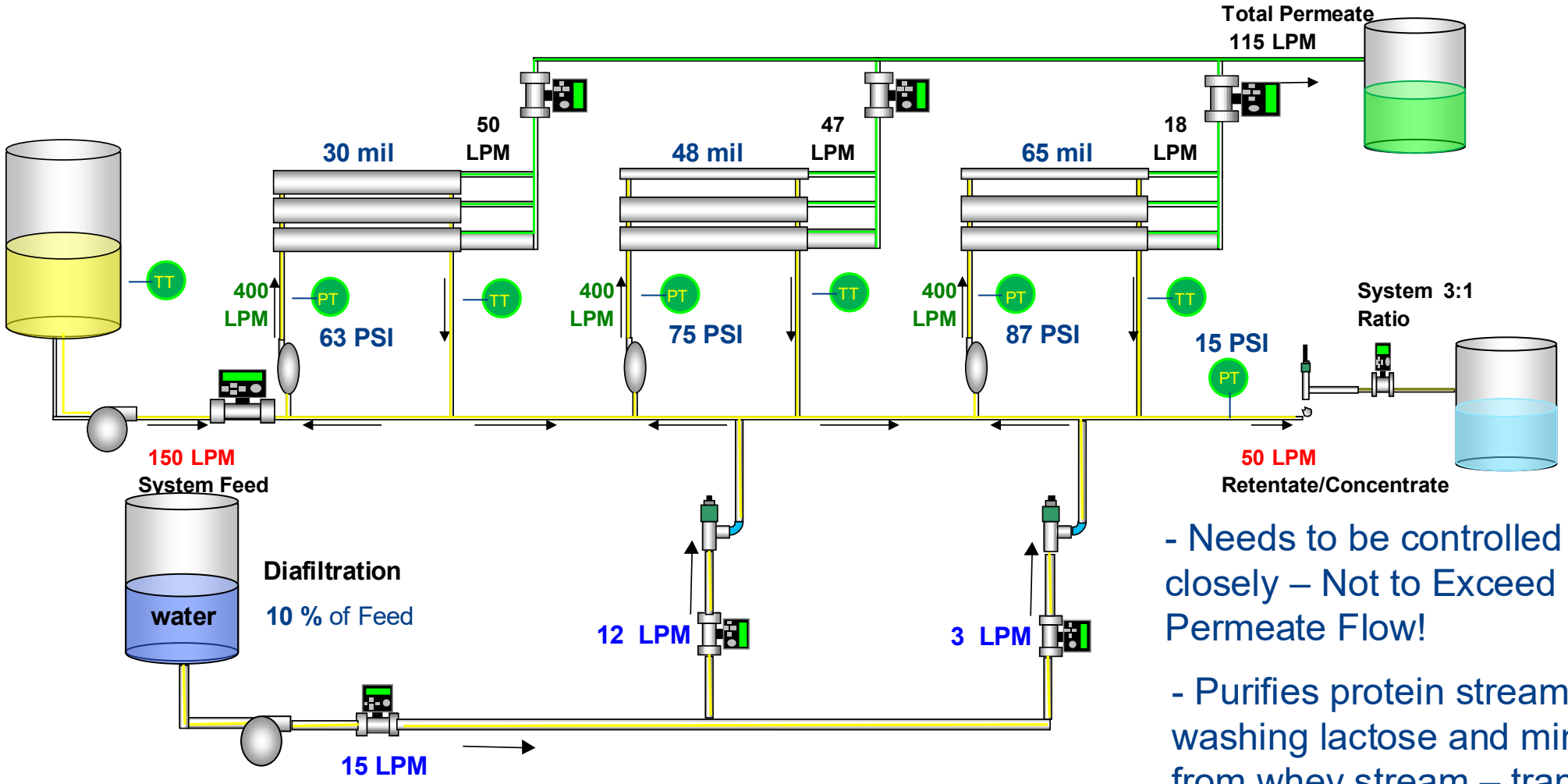
System Flows - Diafiltration



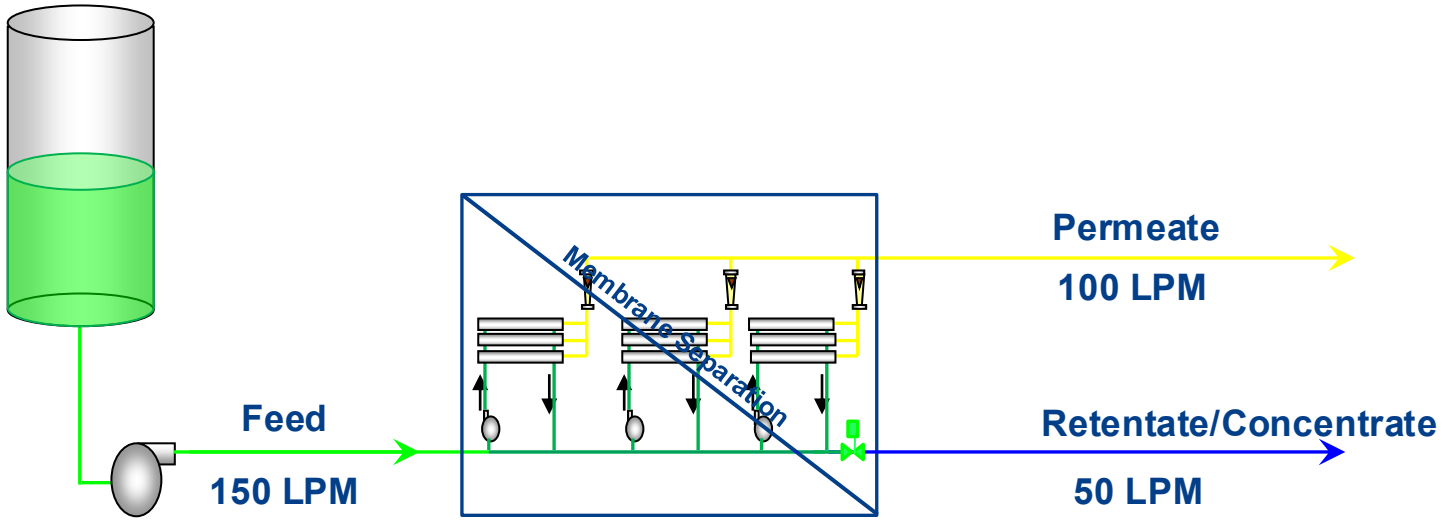
- Needs to be controlled closely – Not to Exceed Permeate Flow!

- Purifies protein stream by washing lactose and minerals from whey stream – transport vehicle

General

System Ratio

Feed ÷ Concentrate = Ratio (Concentration Factor)



150 LPM ÷ 50 LPM = 3 : 1 Ratio

A 3:1 ratio means that the Feed quantity is 3 times greater than the Retentate/Concentrate quantity

General

Ratio/CF and Diafiltration "Rules of Thumb"

How they work together

It is very important to understand how Diafiltration and Concentration affect the total solids and the PDB* value of the concentrate. The table shows how changing diafiltration and concentration parameters impact the solids and PDB* value.

	Total Solids	PDB
Increase CF	Increase ↑	Increase ↑
Decrease CF	Decrease ↓	Decrease ↓
Increase DIAF	Decrease ↓	Increase ↑
Decrease DIAF	Increase ↑	Decrease ↓
CF ↑ & DIA ↑	? (unknown)	↑↑
CF ↑ & DIA ↓	↑↑	? (unknown)
CF ↓ & DIA ↑	↓↓	? (unknown)
CF ↓ & DIA ↓	(unknown)	↓↓

Remember:

- Make small changes to diafiltration and ratio
- Refer to chart to anticipate results of changes
- Do not allow diafiltration water to exceed permeate flow
- Monitor solids by loop to prevent "backing up"

(PDB* = Protein Dry Basis)

Major Applications in Dairy Processing

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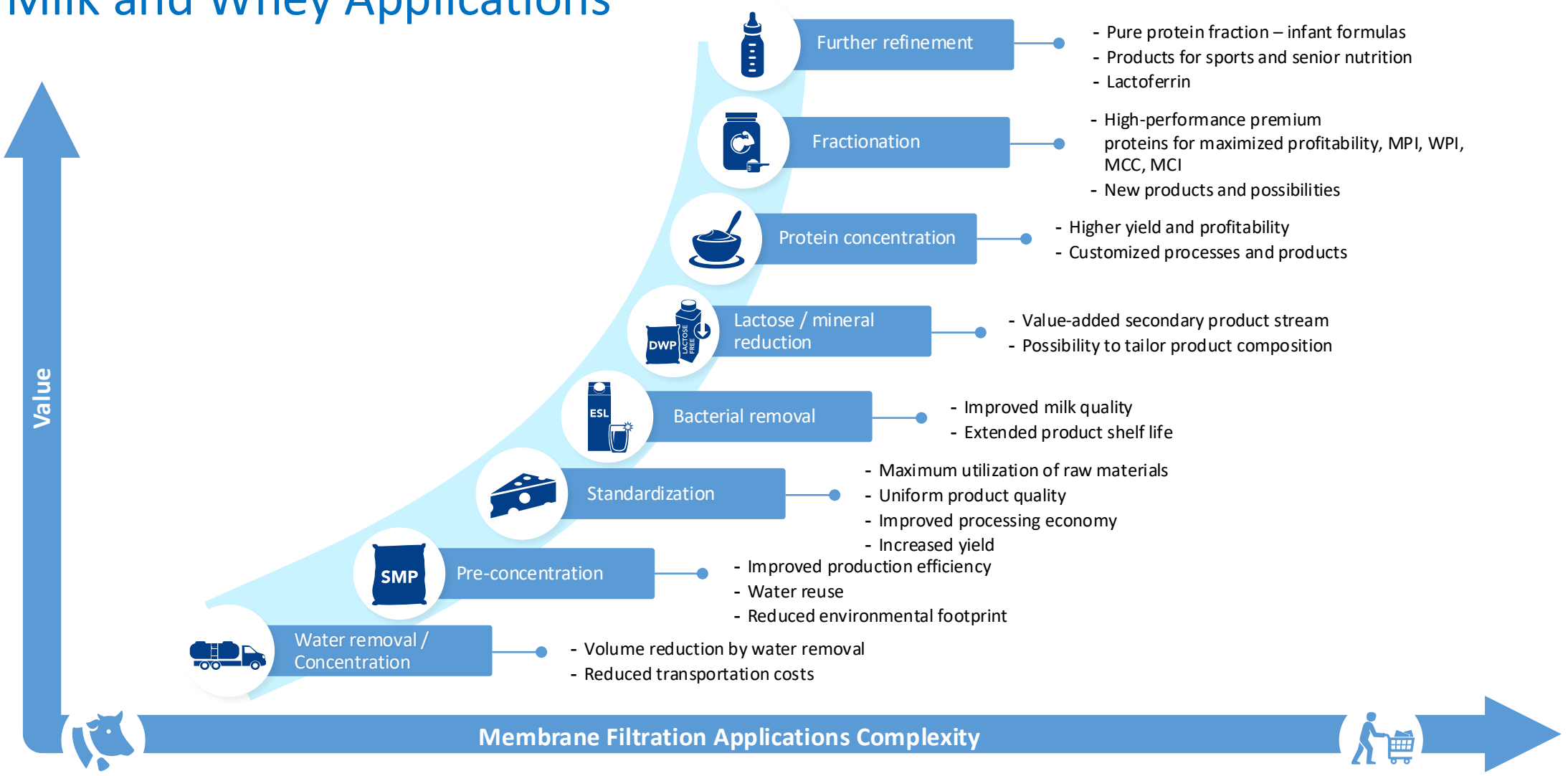
Adding value with membrane filtration

Milk and Whey Applications

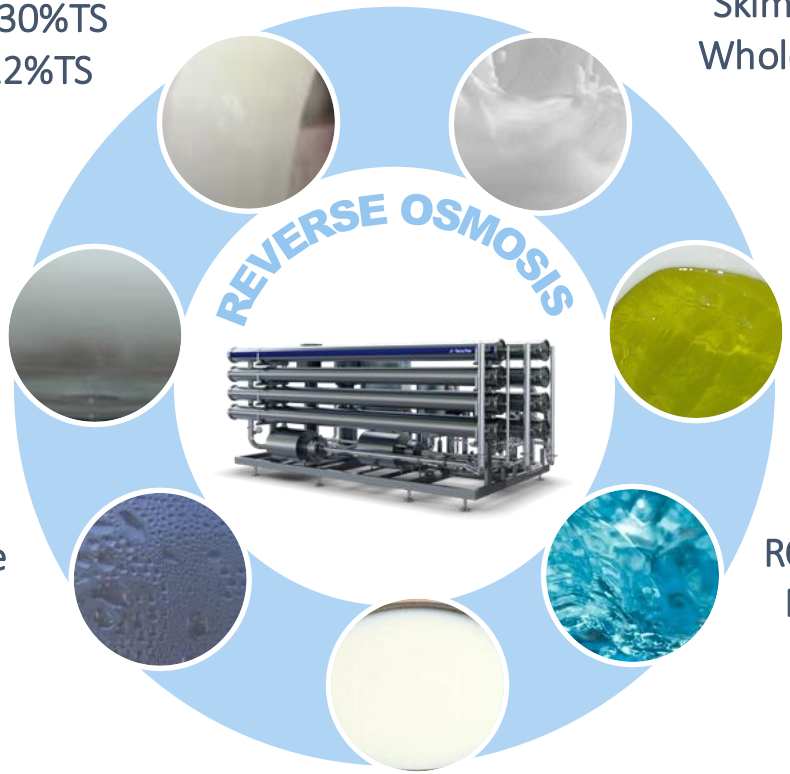


General

Dairy Applications Membrane Filtration RO Overview

Whey
Sweet Whey – 22-30%TS
Acid Whey – 18-22%TS

Milk
Skim Milk – 24-36%TS
Whole Milk – 30-36%TS



White Water
Skim Milk – 3-10x CF

UF Permeate
Sweet UF Perm– 20-27%TS
Acid UF Perm – 17-20%TS

Evaporator Condensate Polishing
Evap Cond– 10-20x CF

RO / NF Permeate Polishing
RO Permeate– 10-20x CF
NF Permeate 6-15x CF

Buttermilk
Sweet Buttermilk – 28-32%TS

Lower transportation costs

Increased Dryer Capacity

Evaporator Elimination or Decreased Size

Product Recovery

Water Reuse Recovery

Optimized Waste Water

General

Dairy Applications Membrane Filtration NF Overview

Whey
Sweet Whey 22-30%TS
Acid Whey 18-22%TS
Salt Whey 90% Salt Reduction

Milk
Skim Milk 24-36%TS
Whole Milk 30-36%TS
30-40% Deimineralization

Whey Derivatives
WPC35 38-42%TS
WPC80 36-40%TS
WPI90 33-36%TS
MFR 23-24%TS

Milk Derivatives
MPC70 28-32%TS
MPC80 24-24%TS
MPC85 23-24%TS
MPI90 20-22%TS
MCC 16-18%TS

UF Permeate
Sweet UF Perm– 23-28%TS
Acid UF Perm – 18-21%TS

Chemical
Caustic Reclaim

Lower transportation costs

Increased Dryer Capacity

Evaporator Elimination or Decreased Size

Chemical Recovery

Deminerization

Optimized Waste Water

General

Dairy Applications Membrane Filtration UF Overview

Whey
Sweet Whey - WPC35 to WPC80
Acid Whey – WPC35 to WPC60

Milk
Skim Milk – MPC42 to MPI90
Skim / Whole Milk – Cheese Milk Protein Standardizing 1.5-4X
Various Milk Drinks

Whey Derivatives
High Fat - WPC35 to WPC70
MF Permeate – WPI90
MFR 30-36%TS

Milk Derivatives
MPC70 34-37%TS
MPC80 28-31%TS
MPC85 27-30%TS
MPI90 26-28%TS
MCC 22-24%TS

Cheese & Fermented Products
White Cheese (Feta, Domiati, Queso Fresco)
Greek yogurt, Skyr, Quark, Cream Cheese

Whey and Milk
Lactoferrin - Purification, Concentration

UF Permeate
De-calcification

Cheese Brine
Clarification, Micro Removal

Higher Product Yields

Increased Dryer Capacity

Evaporator Elimination or Decreased Size

Fractionation of Products

Clarification of Products

High Value Products

General

Dairy Applications Membrane Filtration MF Overview

Whey
Sweet Whey - Bacteria removal

Milk
ESL – Extended Shelf Life
Bacterial removal

Whey Derivatives
WPC35-60 – Fat Removal
(WPI)

Milk Derivatives
MCC, MCI
Native Whey Protein

Fermented Products
Greek yogurt, Skyr, Quark

Cheese Brine
Clarification, Micro
removal

Higher Product Yields

Product Quality

Innovation

Fractionation of Products

Clarification of Products

High Value Products

General

Questions?

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Thank you!

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