COMPLETE
FILTRATION RESOURCES

11 SEPTEMBER 2025

Introductions

We are a Design-Build -Service Firm for Turn-key Membrane Filtration Projects

Services Include

- Process and Equipment Design
- Pilot Trials
- Equipment Fabrication and Installation
- Commissioning and Startup
- Service
- Process Troubleshooting
- CIP Expertise

DEFINITIONS

MEMBRANE TERMINOLOGY (1/2)

Filtration: A means to separate components of a given stream. Typically by particle size.

Membrane/Media: The actual material that is performing the filtration step.

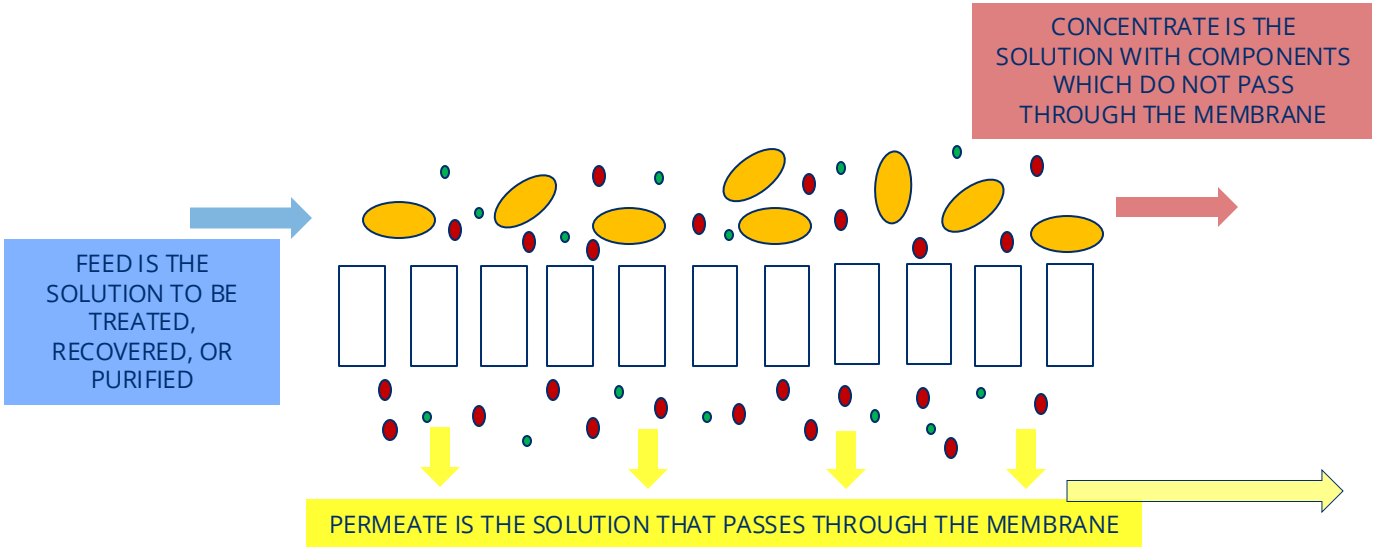
Permeate/Filtrate: The portion of the stream that passes through the filtration media.

Concentrate/Retentate: The portion of the stream that is rejected (does not pass through the filtration media).

Cross Flow: A method of filtration, where the concentrate side moves along the media rather than being stopped at the media surface.

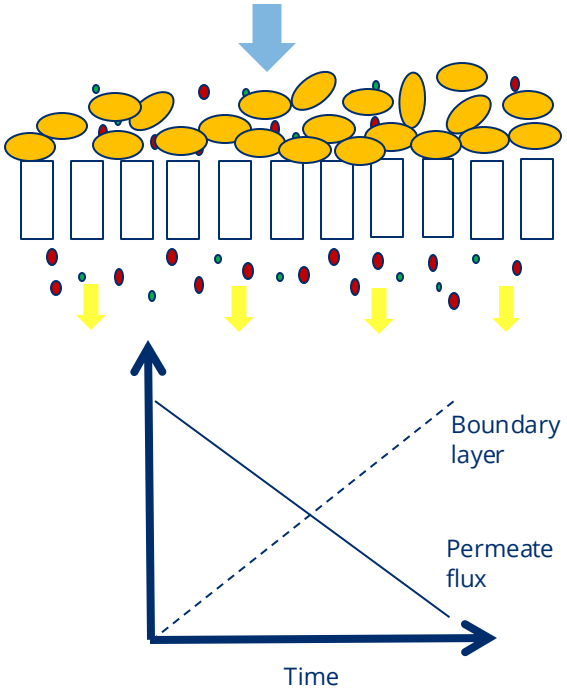
Flux: Generally referred to as the rate permeate will go through a filter media. Often diminishes (slows) over time. This slowing is much greater in dead end filtration than cross flow filtration.

VISUAL FLOW PATHS

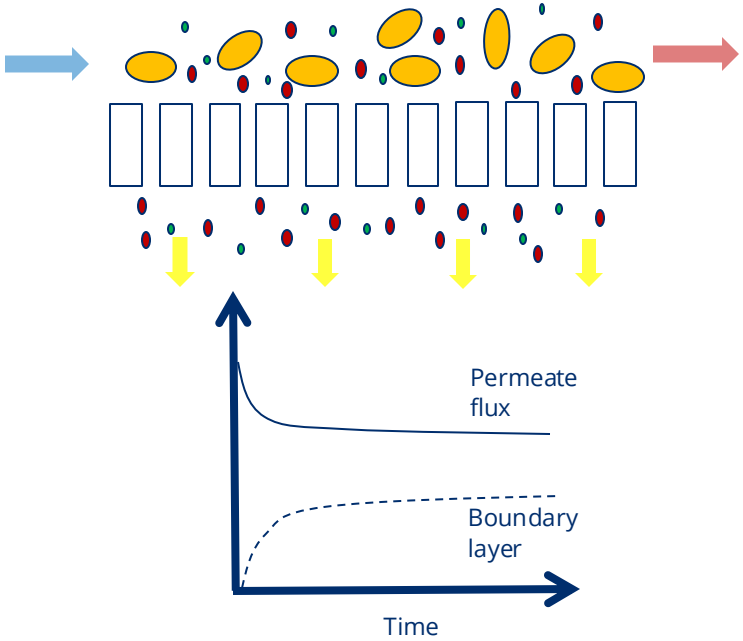


FILTRATION MODES

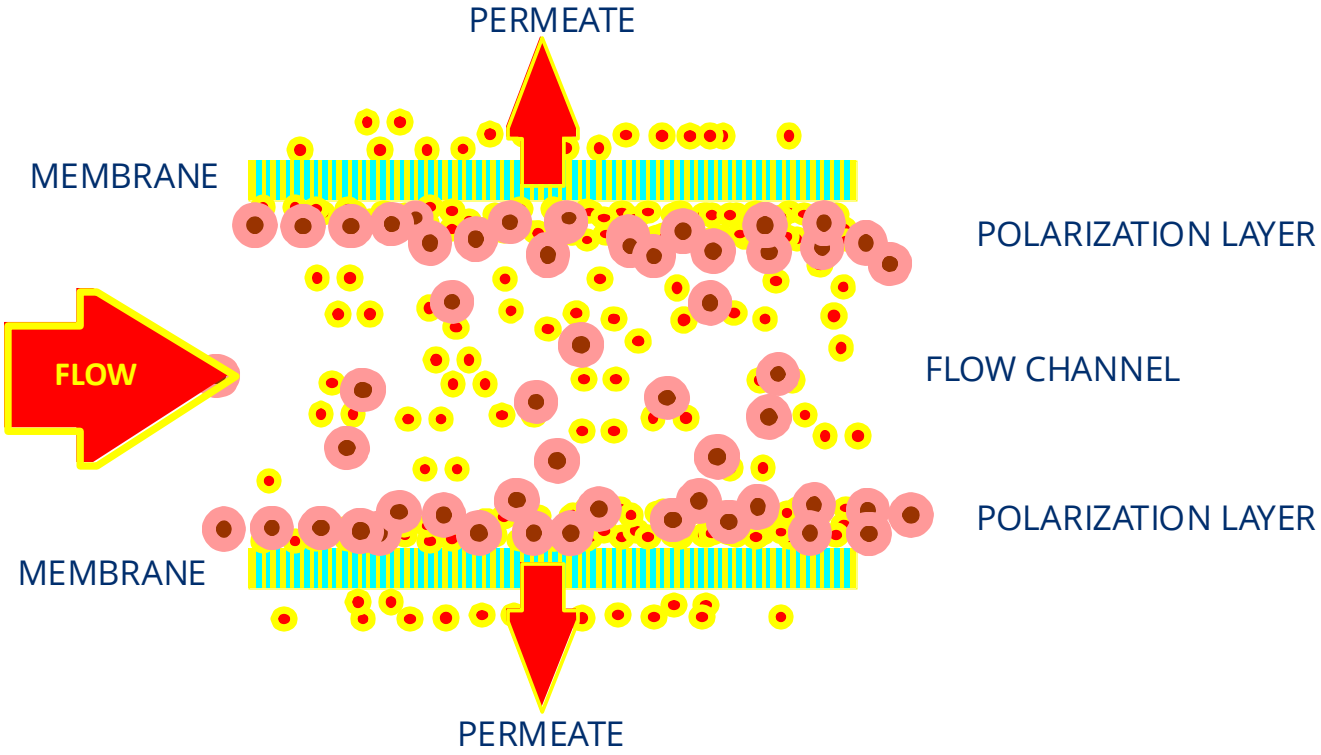
Dead-end filtration



Cross-flow filtration



CROSS-FLOW FILTRATION



MEMBRANE TERMINOLOGY (2/2)

Osmosis: A natural process where certain components will pass from a high concentration through a semi-permeable membrane to a solution of lower concentration to balance the concentrations out.

Reverse Osmosis: A filtration process where pressure is applied to one side of the semi-permeable membrane to allow water to pass through the membrane with very limited amount of other materials to pass.

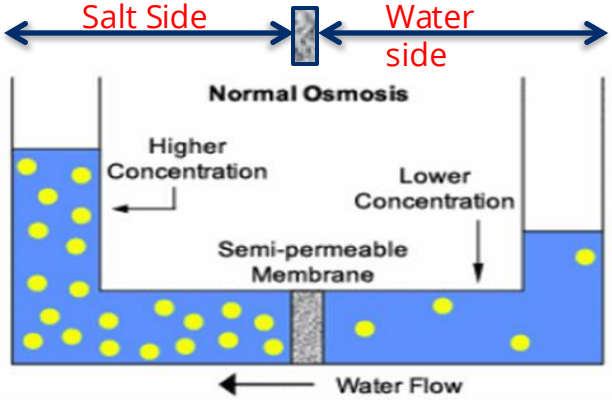
Fouling: Denotes particulates becoming imbedded in the filtration media that reduces the ability of the media to let material pass. Reduces the efficiency of the media.

Stage/Loop: A set of membrane filters with an individual pump to move material through them.

Concentration Factor: Feed divided by concentrate removed from the system. This is often how membrane systems are controlled.

Diafiltration (DF): The addition of water directly to a Loop to assist in either washing product or impurities through the membranes.

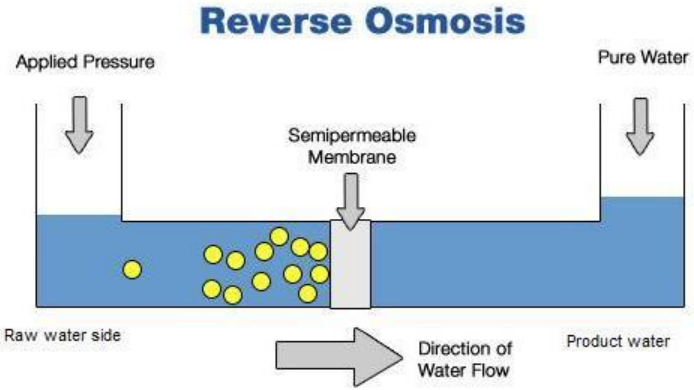
REVERSE-OSMOSIS



Osmosis

Water diffusing from 'Water side' to 'Salt side'. Natural phenomenon

Osmotic pressure is the psi exerted by water to move towards salt-side



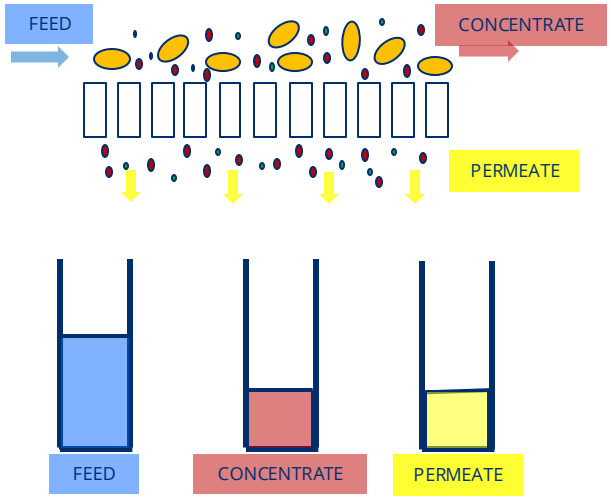
Reverse-Osmosis

Applied pressure on 'Salt side' causes water to be forced out into the 'water side'

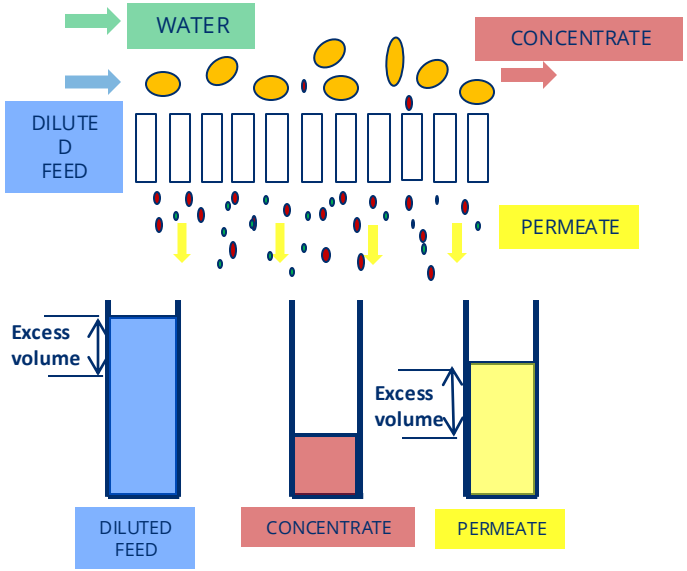
Why RO need high pressure?
Force water and overcome osmotic pressure

DIAFILTRATION

Normal process



Diafiltered with Water



- **DF <u>dilutes concentration of smaller permeable species increasing permeation</u> while the concentration of larger retainable particles is unaffected**
- **Excess volume needs to be processed increasing energy requirement**
- **Can be used on all cut-offs MF – RO**
- **More on theory and controls later**

CROSSFLOW FILTRATION

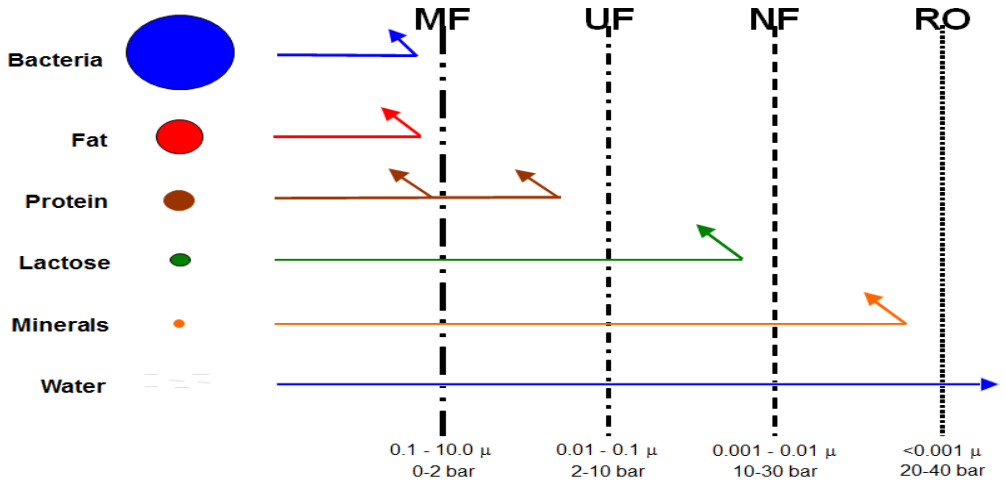
✓In cross-flow filtration, the liquid flows across the surface of a membrane while a small amount is permitted to flow through the membrane.

✓The velocity of the liquid flowing across the membrane keeps material from settling on the membrane and fouling it.

✓Increasing the velocity of liquid flow across the membrane surface reduces fouling.

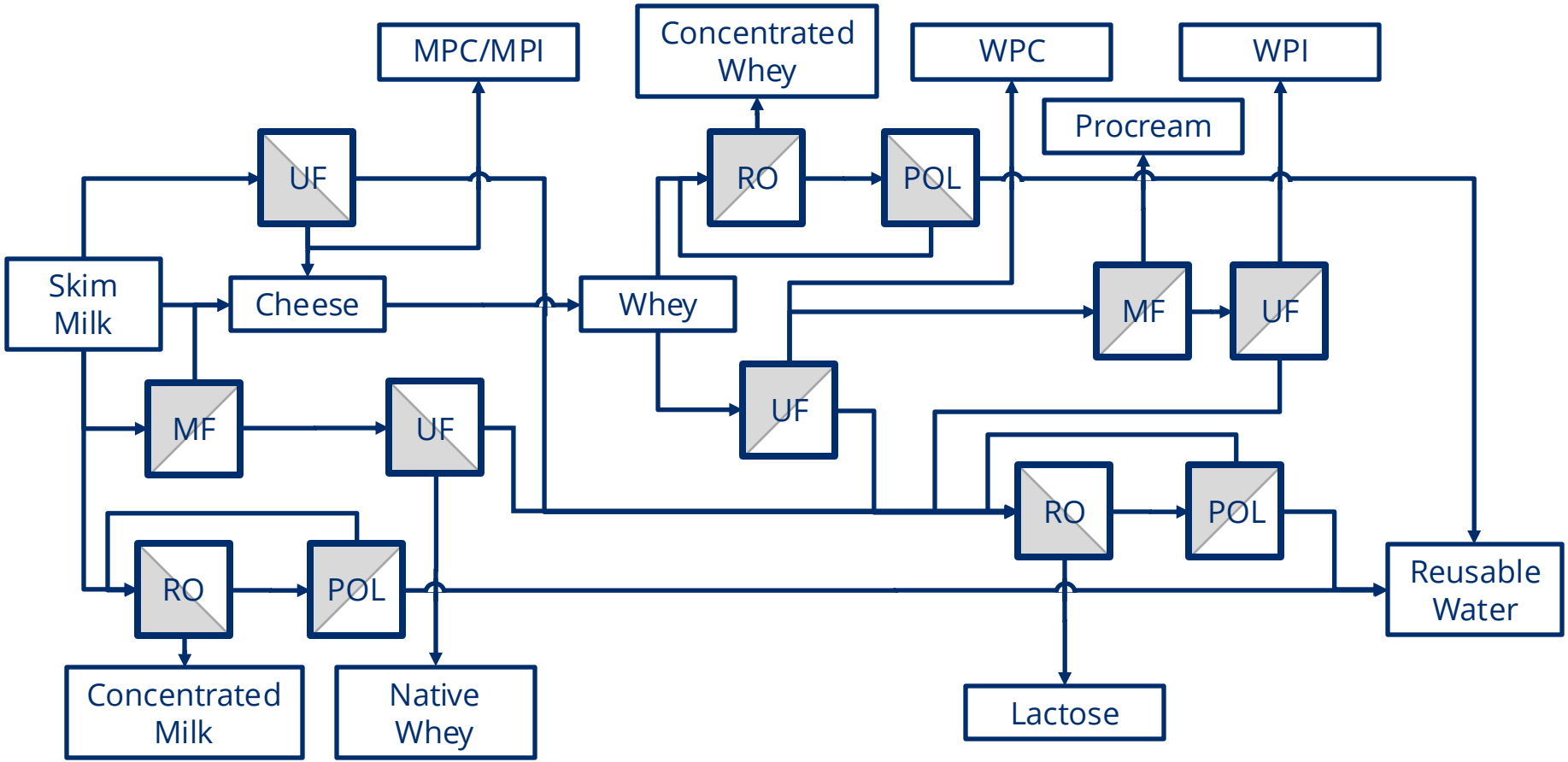
✓Cross-flow velocity allows you to control “fouling”, which is the building of a gel layer on the surface of the membrane. This is called “Concentration Polarization”

FILTRATION SIZES

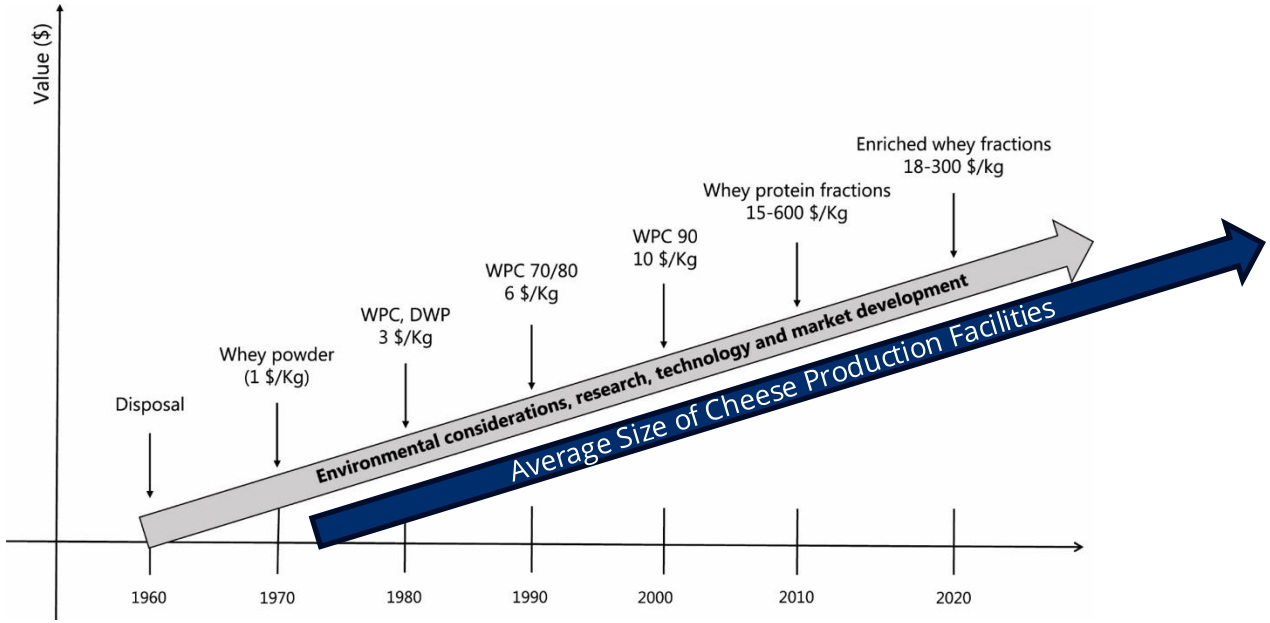


- MF rejects suspended matter – Casein and fat globules (Size exclusion)
- UF rejects large dissolved components – Whey proteins (Size exclusion)
- NF permeates only monovalent ions – Eg. Sodium, Potassium (size, diffusion & interaction)
- RO permeates water – size & diffusion

FILTRATION IN DAIRY

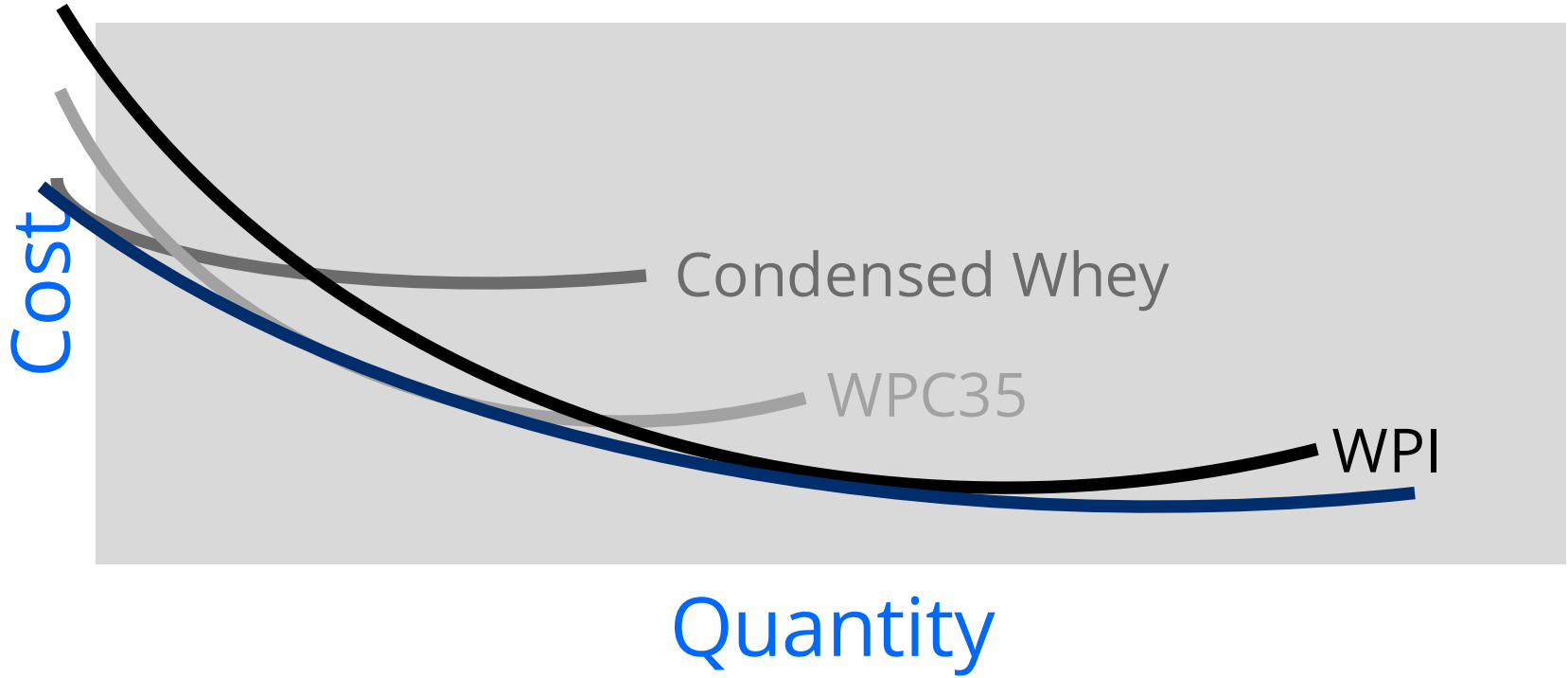


HISTORICAL DEVELOPMENT OF WHEY FILTRATION



Time evolution of the dairy industry through the profitable and sustainable valorization of whey towards the production of value-added high quality products. From "WHEY - The waste-stream that became more valuable than the food product," by P. Tsermoula, et. al., 2021, *Trends in Food Science & Technology, 118*(A), p. 230-241, Copyright 2021 CC BY 4.0 DEED.

ECONOMIES OF SCALE



SPIRAL ADVANTAGES/DISADVANTAGES

Advantages

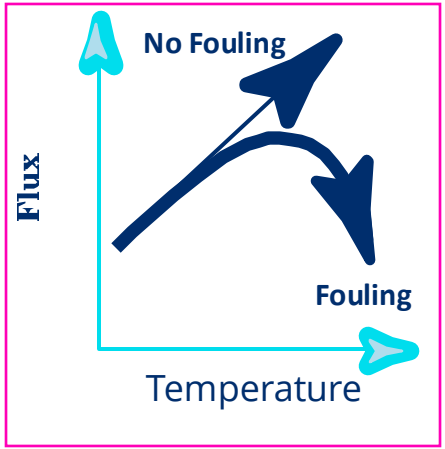
- ✓ High packing density due to spiral packing. Hence a large surface area to product volume, reducing floor space requirements
- ✓ High pressure operations
- ✓ Easy replacement for operators
- ✓ **Low capital and operating expenses compared to other configurations**

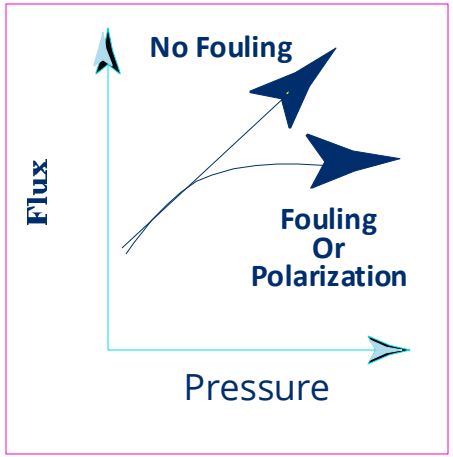
Drawbacks

- ✓ Short lifespan (~1 year)
- ✓ Proper cleaning operations are required
- ✓ Fouling occurs if proper conditions are not maintained
  - ✓ Pre-filtration
  - ✓ Microbiological
  - ✓ Mechanical – Cross flow

KEY PROCESS VARIABLES

TEMPERATURE AND PRESSURE





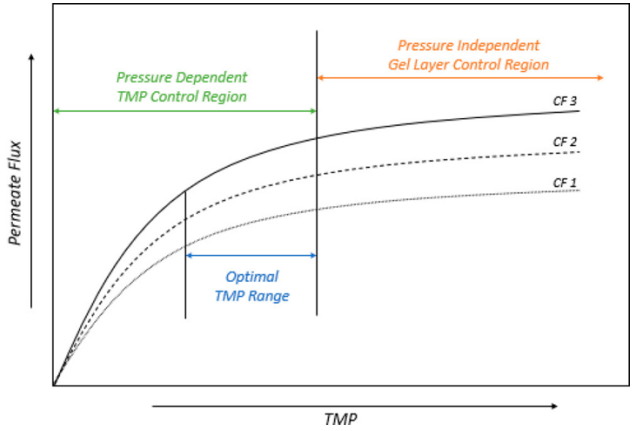
At high temp for dairy >70F

- Bacteria can double every 20 min
- Calcium phosphate fouling
- Protein gelation if pH is lowered
- Biofouling occurs

At very high pressures

- The dispersed polarization layer can form a condensed gelled cake layer leading to phase change and fouling
- Critical flux- Flux becomes Pressure Independent
- Decreased rejections for MF and UF

TRANSMEMBRANE PRESSURE



WHAT IS IT?

Transmembrane pressure (TMP) is the average pressure minus permeate pressure across a membrane, often referred to as the pressure gradient. It is the driving force through the membrane

IMPORTANCE

In addition to affecting permeate flux, TMP influences the gel layer formation which in turn affects fouling and separation quality. While other factors are at play, typical filtration operation yields best results running at a TMP which is just under the limiting flux.

OPERATING PRESSURES

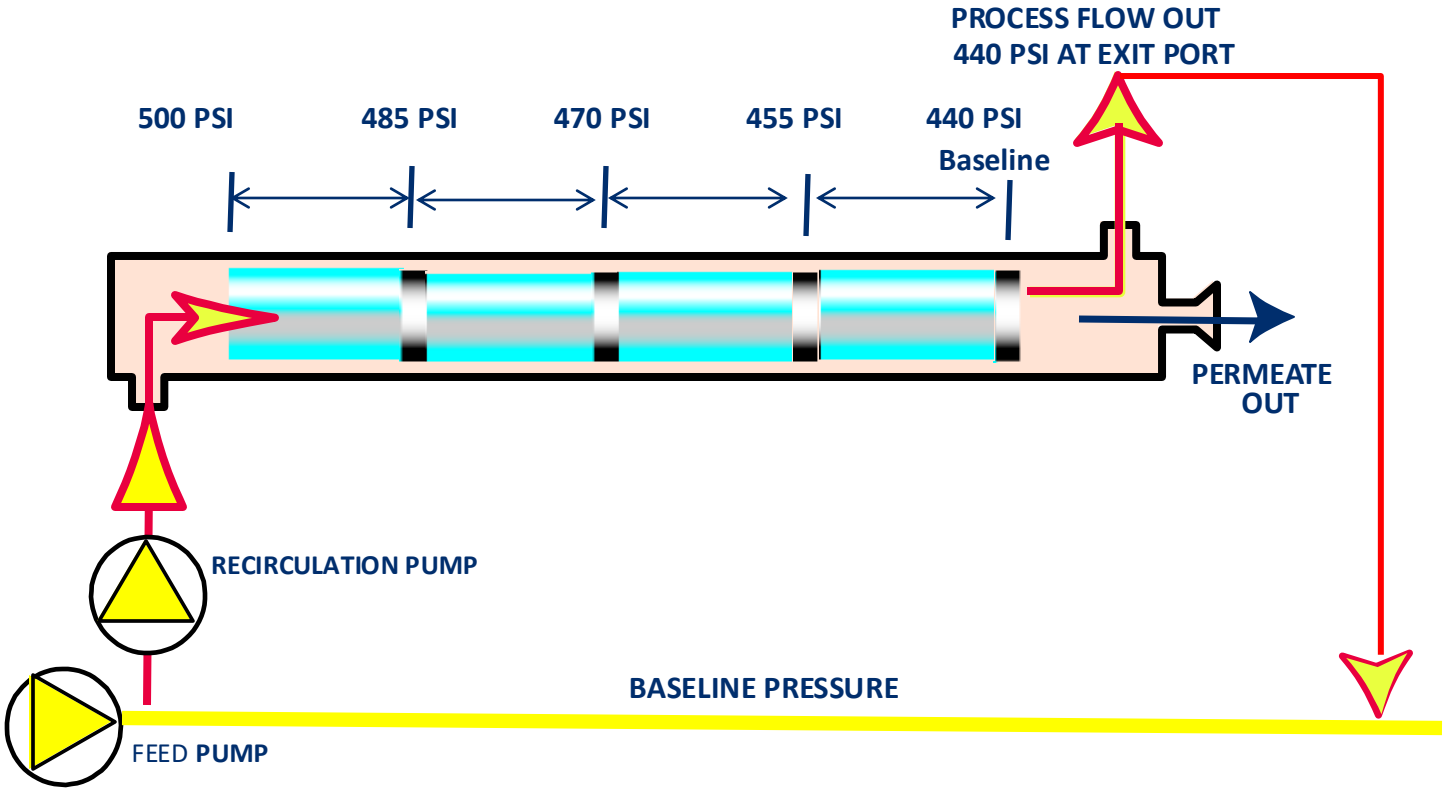
Microfiltration (low pressure)	0-20 psi
Ultrafiltration (low pressure)	15-120 psi
Nanofiltration (high pressure)	150-800* psi
Reverse Osmosis (high pressure)	200-1,000*+ psi

Note how NF operates at high pressure similar to RO. Since monovalent ions are present on the permeate side, the osmotic pressure is lower requiring a lower pressure.

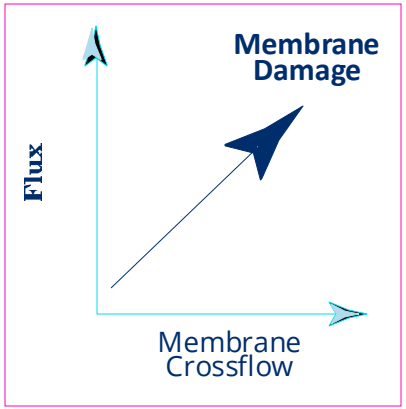
PRESSURE DROP

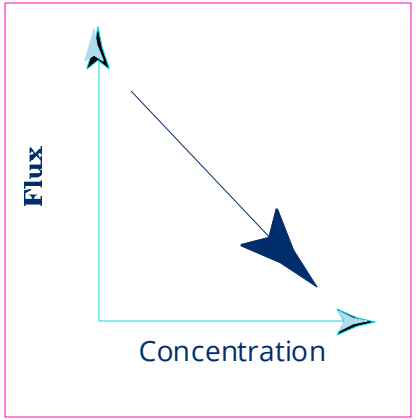
- ✓ In most cases higher pressure drops increase both crossflow and TMP
- ✓ Typically operate at maximum crossflow, which means maximum pressure drop
- ✓ Spiral elements target 12-15 psi/element, depending on the mil spacer
- ✓ Tubular and ceramic elements pressure drops vary greatly based on length and module build

PRESSURE DROP



VELOCITY AND CONCENTRATION





At very high cross-flow

- High velocity can cause membrane crushing as it exceeds mfg. spec pressure

High concentration

- Increased solutes can lead to solubility, viscosity, fouling cake, osmotic pressure
- Last stage of filtration skid several times faces membrane issues

PROCESS PRINCIPLE – DF ADDITION THEORY

DF water is commonly used in UF applications as a way of rinsing out small molecules such as sugars and minerals.

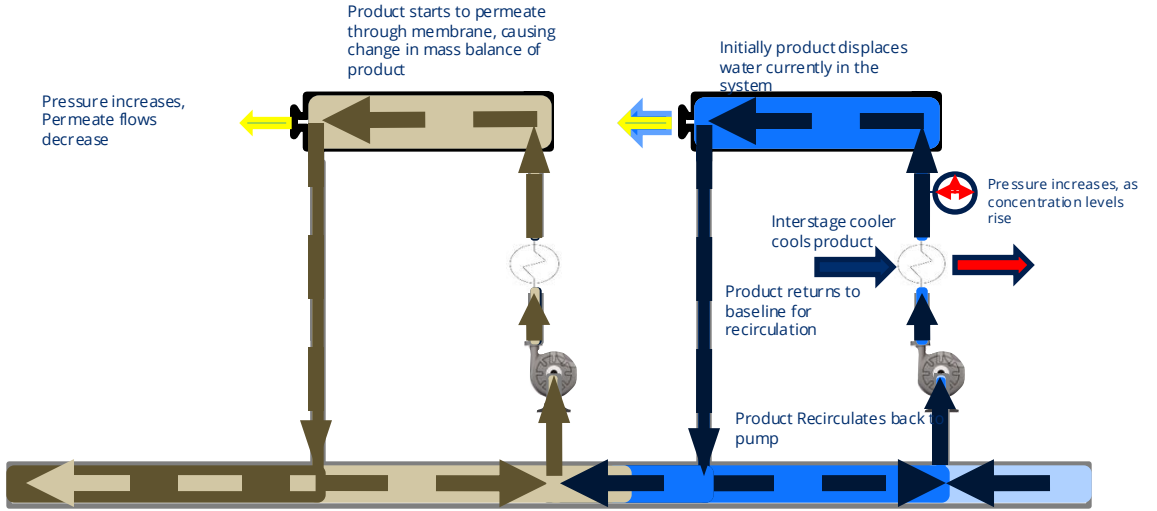
- ✓Scenarios and Adjustments:
  - ✓High Protein and TS – Open Ratio and let more concentrate out
  - ✓Low Protein and TS – Close Ratio and let less concentrate out
  - ✓Low Protein and high TS – Add more DF water
  - ✓High Protein and low TS – Add less water

- ✓For Process Controls, DF water is added as a total % of feed, and as a percentage of permeate flow per stage.

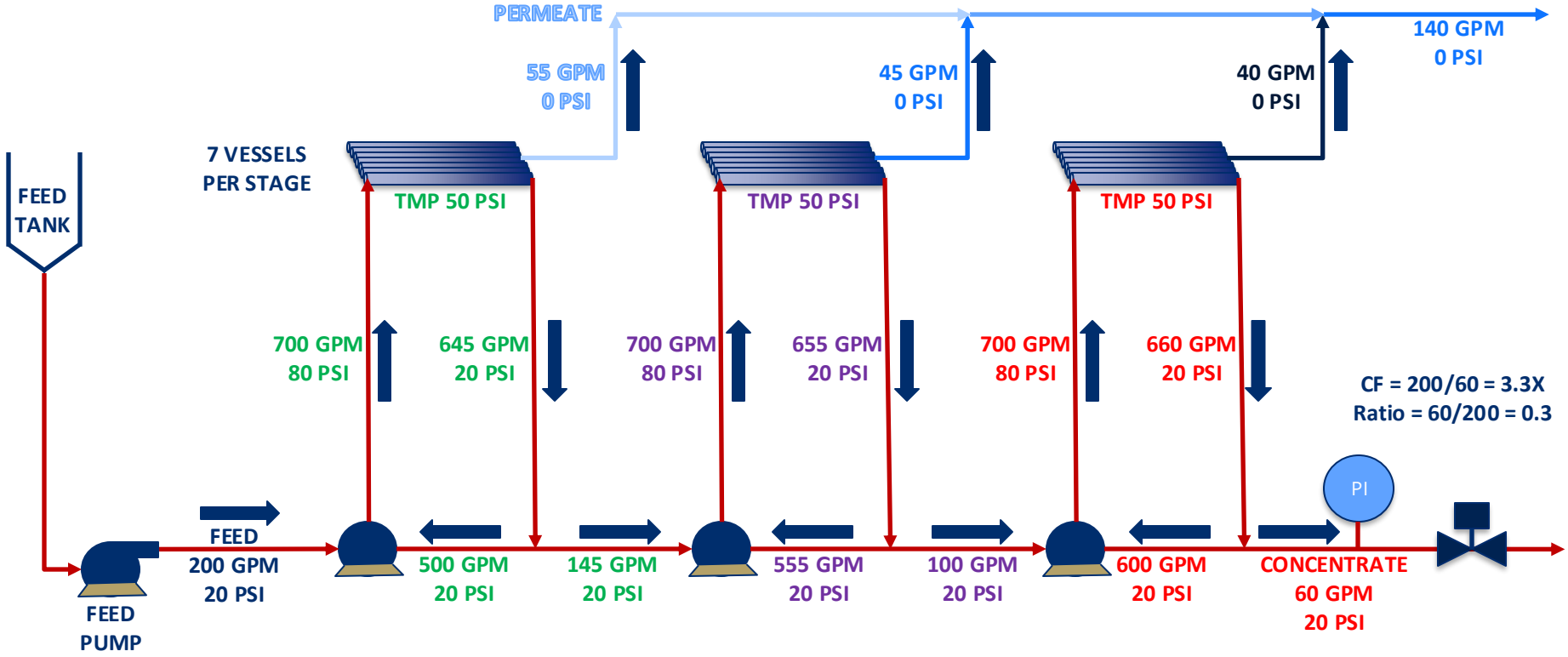
Solids control per stage can be an effective way to optimize the surface area by preventing early peaks and large dilutions

OPERATING P&ID EXAMPLES

PRODUCTION OVERVIEW

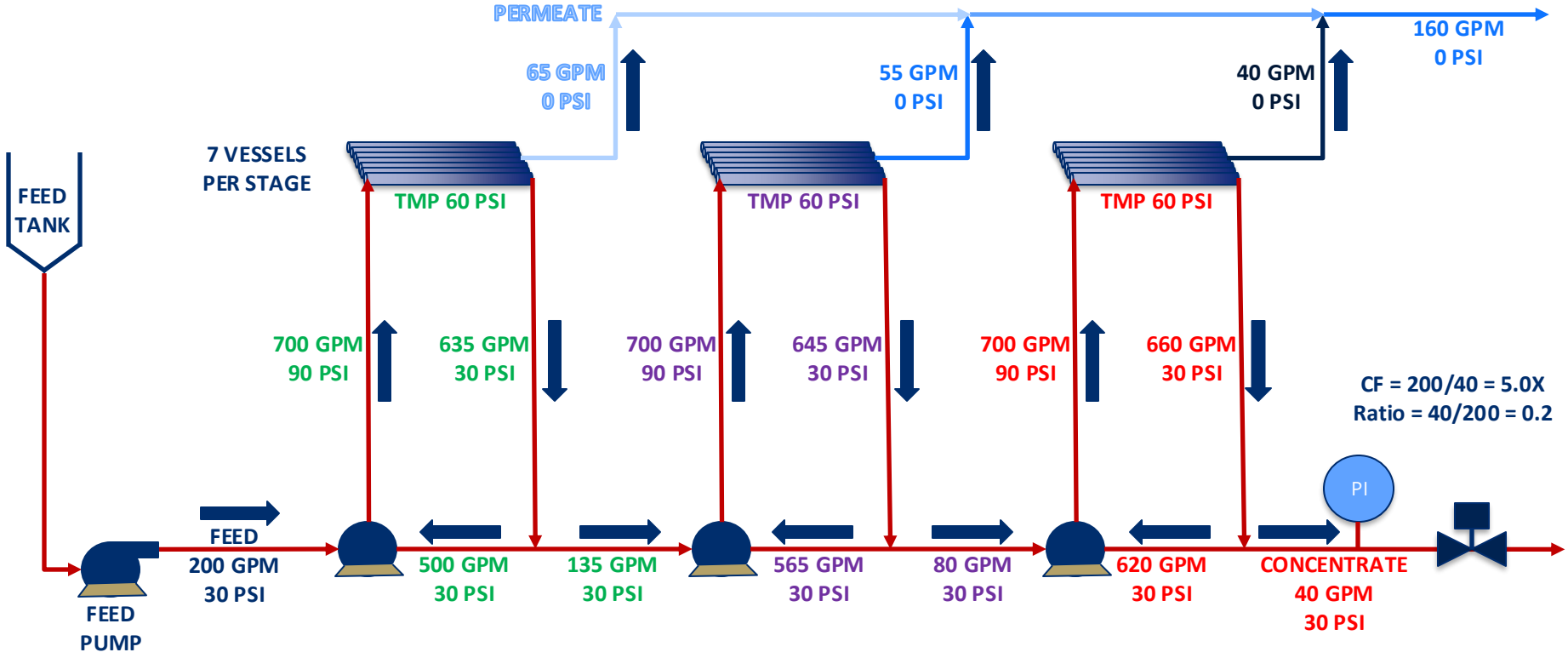


STAGE FLOWS



Concentration Factor → CF = 200/145 = 1.38X CF = 145/100 = 1.45X CF = 100/60 = 1.67X

STAGE FLOWS – DECREASE RATIO



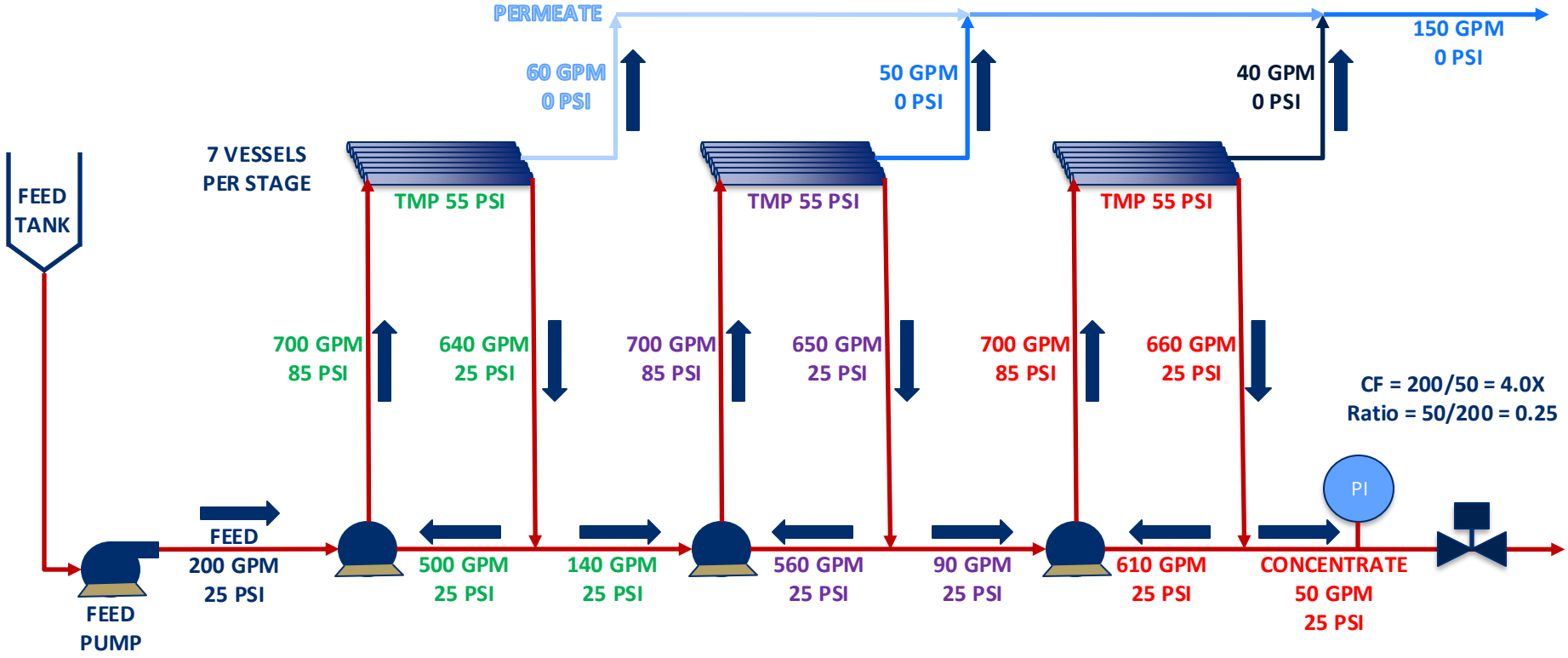
Concentration Factor

CF = 200/135 = 1.48X

CF = 135/80 = 1.69X

CF = 80/40 = 2.00X

STAGE FLOWS – INCREASE RATIO



Concentration Factor

CF = 200/140 = 1.43X

CF = 140/90 = 1.56X

CF = 90/50 = 1.80X

QUESTIONS?

THANK YOU

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