

Finding the “WHY?”

FUNDAMENTALS OF FILTRATION PROCESSING

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WHY ME?

- Food Science, Food Processing, Management Background (sure..mostly academic!)
- 15 years of membrane experience
- 10 years at SDSU (Ph.D. work, IDIP and Plant Manager)
- Over 150 individual pilot trials on membranes
- Various products tested on variety of formats
- Mentored many employees / students who now work in the industry at many levels



YIKES!



BRIEF OUTLINE

- **The “Why” We’re Here**
 - Background
- **Filtration Processing Fundamentals**
 - Shared Learning
- **New Fundamentals?**
 - Artificial Intelligence & Membrane Processing
- **Revisiting Last Year’s Talk**
 - Pilot Research and Student Development



WHY I'M INTERESTED IN THE "WHY"

- Not just because my 3-yo is asking it incessantly lately
- Educational Aspect
 - Student and Colleague Understanding of Topics
- Conflict Resolution
 - Break through impasse through mutual understanding
- Development of New Ideas
 - Generate questions
- The What comes through the Why

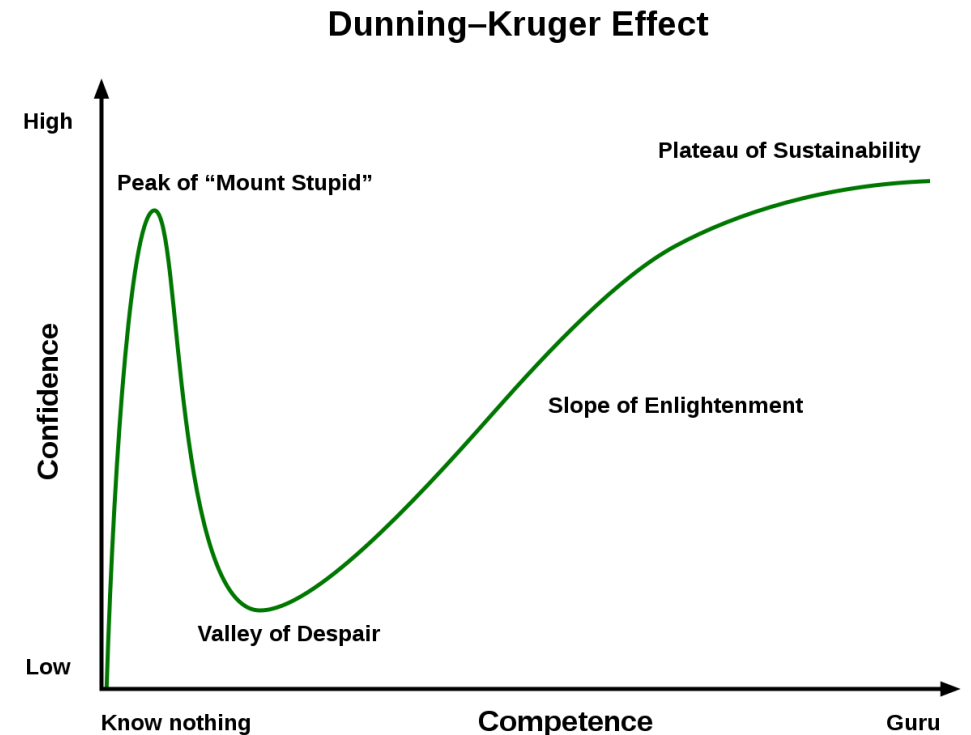


Buckle in.. You can be my students for awhile!



“WHY” THIS PRESENTATION

- **Why present about the fundamentals of membrane processing?**
 - Mutual foundation of understanding for attendees
 - Wholistic view of processes
 - Give conference attendees ability to share a common vocab and understanding to better acquire knowledge from time listening
 - We are here at MTF to ask the ‘WHY’ of the presentations and information
- **Let’s dive deeper into the fundamentals...**
 - Focusing on some ‘why’ questions I get a lot



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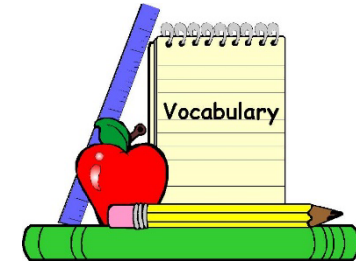


FILTRATION *FUNDAMENTALS*

Overview Of Topics

- **Shared Lexicon**

- Let's define some common vocabulary terms



- **Filtration Basics**

- Membranes & Their Characteristics

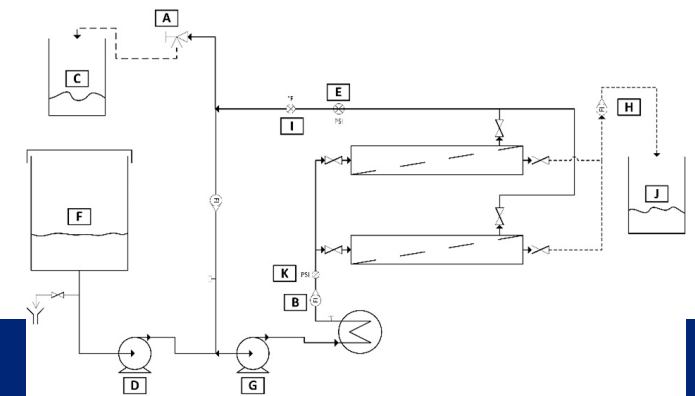


- **Important Processing Variables**

- Pressure, Flow, Temperature, Time
- Concentration Factor and Diafiltration (*common 'why' ?'s)
- Operational Design

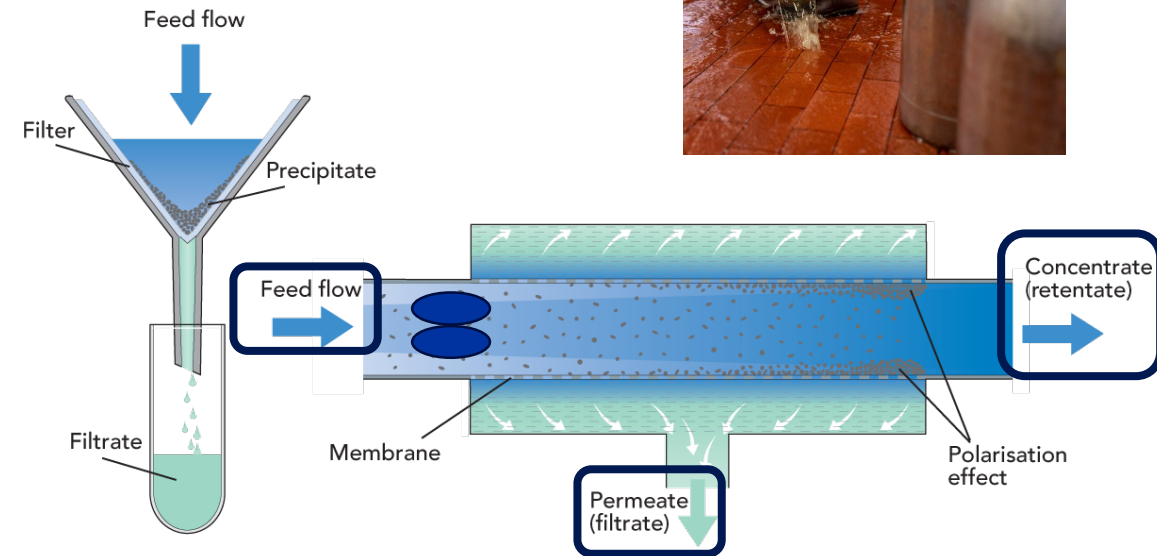
- **Additional Considerations**

- CIP and Durability

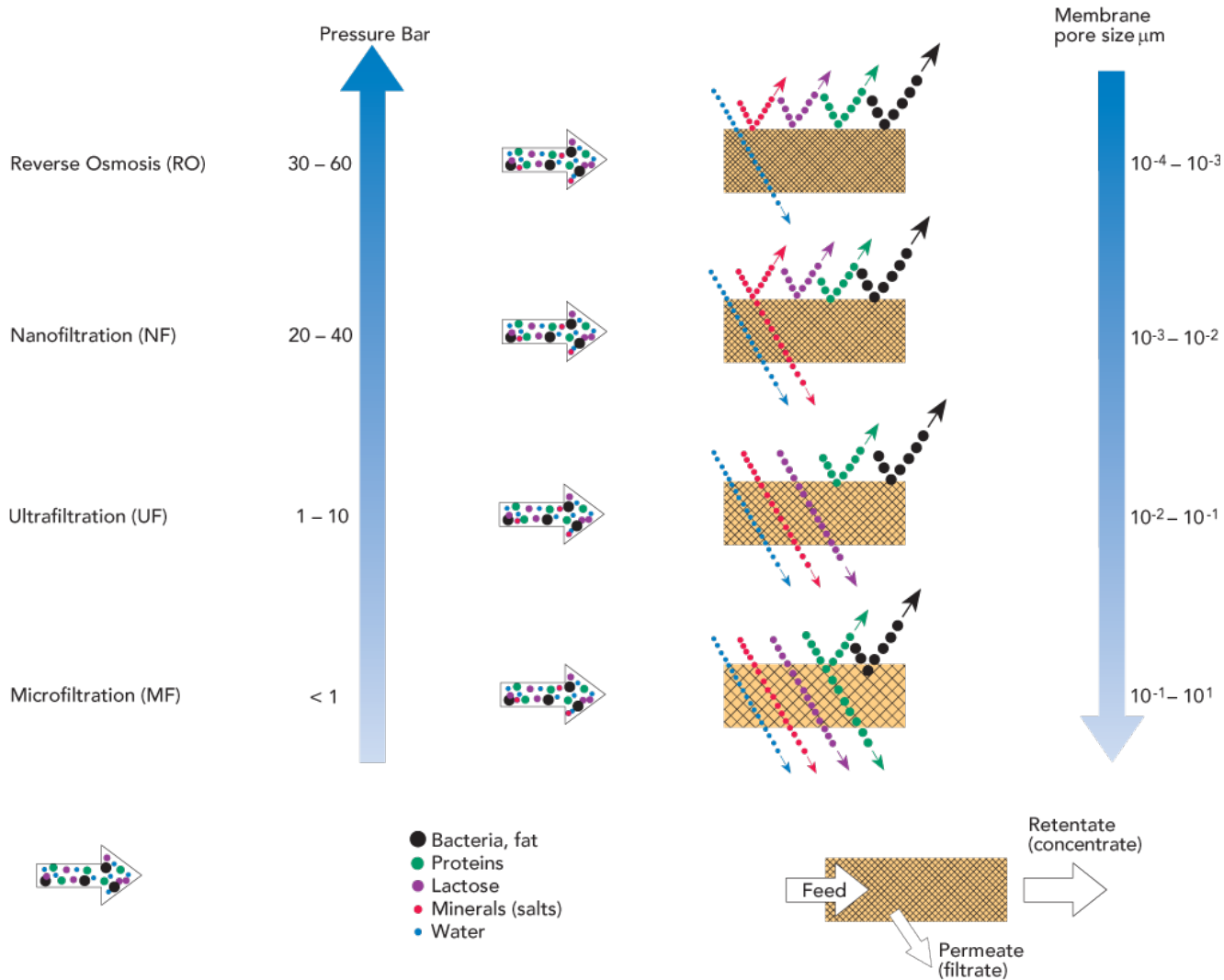


FILTRATION *FUNDAMENTALS* - VOCAB

- **Feed**
 - Material or solution fed to membrane to be fractionated
- **Retentate or Concentrate**
 - Retained portion of Feed, after interaction with membrane
- **Permeate**
 - Portion of Feed that goes through membrane
- **Flux**
 - Permeate flow rate per unit membrane surface area (e.g., L/m²/h)
- **Fouling**
 - Feed composition material that deposits on, or near, membrane surface
 - Reversible or irreversible
- **Crossflow**
 - Tangential movement of feed/retentate across surface of membrane



FILTRATION *FUNDAMENTALS* - BASICS



■ Membrane

- Selectively permeable layer
- Polymer (organic), Inorganic, or combination
- Asymmetric design

■ Pore Size or Molecular Weight Cutoff

- Guides selection of process to use and equipment to run

From: Dairy Processing Handbook – Tetra Pak



FILTRATION *FUNDAMENTALS* - BASICS

Your Mileage Will Vary...

- **Membrane Composition**

- Hydrophobicity, Compatability

- **Element Design & Construction**

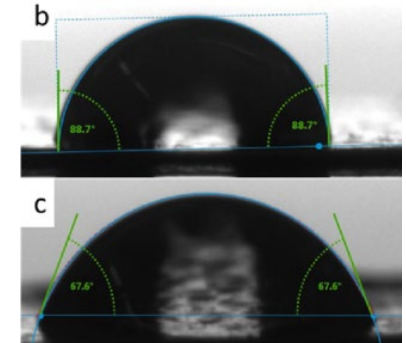
- Spiral-wound, Tubular (Hollow Fiber, Ceramic), Plate & Frame

- **Feed Spacer**

- Material, Design, Shear, Turbulence

- **Robustness**

- Mechanical, Chemical



<https://doi.org/10.3390/membranes9020032>



FILTRATION *FUNDAMENTALS* - VARIABLES

Trust the Process...

▪ Pressure

- TMP and Pressure Drop (ΔP)



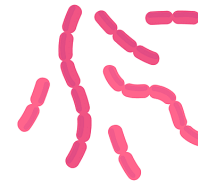
▪ Crossflow

- Velocity needed, but element dictates capabilities



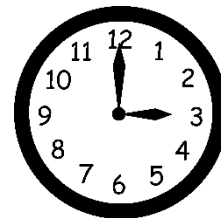
▪ Temperature

- Impacts component solubility & viscosity
- Microbiological issues (20h)



▪ Time

- Processing time has impacts



**Let's review the common
'Why' questions I get?**



FILTRATION *FUNDAMENTALS* - PROCESSING

Concentration Factor

- **Concentration Factor = $\text{Feed}_{\text{qty}} / \text{RET}_{\text{qty}}$**
 - Typically, said as “# x” concentration factor.
 - E.g., 100 kg Milk yields 20 kg RET; CF = 5.0x
- **Know your Basis**
 - Know what your basis is (any economists?), then calculate CF
- **What is the CF based on?**
 - Mass (lb or kg), Concentration of a component (% protein), Flowrate (gpm)

How about an example?



FILTRATION *FUNDAMENTALS* - PROCESSING

Concentration Factor – 2x Skim milk EXAMPLE (Basis)

Start with 100 kg Skim Milk

Skim Milk Composition

Component	Skim (%)	Permeable? (UF / RO)
Water	90.5%	Y / Y
Carbohydrates	5.0%	Y / N
Protein	3.5%	N / N
Minerals / Ash	0.9%	Y / N
Fat	0.1%	N / N

ULTRAFILTRATION

- UF 2x by mass
 - 100 kg / 2x = 50 kg RET with 2x protein and 1x carbohydrates
- UF RET
 - Protein = 7.0%
 - Carbs = 5.0%

REVERSE OSMOSIS

- RO 2x by mass
 - 100 kg / 2x = 50 kg RET with 2x protein and 2x carbohydrates
- RO RET
 - Protein = 7.0%
 - Carbs = 10.0%

***Need shared understanding of component of interest**



FILTRATION *FUNDAMENTALS* - PROCESSING

Concentration Factor - Permeability

▪ “Permeable” Components & CF Basis

- One of most difficult for me to learn was about mass balance and how determining which component of interest is being concentrated

Component	(% wt/wt	Permeable?			
		MF	UF	NF	RO
Water	90.5%	Y	Y	Y	Y
Carbohydrates	5.0%	Y	Y	Y & N	N
Protein	3.5%	Y & N	N	N	N
Minerals / Ash	0.9%	Y	Y	Y & N	N
Fat	0.1%	N	N	N	N

Next: Permeability and Diafiltration



FILTRATION *FUNDAMENTALS* - PROCESSING

Diafiltration (DF) - Overview

- **Purification of RET**

- Washes out permeable components
- Common diluent = Water. Others include downstream permeates or buffers.

- **Know your Basis**

- DF on feed? DF on retentate stage?
- Location of DF in process impacts process efficiency (mass, physical properties)

- **Examples**

- Where DF is added in the process
- Basic DF calculation in UF Skim milk



FILTRATION *FUNDAMENTALS* - PROCESSING

Diafiltration – Basis for Clarity

Add 100 kg of DF Water

Component	Skim (%)	2x UF Skim (%)
Water	90.5%	86.9
Carbohydrates	5.0%	5.0%
Protein	3.5%	7.0%
Minerals / Ash	0.9%	0.9%
Fat	0.1%	0.2%
Total Solids	9.5%	13.1%
Mass (kg)	100 kg	50 kg

IF ADD TO SKIM:

- Before UF
- 100% DF on Feed Basis

▪ MPC Purity: 

IF ADD TO 2X UF SKIM:

- After stage 2 of UF
- 100% DF on Feed Basis, or 200% DF on stage Basis

▪ MPC Purity: 

Be clear what basis for DF addition you're working with




FILTRATION *FUNDAMENTALS* - PROCESSING

Diafiltration – Calculating Total DF

Component	Skim (%)	UF Permeable?
Water	90.5%	Y
Carbohydrates	5.0%	Y
Protein	3.5%	N
Minerals / Ash	0.9%	Y
Fat	0.1%	N

- **Want MPC80**
 - Starts with MPC37
 - $3.5\% / 9.5\% = 37$

Good Info to Have:

-  **RET %TS at end of UF**
 - 25% TS
- **Find Permeable Solids**
 - $5.0 + 0.9 = 5.9\%$

- MPC80 @25%TS = $0.8 * 25 =$ target 20% Protein in RET
- $25\% - 20\% = 5\%$ *this is what we have to reduce Permeable Solids to (5.9->5.0)
- $[(5.9 / 5.0) - 1] * 100\% = 18\%$ (wt/wt) water added to quantity to reduce PS
- Add calculated water, then UF to final RET %TS (25%)



FILTRATION *FUNDAMENTALS* - VARIABLES

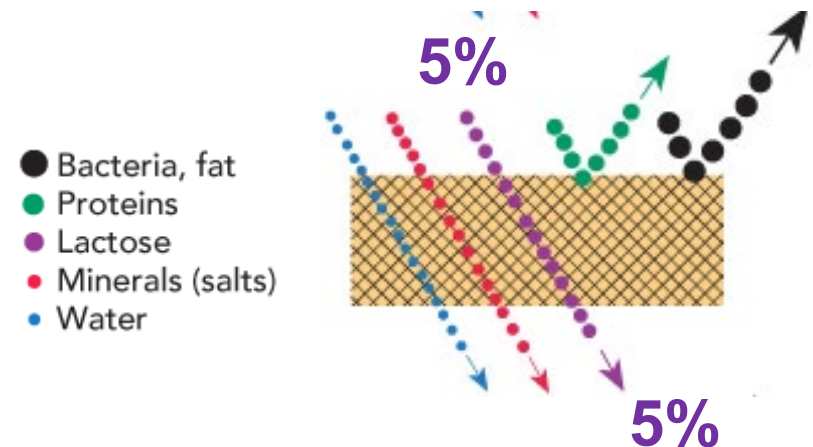
Diafiltration – “Permeable Solids” Explainer

▪ Permeable Solids

- Components in Feed that can freely pass through membrane selective layer

▪ **BIG ASSUMPTION (for calculation purposes)**

- For permeable solids: Concentration (%) of component will be equal on RET and PERM side of membrane
 - E.g., Lactose @ 5% during UF of milk



FILTRATION *FUNDAMENTALS* - VARIABLES

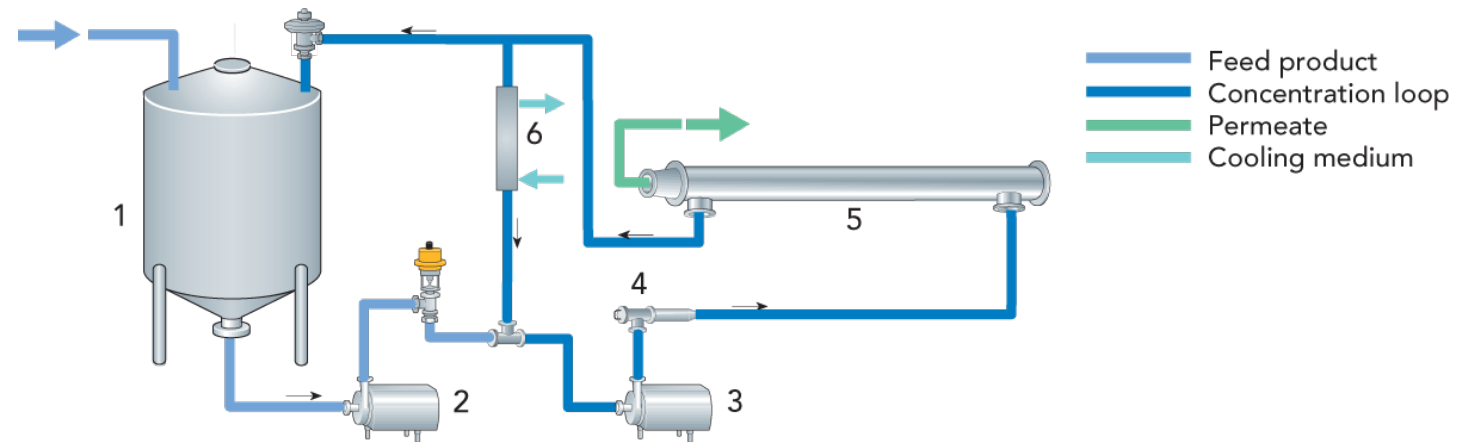
Other Processing Variables - Operational Design

▪ Batch

- Reduced Capacity
- True Batch, Fed Batch
- Manual Diafiltration

▪ Continuous

- Stage Designs
- Higher Throughput
- Inline Diafiltration capabilities



FILTRATION *FUNDAMENTALS* - LONGEVITY

Membrane Processing - Additional Considerations

- **Cleaning of Membranes and Systems**
 - Water & Chemical Use
 - Time needed
 - Safety & Sanitation
 - Equipment design can be more important than membrane selection, as far as safety and sanitation

- **Durability**
 - Materials

- **Search for CI (*continuous improvement*)**
 - Industry, and membrane process specific



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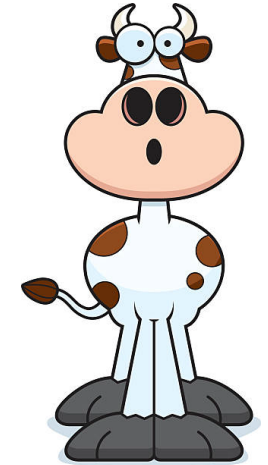


SWITCHING GEARS - WHY THE AI?

AI – Change Agent

▪ What is AI?

- Artificial Intelligence = Computer systems able to perform tasks that normally require human intelligence
- Essentially a computer that can rapidly access available data to formulate an answer



▪ Why Should I Care?

- Embrace the change
- Rapid development and dissemination of AI is already changing our daily lives



AI's Impact on Our Industry? – Let's Ask

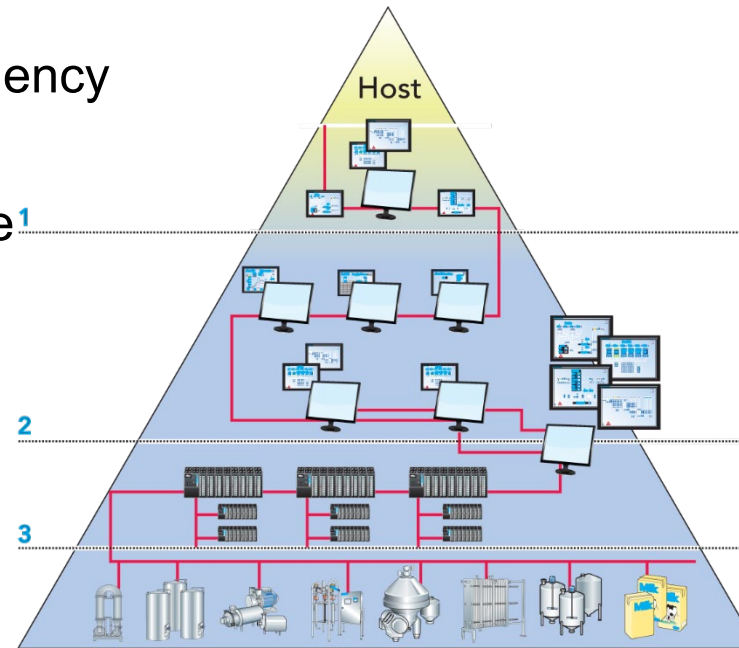


WHY THE AI?

That's What ChatGPT Said....

▪ How will AI change membrane filtration for food processing?

- Optimization & Efficiency
 - Analyzing real-time data to adjust for efficiency
- Predictive Maintenance
 - Monitor system, and suggest maintenance¹
- Quality Control
 - Safety and Quality
- Process Monitoring
 - Can alert humans if out-of-spec alert
- Adaptive Filtration
 - Adjust based on selected factors
- Data-Driven Decision Making
 - Find correlations and trends not readily apparent to human operators



WHY THE AI?

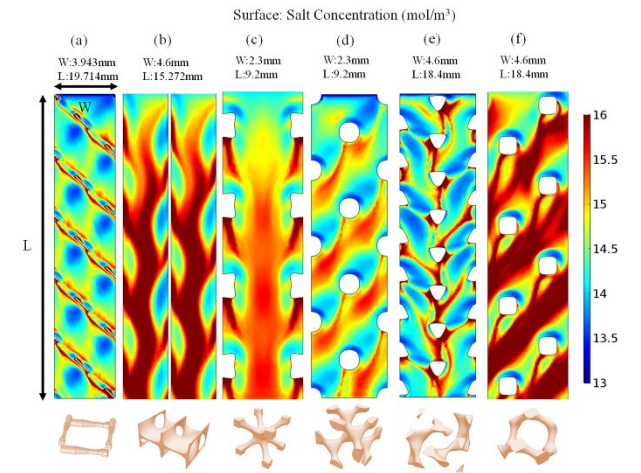
The Time Machine

■ What's Next With AI?

- Membrane and Equipment Construction & Design (e.g., CFD)
- Membrane Processing Research and Empirical Data
- Associated industries (e.g., farming, dairy production, waste mitigation)

■ Caution Ahead

- Dependent on measurement of, and access to, **data**
- Still need humans
- Who/what determines if AI suggestion is correct?
- Good questions and training data for accuracy



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REVISITING MTF22 (BRIEFLY)

▪ Pilot Trials for Membrane Research

- Six P's of Pilot Planning
- K.I.S.S. (Keep It Simple, Silly)

▪ Recruiting New Students

- Labor Challenges Continue
- Value Model of Education
- Keep Getting Hands-On



Let's Get to Work!
Six P's for Pilot Trials, and Recruiting for
the Next Generation of Our Industry

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WRAP-UP: BIG PICTURE

Key Takeaways

- **Learn and Teach the “Why”**
- **Have a common vocabulary, even if you have to make it up**
- **Potential impacts of AI in our industry**
- **K.I.S.S.**
- **Keep reaching out to prospective students**



THIS IS MY WHY...



THANK YOU!

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**SOUTH DAKOTA
STATE UNIVERSITY**
Department of Dairy
and Food Science

THANKS FOR YOUR TIME!

“Tell me and I forget. Teach me and I remember. Involve me and I learn”

– Benjamin Franklin

“I have no special talent. I am only passionately curious”

– Albert Einstein

