PROCESS INTENSIFICATION USING HOLLOW FIBERS FOR SINGLE-PASS TANGENTIAL FLOW FILTRATION

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Abstract

- SepraPor® hollow fiber tangential flow filters can be implemented in series to achieve continuous process intensification.
- An analytical model was developed to predict filtration performance and aid in designing best-fit SPTFF assemblies.

Single-Pass Tangential Flow Filtration (SPTFF)

Batch - Recirculation Mode

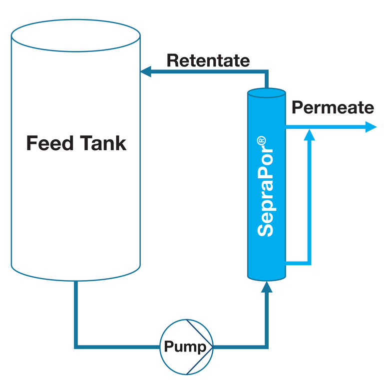
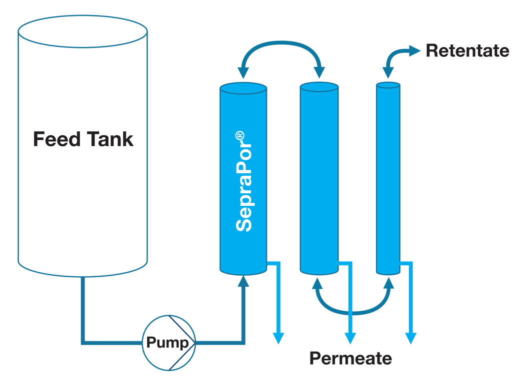


Figure 1. Solution from a feed tank is recirculated through a TFF filter until it reaches the desired concentration.

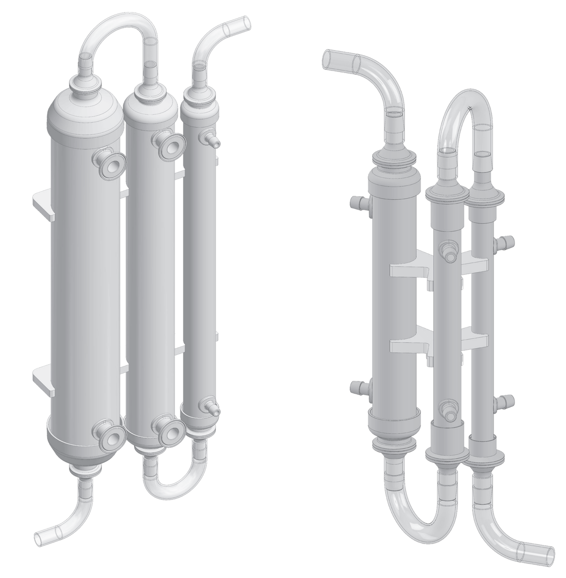
Continuous - SPTFF



Advantages:

1. Reduce fluid volumes for storage and tank requirements
2. Intensify subsequent processes, such as chromatography
3. Steady-state, continuous flow

Figure 2. Solution from a feed tank or initial processing step is fed through a series of TFF filters, concentrating the solution, before being fed directly into a secondary processing step.



Inherent flexibility with hollow fiber filters

Fiber Lumen

Fiber Count

Path Length

Figure 3. Examples of potential hollow fiber SPTFF assemblies.

Analytical Model

Continuous Open – Shell Model

Gel layer model considers concentration polarization

Assumptions

1. Laminar flow (Re < 2000)
2. Flow distributed uniformly among the fibers
3. Fluid is Newtonian

Q: Inlet flow rate

P: Pressure

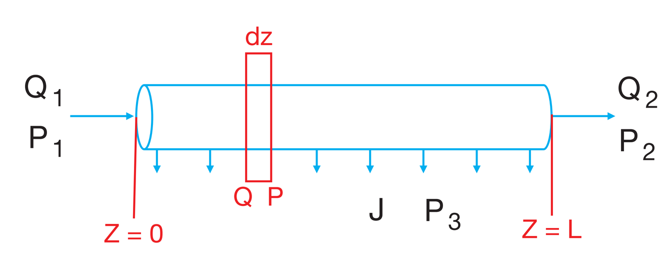
J: Permeate flux

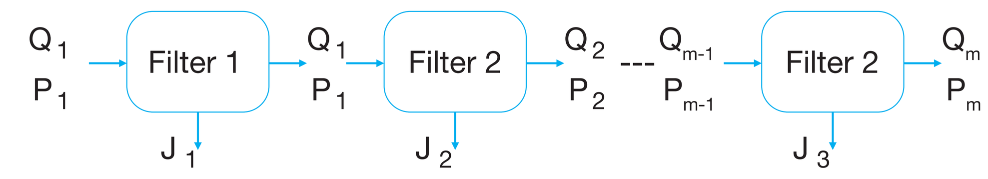
VCF: Volumetric conversion factor

di: Fiber lumen

dw: Membrane wall thickness

κ: Permeability





Individual Fiber

Mass Balance $\frac{dQ}{dz} = -\pi d_i J$

Permeate Flux (m/s)

Momentum Balance $\frac{dP}{dz} = -\frac{128\mu Q}{\pi d_i^4}$

Dimensionless Form

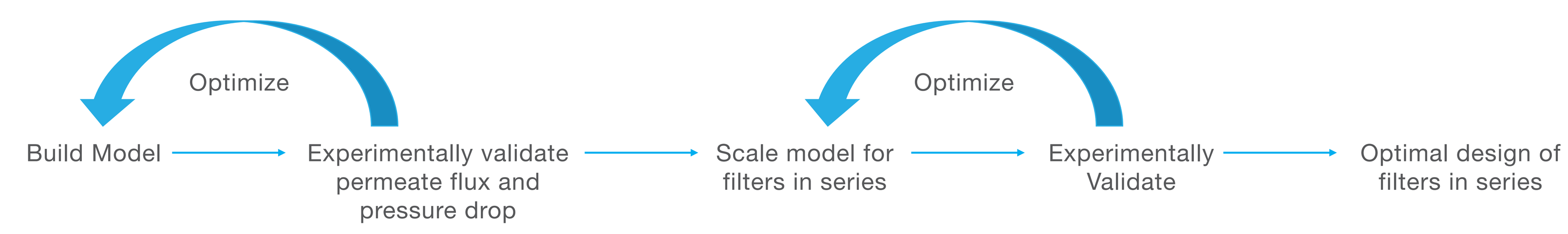
$z' = \frac{z}{L}$ $P' = \frac{P - P_3}{P_1 - P_3}$

$Q' = \frac{128\mu L}{\pi d_i^4 (P_1 - P_3)}$ $T_L = \frac{128\kappa L^2}{d_i^3 d_w}$

Filters in Series

$$Q'_m = [VCF_i] * Q'_{m-1}$$

$$Q'_m = \frac{n_1 \sqrt{128\kappa L^2 / d_i^3 d_w}\, \sinh\left(\sqrt{128\kappa L^2 / d_i^3 d_w}\right)}{VCF \times \cosh\left(\sqrt{128\kappa L^2 / d_i^3 d_w}\right) - 1}$$



Experimental Model Validation

The model was initially validated using water flux experiments with samples of varying porosity ratings, effective filtration areas, and fiber lumen diameters. **Figures 4 and 5** show that the experimental data closely followed the analytical model predictions for permeate flow rate and pressure drop across the sample filters.

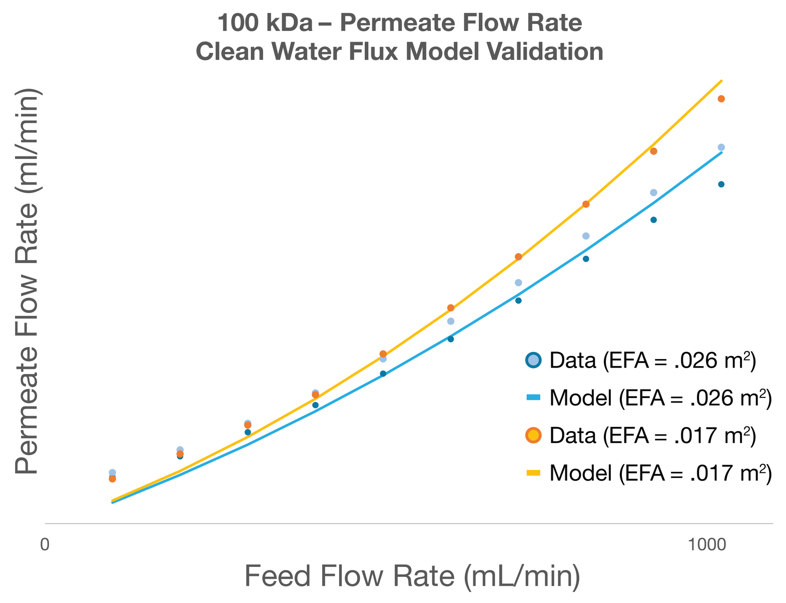


Figure 4. Permeate flow rate vs feed flow rate experimental data from 100 kDa, 1 mm lumen sample filters with varying effective filtration area compared to the analytical model prediction.

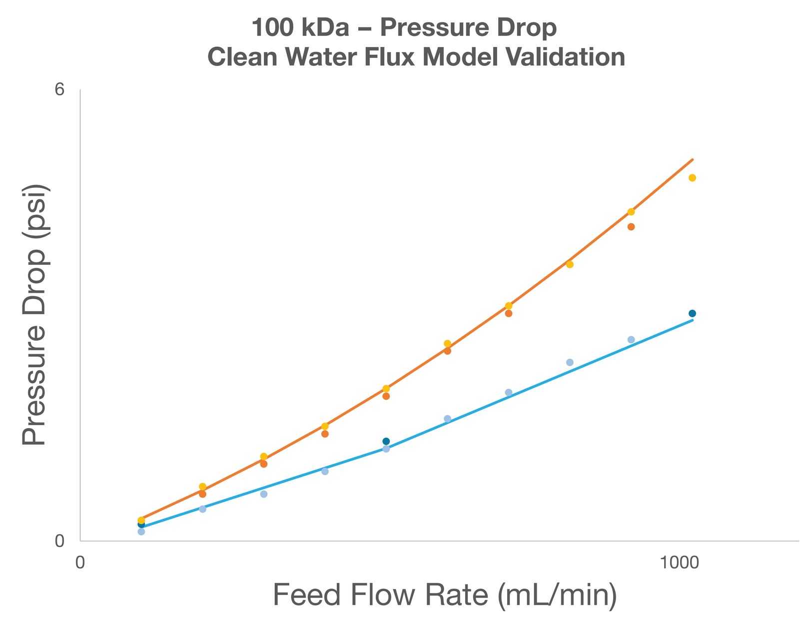


Figure 5. Pressure drop vs feed flow rate experimental data from 100 kDa, 1 mm lumen sample filters with varying effective filtration area compared to the analytical model prediction.

Performance Optimization

Pressure optimization curves are necessary for increasing the filtration performance of the SPTFF assembly. Concentration polarization results in a filtration plateau after reaching an optimal TMP. This is caused by the formation of a gel layer of more concentrated solution than the bulk fluid due to concentration polarization. **Figure 6** shows the performance of a clean water experiment, with no concentration polarization, versus the filtration optimization of a 0.23 wt % aqueous PVP K-90 solution.

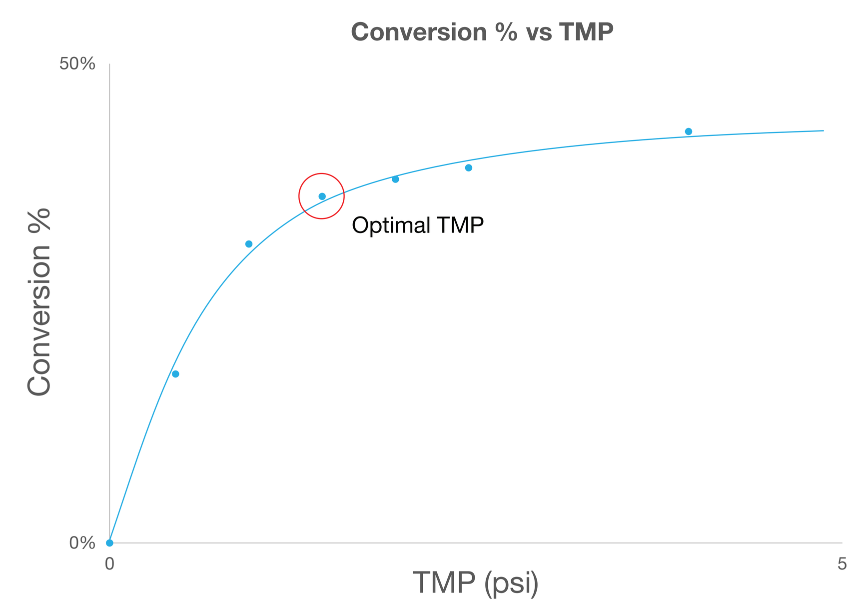


Figure 6. TMP optimization curves for 0.23 wt% PVP K-90 aqueous solution and clean water at a feed flow rate of 10 mL/min with a 100 kDa, 1 mm lumen filter.

Future Outlook

Given	Best-fit SPTFF Assembly
Concentration Factor Solution Viscosity Membrane Porosity Feed flow rate and/or Shear Rate Range	Optimal TMP for filtration performance and effective filtration area that will achieve the desired concentration factor

Collaboration Opportunities

To collaborate with Meissner and to discuss how SPTFF could be used for your process intensification, contact:

Thomas Lazzara, Director of R&D
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References

Baker, Richard W. "Concentration Polarization." Membrane Technology and Applications, 3rd ed., Wiley, Hoboken, NJ, 2012.

Bruining, W.J. "A general description of flows and pressures in hollow fiber membrane modules." Chemical Engineering Science, vol. 44, no. 6, 8 Dec. 1989, pp. 1441–1447, https://doi.org/10.1016/0009-2509(89)85016-x.

Huter, Maximilian Johannes, et al. "Model validation and process design of continuous single pass tangential flow filtration focusing on continuous bioprocessing for high protein concentrations." Processes, vol. 7, no. 11, 2019, p. 781, https://doi.org/10.3390/pr7110781.

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