Jason Bell, Chief Applications Scientist
SmartFlow Technologies

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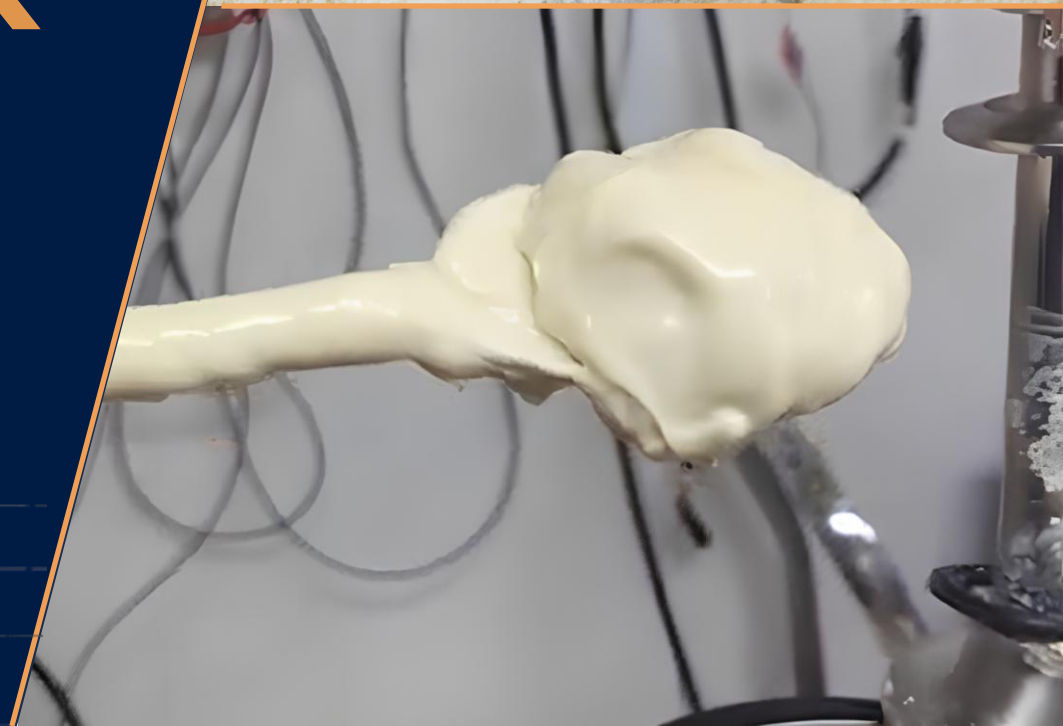
Concentrating Nature's Bioactivity™

Breaking the Practical Solids Limit in Dairy UF Systems to Unlock Dryer Capacity

How viscosity and fluid dynamics influence practical concentration limits in dairy ultrafiltration systems.



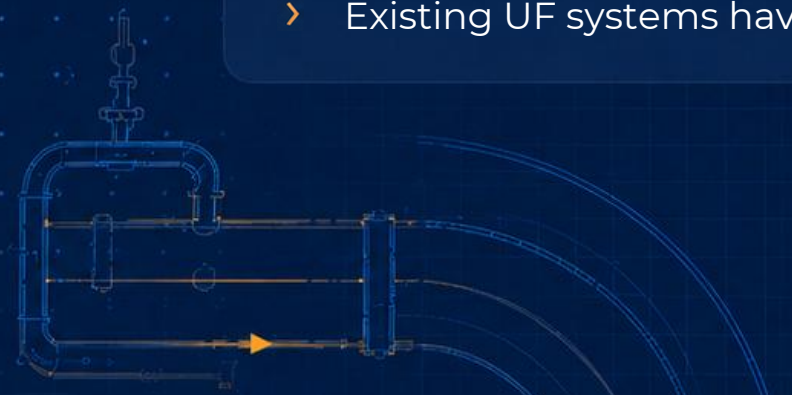
Membrane Technology Forum – Minneapolis 2026

Dairy UF Already Works Well

Existing Systems Are Highly Developed

- **Dairy UF systems are already highly optimized**
- **5 kDa, 10 kDa, and 20 kDa systems are widely established**
- **Protein retention and product quality are already very strong**
- **Spray dryers often become the plant bottleneck**

- Membrane performance is well understood
- Product quality targets are routinely achieved
- Existing UF systems have enabled significant industry growth



> ***The challenge at elevated solids increasingly becomes one of viscosity and hydraulic management.***

The Practical Solids Limit

Where Practical Limits Begin to Appear

Viscosity rises rapidly as solids concentration increases

Pressure losses escalate quickly

Recirculation becomes harder to maintain

Operating windows narrow significantly

- Fouling behavior accelerates
- Pumping and circulation become less stable
- Small hydraulic changes create larger process effects

> ***Most dairy UF systems eventually encounter a practical solids limit where stable operation becomes increasingly difficult as viscosity rises.***

What Changes at Elevated Solids?

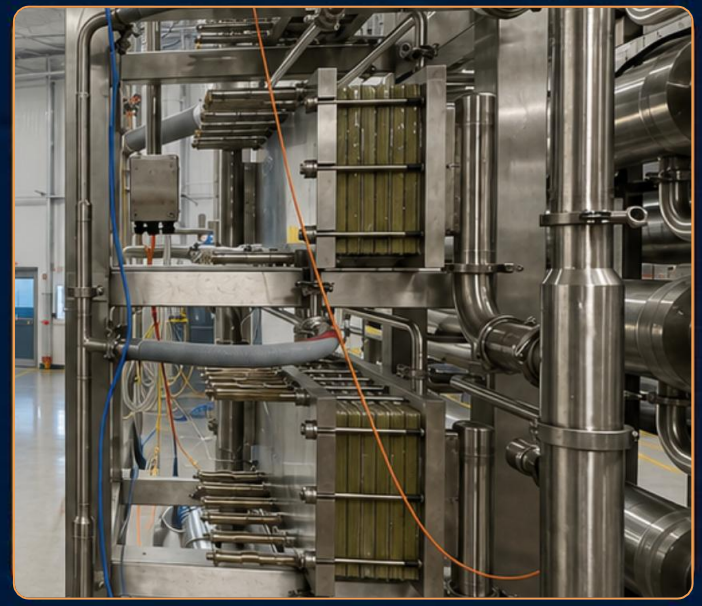
Flow Behavior Begins to Change

Lower Solids Operation

- More uniform flow distribution
- Stable recirculation
- Easier hydraulic management

Elevated Solids Operation

- Pressure-drop escalation
- Flow maldistribution begins to develop
- Hydraulic sensitivity increases
- Operating windows narrow rapidly



Many high-solids dairy streams exhibit shear-thinning behavior

Viscous fluids seek the path of least resistance

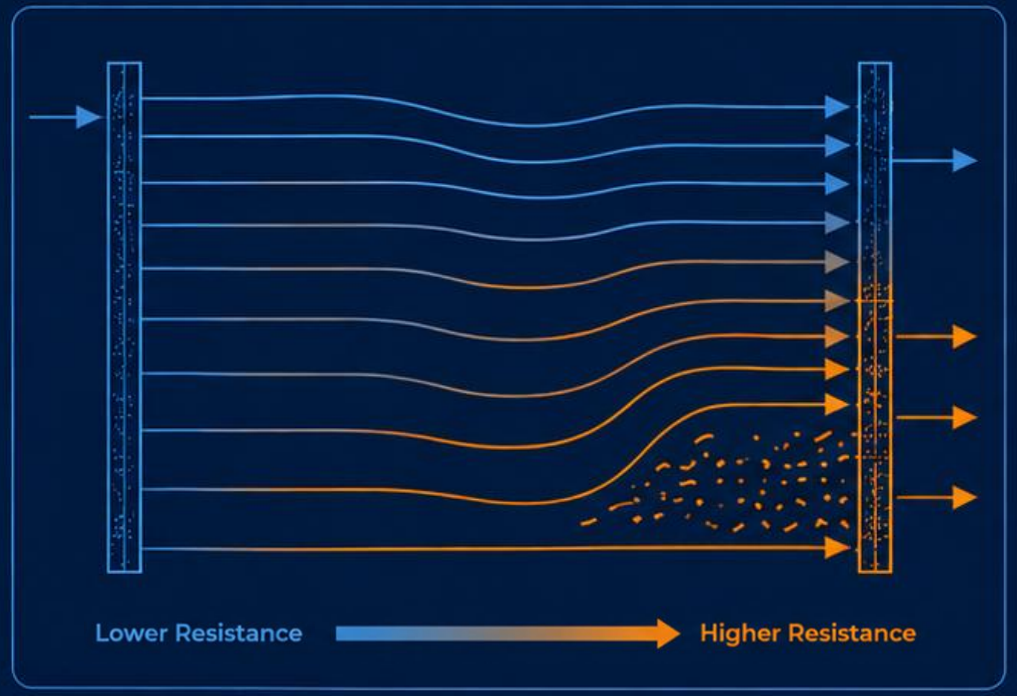
Portions of the membrane surface become underutilized

Effective membrane utilization decreases as flow distribution becomes less uniform

As viscosity rises, maintaining controlled and uniform fluid movement becomes increasingly important.

Why the Practical Solids Limit Develops

Hydraulic Restriction and Flow Maldistribution



- Compact flow paths become increasingly sensitive at elevated viscosity
- Fluids begin seeking lower resistance pathways
- Flow maldistribution reduces effective membrane utilization
- Stable recirculation becomes progressively harder to maintain

- Small hydraulic differences become amplified
- Flow instability increases late in concentration
- Fouling and hydraulic instability can compound together

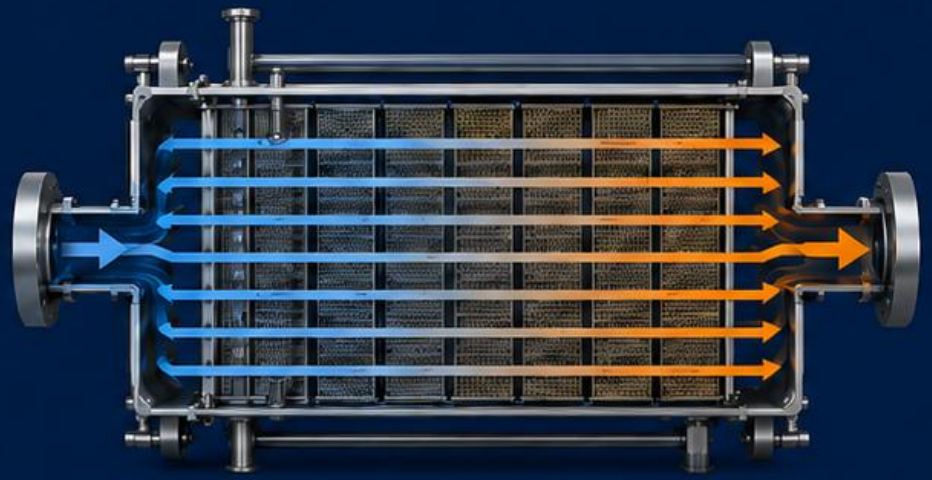
> ***In many systems, the practical limit is reached when hydraulic stability begins to deteriorate.***

Controlled Fluid Dynamics

Alternative Hydraulic Approaches

- Internal fluid dynamics become increasingly important at elevated solids
- Larger hydraulic flow paths can improve circulation stability
- Better flow distribution reduces maldistribution effects
- Controlled recirculation improves membrane utilization

Controlled, Uniform Flow Paths



Uniform distribution → Stable recirculation → Effective filtration

- Reduced hydraulic restriction
- Improved recirculation stability
- Better control of shear exposure through the filtration path
- Better management of high-viscosity, shear-sensitive flow behavior

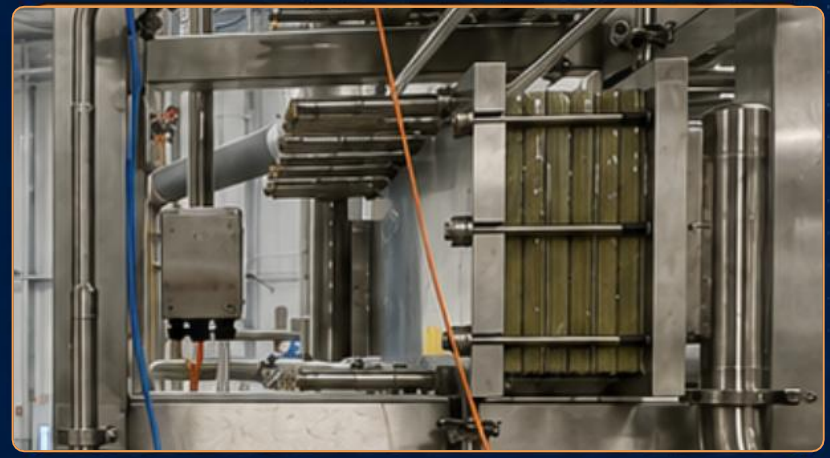
> ***At elevated solids, maintaining controlled fluid dynamics within the filtration device becomes critical.***

Observed High-Solids Behavior

Pilot Evaluations of Dairy Protein Concentrates

Observed Trends

- Hydraulic sensitivity increased significantly at elevated solids
- Flow instability increased late in concentration
- Improved hydraulic control enhanced late-stage operability
- Stable concentration was maintained without gel transition in evaluated runs
- Stable operation was maintained deeper into concentration than typically expected for comparable protein streams



Generalized Data

- Representative of MPC80+ concentration behavior
- Starting solids: ~20–25%
- Final solids: low to mid-30's %DM
- Steady flux: ~24 hrs. between CIP
- Final flux: ~5 LMH range
- Similar hydraulic behavior has also been observed during commercial-scale operation

Why This Matters

Plant-Level Implications

- Additional upstream water removal reduces dryer load
- Existing dryer assets become more productive
- Higher feed concentrations allow dryers to operate closer to their practical viscosity limits
- Additional mechanical water removal reduces thermal water removal demand

More Upstream Water Removal → Less Dryer Load → More Productive Dryer Assets

- Atomization and spray behavior become increasingly sensitive at elevated viscosity
- Higher concentration feeds allow the dryer to operate deeper into its available operating window
- Potential deferment of dryer expansion projects

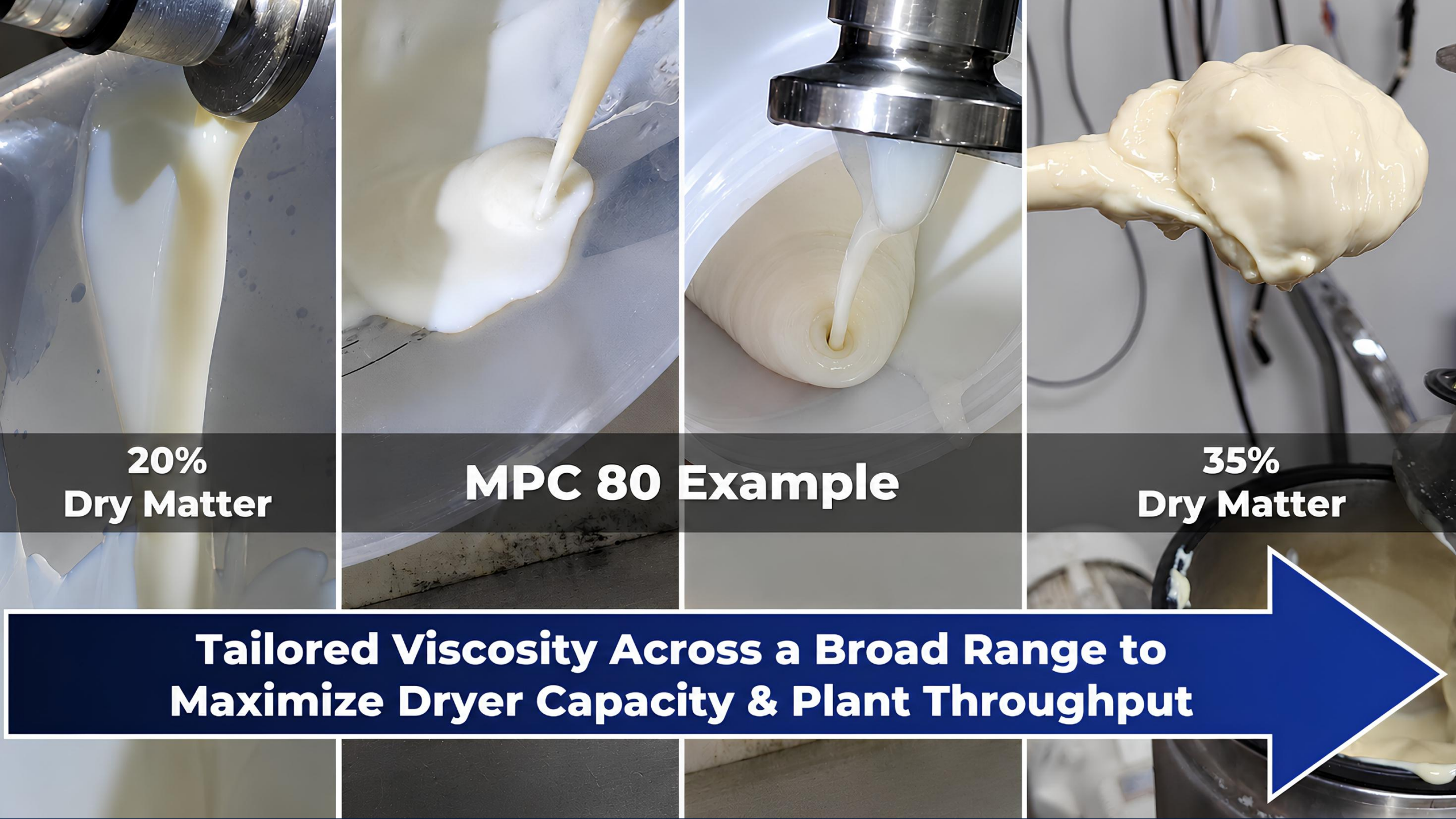
> ***"Removing more water upstream allows existing drying assets to process more product before capacity expansion becomes necessary."***

Unlocking Additional Dryer Capacity Through Higher Solids Concentration

- Traditional concentration endpoints are often driven by operability limits rather than membrane performance
- Fluid management becomes increasingly important as viscosity rises
- Maintaining stable recirculation can extend practical concentration ranges
- Higher concentration feeds can improve utilization of existing dryer assets

- More water removed mechanically
- Less water removed thermally
- Improved utilization of existing infrastructure
- Potential for increased powder production without major dryer expansion

> ***The practical solids limit is often determined by hydraulic stability rather than membrane capability.***


20%
Dry Matter
MPC 80 Example
35%
Dry Matter
Tailored Viscosity Across a Broad Range to
Maximize Dryer Capacity & Plant Throughput

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> ***The opportunity isn't simply to concentrate further.***
>
> ***The opportunity is to maintain stable operation at elevated solids so existing plant assets can be utilized more effectively.***

Questions?

Jason Bell
Chief Applications Scientist
SmartFlow Technologies

Jbell@smartflow-tech.com
919-522-8780
www.smartflow-tech.com

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