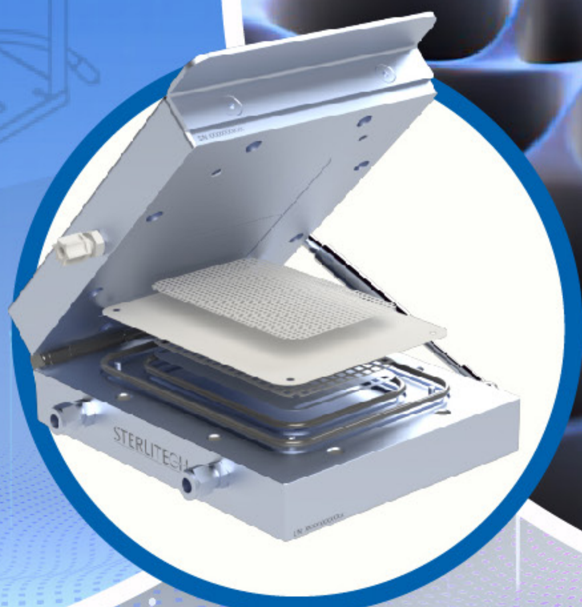
STERLITECH
Corporation

Cross/Tangential Flow Filtration Handbook



About this Handbook

The Cross/Tangential Flow Filtration Handbook gives a general introduction to the principles and applications of crossflow filtration using systems and filters from Sterlitech. Detailed instructions for product storage, preparation, usage, and maintenance are included.

1. Introduction

The use of membranes to perform separation with the intention of concentrating, recovering, or purifying is a common filtration technique used in a range of fields and industries. Referred to as crossflow filtration in water treatment applications, it's more commonly known as tangential flow in biological field studies , however, both operate along the same principles.

1.1 What is Crossflow/Tangential Flow Filtration?

Crossflow filtration (CFF), also known as tangential flow filtration (TFF), is a filtration technique in which the feed solution passes tangentially along the surface of the filter. Some of the feed stream will permeate through the membrane while the rest will continue to flow through the system as a concentrate (see Figure 1.1).

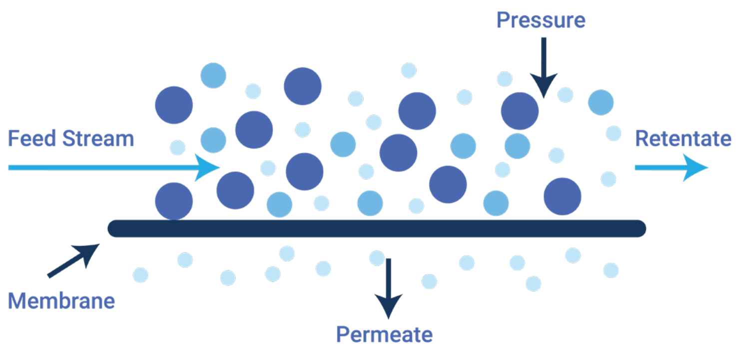


Figure 1.1 Tangential/Cross Flow Filtration

Solution that is directed to the membrane surface is called the feed. Solution that passes across the membrane is the permeate. Solution that passes along the membrane surface and back to the feed reservoir is called the concentrate, or retentate. This solution is usually pumped back to the feed reservoir and recirculated.

Table 1.1 provides examples of studies, which utilized Sterlitech CFF/TFF cells in their studies and are listed here to illustrate the potential applications. These studies are good references for understanding the operation of Sterlitech's CFF/TFF cells.

1.2 Difference between CFF/TFF and Dead-End Filtration

Dead-end filtration, or direct flow filtration (DFF), is another common filtration method, which operates without a crossflow component to the feed stream (see Figure 1.2). The bulk feed flow is transverse (perpendicular) to and towards the membrane surface during dead-end filtration, so all non-permeable substances accumulate on the membrane during the filtration cycle and are removed during the backwash cycle. The greater substance accumulation usually results in lower average flux values than those achieved by crossflow filtration

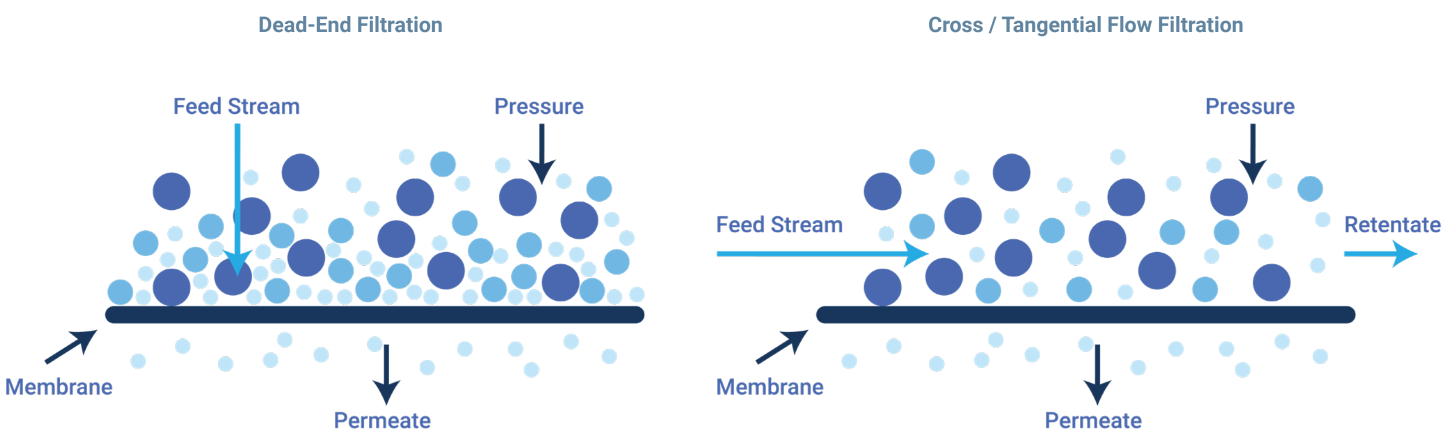


Figure 1.2 Comparison of Dead End Filtration and Cross / Tangential Flow Filtration

In CFF/TFF, the crossflow/tangential flow across the membrane reduces the fouling rate by increasing the back transport of fouling agents from the membrane surface, through inertial lift, surface drag, and shear diffusion mechanisms. The feed's flow direction also reduces the concentration polarization formed at the membrane surface, further reducing the membrane's fouling rate. In addition, the retentate solution can easily be recirculated, allowing thorough processing of large volumes of solution.

There are several advantages to using the CFF/TFF process:

- Lower energy consumption which leads to reduced operating cost
- Fewer chemical additives required to remove impurities (e.g. flocculants for wastewater treatment)
- Improved in production efficiency and quality control
- Processes can be scaled depending on sample size
- Membrane housings accommodate a range of coupon sizes

1.3 Common CFF/TFF Applications

Sterlitech's CFF/TFF filtration kits, systems, and skids provide users with a comprehensive solution compatible with a wide range of applications within markets including but not limited to water treatment, membrane research and development, waste management, chemical production, food & beverage, biopharmaceutical, and medical. They are designed to be versatile enough to meet the dynamic needs of researchers and engineers alike and are ideal for research and development, small-batch processing, and simulating larger commercial processes.

Table 1.1 provides examples of studies, which utilized Sterlitech CFF/TFF cells in their studies and are listed here to illustrate the potential applications. These studies are good references for understanding the operation of Sterlitech's CFF/TFF cells.

Pump	Membrane Process	Reference
Desalination	FO	Eddouibi, J., Abderafi, S., Vaudreuil, S. and Bounahmidi, T., 2021. Water desalination by forward osmosis: Dynamic performance assessment and experimental validation using MgCl2 and NaCl as draw solutes. Computers & Chemical Engineering, 149, p.107313.
Watewater Treatment	MF	Echakouri, M., Salama, A. and Henni, A., 2021. Experimental and computational fluid dynamics investigation of the deterioration of the rejection capacity of the membranes used in the filtration of oily water systems. ACS ES&T Water, 1(3), pp.728-744.
Membrane Development	MF/UF	Chen, X., Huang, G., An, C., Feng, R., Wu, Y. and Huang, C., 2019. Plasma-induced PAA-ZnO coated PVDF membrane for oily wastewater treatment: Preparation, optimization, and characterization through Taguchi OA design and synchrotron-based X-ray analysis. Journal of Membrane Science, 582, pp.70-82.
Membrane Development	Nano-composites	Alawady, A.R., Alshahrani, A.A., Aouak, T.A. and Alandis, N.M., 2020. Polysulfone membranes with CNTs/Chitosan biopolymer nanocomposite as selective layer for remarkable heavy metal ions rejection capacity. Chemical Engineering Journal, 388, p.124267.
Brine Concentration	NF	Korak, J.A., Flint, L.C. and Arias-Paić, M., 2021. Decreasing waste brine volume from anion exchange with nanofiltration: implications for multiple treatment cycles. Environmental Science: Water Research & Technology, 7(5), pp.886-903.
Water Treatment	RO/NF	Mortensen, E.R., Cath, T.Y., Brant, J.A., Dennett, K.E. and Childress, A.E., 2007. Evaluation of membrane processes for reducing total dissolved solids discharged to the Truckee River. Journal of Environmental Engineering, 133(12), pp.1136-1144.
Water Reuse	RO/NF	Hafiz, M., Hawari, A.H., Alfahel, R., Hassan, M.K. and Altaee, A., 2021. Comparison of Nanofiltration with Reverse Osmosis in Reclaiming Tertiary Treated Municipal Wastewater for Irrigation Purposes. Membranes, 11(1), p.32.
Enzyme Separation and Recovery	UF	Chen, Y., 2021. Development of an Integrated Soluble Sugar and Biomethane Production System from Sugar Beets and Dairy Manure (Doctoral dissertation, University of California, Davis).
Medical Application	UF	Humudat, Y.R. and Al-Naseri, S.K., 2020. The role of controlling zeta potential for endotoxin removal in dialysis water preparation. Desalination and Water Treatment, 208, pp.239-243.
Biomass Harvesting	UF	Hafiz, M.A., Hawari, A.H., Das, P., Khan, S. and Altaee, A., 2020. Comparison of dual-stage ultrafiltration and hybrid ultrafiltration-forward osmosis process for harvesting microalgae (Tetraselmis sp.) biomass. Chemical Engineering and Processing-Process Intensification, 157, p.108112.
Diafiltration	UF	Al-Mutwalli, S.A., Dilaver, M. and Koseoglu-Imer, D.Y., 2020. Performance Evaluation of Ceramic Membrane on Ultrafiltration and Diafiltration Modes for Efficient Recovery of Whey Protein. Journal of Membrane Science and Research, 6(2), pp.138-146.

FO: Forward Osmosis; MF: MicroFiltration; UF: UltraFiltration; NF: NanoFiltration; RO: Reverse Osmosis.

Table 1.1 Various Applications of Crossflow Filtration

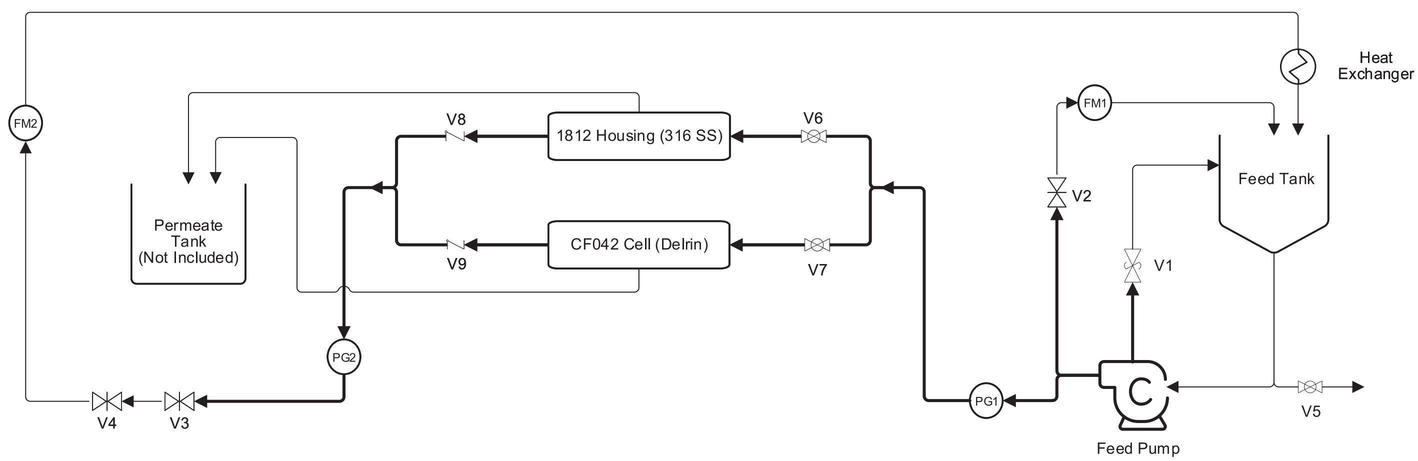
2. CFF/TFF Filtration Systems

CFF/TFF systems can vary in complexity depending on the application, objectives, and design. Most systems will utilize the same essential components for basic operation.

2.1 System Operation

Figure 2.1 demonstrates a common scheme for a basic CFF/TFF system. Liquid flow in the system is maintained and adjusted by pumps and valves in the process lines (only the feed pump is shown in Figure 2.1). Table 2.1 provides a summary of the parts and their function in a typical CFF system.

During operation, fluid is pumped from a feed tank into the CFF/TFF cell feed inlet, flows across the membrane surface (crossflow/tangential flow), out of the CFF/TFF cell concentrate outlet, and returns to the feed tank. The sweeping action helps to prevent larger molecules and aggregates from being retained on the surface of the membrane. This is necessary to reduce concentration or gel polarization (the formation of a concentrated layer on the membrane surface). As fluid flows through the narrow feed channel a pressure drop is created between the feed inlet and concentrate outlet. The applied membrane pressure can be further manipulated to prevent membrane fouling by controlling the transmembrane pressure (TMP) through flow restriction at the concentrate outlet. TMP is the force that drives permeate along with any molecules smaller than the pore size of the membrane, through the membrane. CFF/TFF is very efficient at processing large volumes of feed under optimized TMP and crossflow/tangential flow rates.



Legend

V1	Feed Pressure Relief Valve	V8	Backflow Preventer Valve #1
V2	Feed Bypass Valve	V9	Backflow Preventer Valve #2
V3	Pressure Control Valve	PG1	Feed Pressure Gauge
V4	High Pressure Control Valve	PG2	Concentrate Pressure Gauge
V5	Drain Valve	FM1	Feed Bypass Flow Meter
V6	Bank Selector Valve #1	FM2	Concentrate Flow Meter
V7	Bank Selector Valve #2		

Routing Lines Key

. . . . Electrical Signal
——— Low Pressure Fluid Line
━━━ High Pressure Fluid Line

To operate the system:

1.Load a membrane into the CFF/TFF cell and pre-condition prior to use.
2.Establish optimal pressure and flow rates for application/membrane.
3.Run the system until the feed solution is processed as desired.
4.Clean as necessary.
5.Store membrane and equipment accordingly.

Figure 2.1 Configuration of a CFF/TFF system

Components	Parts	Description	Frequency
Pump	Feed pump	Maintains the flow of feed into the filter	Required
	Retentate pump	May be used to maintain and control the flow of retentate back into the feed reservoir	Optional
	Permeate pump	May be used to control flow of permeate from the filter. If used, the pump flow rate must be less than the spontaneous permeate flux to avoid creating negative pressure on the permeate side of the filter.	Optional
	Transfer pump	May be used in washing and diafiltration applications to add liquid (usually buffer) to the feed reservoir at a controlled rate.	Required
Valve		Typically used to adjust pressure, direct flow direction, prevent backflow, etc.	Required
Sensor/ Transmitter	Pressure sensor	Essential in the feed lines to monitor and control the system. A pressure sensor on the permeate side may also be used to monitor permeate pressure.	Required
	Flow sensor	Measurement of flow rates for feed solution, retentate and/or permeate, and any addition of fluid to the feed reservoir is necessary for monitoring and controlling process conditions during filtration. Flow sensors are placed at strategic points in the system.	Required
	Reservoir level sensor	A level sensor in the feed reservoir monitors and controls the amount of liquid in the reservoir	Optional
	Air sensor	An air sensor in the feed stream allows continuous monitoring for air bubbles in the feed prevents the introduction of air into the system. An air sensor can also be used in the transfer line to detect when the transfer reservoir is empty.	Optional
	Additional sensor	Temperature, pH, UV absorbance and conductivity sensors may be included in the system according to the requirements of the specific process.	Optional

Table 2.1 Components of a CFF/TFF System

2.2 Membranes Used in CFF/TFF

Membranes are commonly used in CFF/TFF for separating particles in liquid solutions or gas mixtures. The semi-permeable material acts as a barrier that retains larger particles while allowing smaller molecules to pass through the membrane into the permeate. The four main methods of pressure-driven membrane filtration are Microfiltration (MF), Ultrafiltration (UF), Nanofiltration (NF), and Reverse Osmosis (RO), in order of decreasing pore size (Figure 2.2). The membrane characteristics and their applications are summarized in Table 2.2.

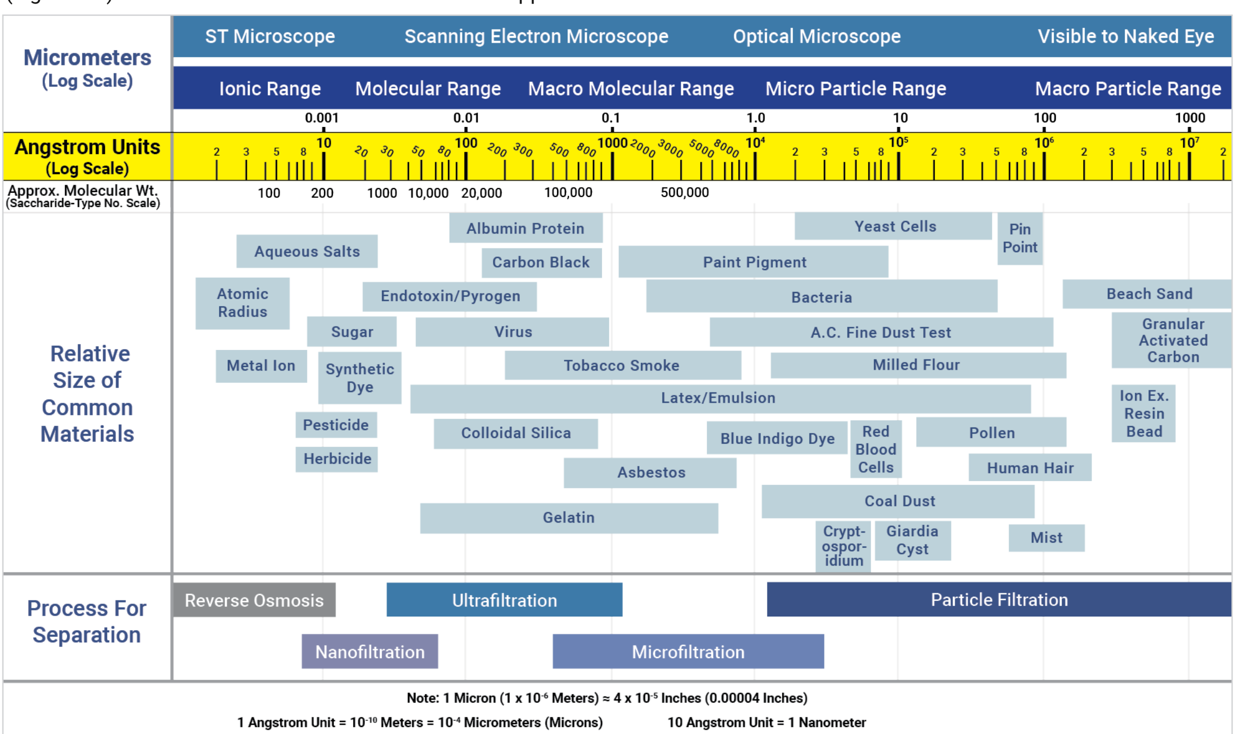


Figure 2.2 The Filtration Spectrum

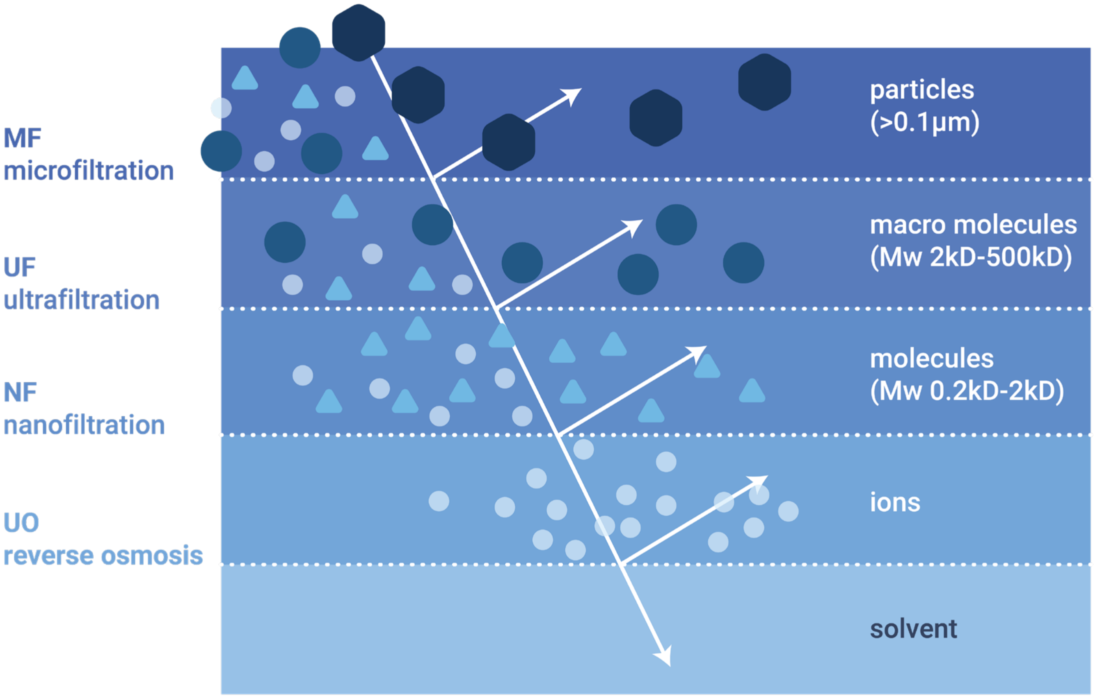


Figure 2.3 Separation Ranges of Different Membrane Processes

Process	Description	Operating pressure (bar)	Application	Comments
MF	Pore sizes ranging from 0.1 to 10 µm	0.1 - 3	Mainly used for large particulates, colloids, and bacteria removal and is especially popular in the food & beverage industry for oil/water emulsion splitting, particle removal, concentration or washing (e.g. pigments, fermentation broths)	MF and UF require low pressure for operation, thus will yield higher flux.
UF	Similar to MF, but with smaller pore sizes ranging from 0.01 to 0.1 µm.	2 - 10	Mainly used in rejecting viruses and polypeptides, and are widely used in protein concentration and wastewater treatment.	
NF	Contain a thin-film composite layer (<1 µm) on top of a porous layer (50 to 150µm) for small ion selectivity. Able to reject multivalent salts and uncharged solutes, while allowing some monovalent salts to pass through.	5 - 30	Used to remove organic matter, color, odor, taste, residual quantities of disinfectants and trace herbicides from large water bodies. Application examples include concentration and desalting of chemical products (dye, optical brighteners, pharmaceuticals) or waste streams	Higher operating pressure required for NF and RO so the overall yield is lower than that of MF and UF. NF can operate at lower pressures than RO, making them ideal for achieving an optimal combination of flux and rejection.
RO	Tighter than NF and are able to reject all monovalent ions while allowing water molecules to pass through in aqueous solutions.	10 - 100	Common applications for reverse osmosis filtration include seawater desalination, chemical product concentration, and wastewater concentration.	

Table 2.2 Application of Typical Membrane Processes

2.3 Membrane Module Configuration

Membranes are usually arranged into devices and hardware as membrane modules. Table 2.3 summarizes the most common membrane module types. These membrane modules are designed and developed by industry manufacturers in order to achieve different characteristics on the hydrodynamic conditions, filtration areas, energy consumptions, etc.

	Module type	Tubular	Capillary	Hollow fiber
Tubular	Diameter (mm)	6 - 25	0.5 - 6	0.04 - 0.5
	Separations	MF, UF, NF	MF, UF, NF	MF, UF
Flat	Module type	Plate and frame	Spiral wound	Cushion type
	Separations	MF, UF, NF, RO	MF, UF, NF, RO	NF, RO

Table 2.3 Common Membrane Module Types and Applications

2.4 System Parameters

Minimum Working Volume

The minimum working volume of a CFF system represents the amount of feed/retentate fluid required to operate the system at the desired crossflow rate without drawing air into the feed pump. The minimum working volume is determined by the design of the system (feed and retentate tubing volume, reservoir bottom design), the filter hold-up volume, and the crossflow rate. It is important to consider the minimum working volume of a system in the design of a CFF process and in particular to confirm that the final target retentate volume is not less than the system's minimum working volume.

Hold-up Volume

The term hold-up volume refers to the volume of liquid in the filtration system. The filter and system should be chosen with the smallest hold-up volume that is compatible with other performance requirements in the process.

Process Capacity

The system process capacity (the volume of starting material that can be processed in one run) should be chosen in relation to the planned volume of starting material. Process capacity is partly a function of system size and design, but also varies according to the tendency of starting material to foul the filter. Using a high-capacity system for a small sample volume will lead to unnecessary loss of material in the system dead volume. For processes that will be scaled up for production, it will be necessary to switch between different systems one or more times during process development (see Table 2.4).

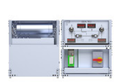
FEATURES AND BENEFITS	 Kits	 Systems	 Analog Skid	 Digital Skid
Cell Compatible	✓	✓	✓	✓
CF/TF and FO Operation	✓	✓	✓	✓
Temperature Regulation	✓	✓	✓	✓
Plug and Play Design		✓	✓	✓
Defined Footprint		✓	✓	✓
Mobile			✓	✓
On-site Training			✓	✓
Data Logging				✓
Touch Screen Interface				✓

Table 2.4 Membrane Process Development Equipment

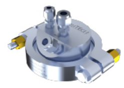
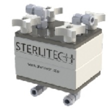
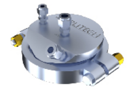
	 Discoverer	 Pioneer	 Innovator	 Explorer	 Researcher	 Developer	 Investigator
Filter Holder	HP4750(X)	CF047	CF016	CG042	CF090	Sepa	1812
Membrane Active Area	14.6 cm^2	14.6 cm^2	20.6 cm^2	42 cm^2	53 cm^2	140 cm^2	0.27-0.46 cm^2
Typical Permeate	1.5-15 mL/min	1-10 mL/min	1-10 mL/min	2-20 mL/min	2.5-25 mL/min	7-70 mL/min	350-2,300 mL/min
Recommended Feed Rate	N/A	0.1-0.5 LPM	0.5-2.5 LPM	0.5-2.5 LPM	0.1-0.7 LPM	0.5-6.0 LPM	See Mfr. Spec Sheet
Max. Operating Pressure* (Model & Material Dependent)	138 bar (2000PSI)	69bar (1000PSI)	69bar (1000PSI)	69bar (1000PSI)	69bar (1000PSI)	138 bar (2000PSI)	69bar (1000PSI)
Material Options	SS316 Hastelloy C-276	SS316	Acrylic Delrin SS316 PTFE Hastelloy C-276	Acrylic Delrin SS316 PTFE Hastelloy C-276	SS316	Acrylic PEEK SS316 PTFE Hastelloy C-276	SS316
Configuration Options	Dead-End	Cross Flow	Cross Flow, Forward Osmosis	Cross Flow, Forward Osmosis	Cross Flow	Cross Flow, Forward Osmosis	Cross Flow

Table 2.5 Membrane Cells & Housings

3. Process Design and Operation

Membrane process development is not trivial, whether planning for a bench-scale experiment or designing a full-size plant. This section provides important factors that need to be considered and offers a general workflow of a membrane process design.

3.1 Membrane Process Development and Considerations

	Step	Considerations
1	Project evaluation	Feasibility
		Size and order
		Experience (own or literature)
		Consider short lab experiment
2	Membrane selection	Choice of membrane (lab, pilot, plant scale)
		Performance measurement (flux, rejection)
		Pressure and temperature range
		Possible concentration factors
		Fouling indicators
3	Process optimization	Parameter influence (pressure, temperature, pH, concentration)
		Performance measurement (flux, rejection)
		Operation cycle (filtration, backwash, cleaning)
		Scale-up design (module, stage, flow, pressure, process integration)
4	Process simulation	Software simulation, optional

Table 3.1 Development of Membrane Processes (part 1)

	Step	Considerations
5	On-site Pilot Test	Process stability
		Feed variation
		Staff training
		Operation modes
		Prior design adaption
		Decision on production plant
6	Plant design	Energies
		Components selection (membrane module, piping, pump, measurement and control, vessel)
		Control system
		Construction supervision
		Functional tests

Table 3.1 Development of Membrane Processes (part 2)

Factor	Decision
Major feed components (particle type and size)	Membrane type
Solids present?	Pre-treatment required? Module type and size
Separation requirements	Process choice and membrane selection
Desired concentration of permeate and/or retentate	Operational conditions
Required capacity, batch/continuous process	Scale and membrane area required
Use of concentration and permeate	Which one of concentrate and permeate is the desired product and how to handle the waste
Temperature range	Membrane and module compatibility
pH range	Membrane and module compatibility
By-components, organic solvents	Membrane and module compatibility
Viscosity	Module choice, flow design, pressure drop
Solubility	Maximum concentrating factor allowed during operation
Alternative processes	Advantages and disadvantages of potential processes comparison
Product quality	Analytical methods for product measurement
Biological growth	Fouling control procedures
Air in system	Is oxidation a problem? Membrane and module compatibility

Table 3.2 Common Factors Considered for any Membrane Process Design

3.2 CFF/TFF Preparation

Preparation of membranes for a CFF process involves cutting and positioning the membrane in the module, conditioning the membrane in the system. For some processes the membrane may need to be rinsed to remove storage solution before use, especially in the case of reusing the same pieces of membranes. This section gives a brief overview of preparation procedures.

Cutting Custom Membranes

Sterlitech offers a wide variety of RO/NF/UF/MF membranes that are available pre-cut for use with cells like Sepa, CF042, and CF016. However, if you need to cut your own membrane, you will need the following items:

- The template provided with the cell (Note: Sterlitech also offers steel rule dies that are designed to cut the membrane to the correct size and shape)
- The membrane sheet to be cut
- A pair of sharp scissors
- A pair of latex gloves

To cut membrane filters for the Sepa CF, CF042, and CF016 Cells:

- Take the provided template and place the membrane sheet against it. Be sure to have the latex gloves on to avoid contaminating the membrane surface.
- Cut along the edge of the template with scissors. Hold the scissors at an angle towards the center of the template to avoid under-trimming.

Once finished, the membrane should sit perfectly flat on supports without any bending and extend outside of the inner O-ring to avoid leakage.

Membrane Compaction and Pre-Conditioning

Membrane compaction is a phenomenon that occurs in pressure-driven membrane processes. Once the membrane has been compacted to a certain level, the permeate flux begins to stabilize and fluctuate less. The deformation caused by membrane compaction is often irreversible, especially for flat sheet membranes. If no membrane compaction occurred, flux would have a linear correlation with pressure. In addition, the compaction rate is also proportional to increases in both pressure and temperature. Compaction occurs more frequently in RO since the applied pressures are relatively high. However, compaction may also occur in UF and MF processes, depending on the pressure employed.

Membrane pre-conditioning procedures vary from one manufacturer to another. If no instruction is provided by the manufacturer follow the instructions provided below. To pre-condition the membrane:

- If the membrane appears dry in the packaging, the first step is to pre-wet it before use. Place the membranes in a dry holder and allow them to wet from the inlet side first. It may be best to perform this operation with water or a buffer, then dispose of the first rinse, and introduce the process fluid. This prevents any wetting agents or preservatives from mixing with the process solution.
- Load the membrane into the crossflow cell
- Fill the feed tank with deionized water and pressurize the cell. Ideally, the pH, temperature of the water and the pressure used should be exactly the same as the pH, temperature and pressure that will be used in the actual trials. If the temperature varies throughout the experiment, refer to Section 3.3 to correct for the effect of temperature on the permeate flux.
- Run the deionized water through the cell until the flux is relatively constant to achieve membrane compaction. Flux through the membrane will stabilize after a few minutes.
- Release pressure, discard the deionized water and fill the cell with your sample.

3.3 Operating Parameters

A CFF/TFF process may be controlled by an interplay of several operating parameters according to the specific process requirements. The most important parameters include pressure, flow rates, temperature, pH, and process time.

Pressure

Pressure is directly affecting flux and it can be used to control flow rate and crossflow velocity. Pressure is usually monitored in the feed stream, and sometimes in the retentate stream or the permeate stream depending on the application.

In RO/NF processes, water flux, $J_V\ (m.d^{-1})$, is calculated as

$$J_V = A\,(\Delta p - \Delta\pi)$$

where $(m.d^{-1}.psi^{-1})$, is the water permeability coefficient of the membrane, $\Delta p\ (psi)$ is the applied trans-membrane pressure, and $\Delta\pi\ (psi)$ is the trans-membrane osmotic pressure.

Solute rejection R (unitless) is calculated as

$$R = 1 - \frac{C_P}{C_F}$$

where $Cp\ (M)$ and $CF\ (M)$ are the solute concentrations in the permeate and feed water, respectively.

Crossflow Velocity

Crossflow velocity (CFV) is the linear velocity of the flow tangential to the membrane surface and is reported in [m/sec] or [ft/sec]. CFV affects the hydrodynamic conditions in the cell, and as a result, affects the fouling rate and formation of concentration polarization at the membrane surface.

CFV is calculated by dividing the volumetric flow rate [liter per minute] in the flow channel by the cross-sectional area [m2 or ft2] of the flow channel. For example:

Calculate CFV in the CF042 cell

Flow channel cross sectional area: Channel depth x Channel width = 0.23 x 3.92 cm
Flow rate: 1 L/min = 1/60000 m3/s
CVF = (1/60000 m3/s) / (0.0023 x 0.0392 m)= 0.18 m/s

When shims or feed spacers are inserted in the flow channel, it reduces the depth of the channel. For example, if the channel depth is 0.23 cm, inserting a shim with a thickness of 0.05 cm reduces the flow channel depth to 0.23 - (0.05) = 0.18 cm. CFV is then calculated by dividing the volumetric flow rate in the flow channel by the reduced cross-sectional area of the channel. Adding feed spacers to the flow channel further reduces the channel cross-sectional area. The effective cross-sectional area depends on the spacer thickness and spacer's percentage of open area. More commercially available feed spacers with a wide range of thickness and percentage of open area can be found on Sterlitech's website.

Temperature and pH

Permeate flux through the membrane is generally a function of temperature. The equation below can be used to correct for the effect of temperature on the permeate flux.

$$J_0 = J\left(\frac{\mu}{\mu_0}\right)$$

where J_0 is the permeate flux at the reference temperature (e.g. 25°C), μ0 is the viscosity at the reference temperature (e.g. 25°C), J is the permeate flux at the test temperature, and μ is the viscosity at the test temperature.

Operating temperature also affects solute rejection in the membrane separations involving diffusion of molecules through the dense membrane: e.g. RO, pervaporation, and gas permeation. Increases in feed temperature result in a higher passage of solutes, e.g. salts, due to a higher diffusion rate according to the solution-diffusion model.

The pH of the feed solution affects the rejection of charged species. In RO/NF processes, the rejection generally increases as the feed solution pH increases.

3.4 Cleaning and Storage

Some membranes are designed for single-use/testing, but cleaning and re-use of membranes are sometimes necessary for research purposes or could be an important economic consideration at process development, pilot, and production scales. Typically, the performance of the membrane is checked both before and after use by measuring the rate of water flow through the membrane under controlled conditions. The membrane should be cleaned or replaced when the water flux drops to unacceptable levels.

Membrane Cleaning

Membrane cleaning is required when membrane performance drops significantly, usually shown as flux decrease or pressure increases when the system is under operation. Determining which solution to use to clean a flat sheet membrane depends on the substance it is fouled with. Generally, flushing the system with water with high feed flow and low pressure and partially closed permeate line is a good start. A caustic or oxidant solution for organic fouling and an acidic solution for inorganic causes can be used to help further remove fouling. Keep in mind that different membranes polymers have different pH tolerances and make sure the cleaning solution does not damage the membranes. Please contact Sterlitech for more information.

Membrane Storage After Use

Membranes should be kept wet after use. Control biological growth by adding 0.5% solution of formaldehyde, sodium metabisulfite, or use deionized water and change it out at least once a week. If sodium metabisulfite is used, it is recommended to change it out every three months since it is a little weaker than formaldehyde.

4. Resources

Sterlitech's **Membrane Process and Development Channel** contains videos for assembly, troubleshooting, and product demonstrations.

For additional questions, contact **sales@sterlitech.com**.

Appendix, Abbreviations and Glossary

Channel Height

The height of the path that the feed/retentate solution must pass through.

Concentrate

Also referred to as retentate. The part of the process solution that does not pass through a cross flow filter.

Crossflow Filtration (CFF)

Also known as tangential flow filtration (TFF). In cross flow filtration, the feed solution flows parallel to the surface of the membrane. Driven by pressure, some of the feed solution passes through the membrane filter. The remainder is circulated back to the feed tank. The movement of the feed solution across the membrane surface helps to prevent the buildup of materials on the surface.

Crossflow Rate

The flow rate of feed solution that flows across the surface of the filter and exits the filter as retentate. Higher cross flow rates help “sweep away” material that otherwise accumulates on the surface of the filter. Cross flow rate is most often measured at the retentate outlet.

Crossflow Velocity (CFV)

Crossflow velocity (CFV) is the linear velocity of the flow tangential to the membrane surface and is reported in [m/sec] or [ft/sec]. CFV affects the hydrodynamic conditions in the cell, and as a result, affects the fouling rate and formation of concentration polarization at the membrane surface.

Cutoff

See Nominal molecular weight cutoff (NMWC).

Dead-End Filtration

Also known as direct flow filtration (DFF). In dead-end filtration, liquid flows perpendicular to the filter media. Material that does not pass through the filter remains on the filter surface.

Applied trans-membrane pressure.

Trans-membrane osmotic pressure.

Direct Flow Filtration (DFF)

See Dead-end filtration.

Diafiltration

An operation that uses ultrafiltration filters to remove salts or other microsolutes from a solution. Small molecules pass into the permeate while larger molecules are retained in the retentate. Microsolutes are generally so easily washed through the filter that for a fully permeated species about three volumes of diafiltration solution will eliminate 95% to 99% of the microsolute

Effective Filtration Area

The active area of the membrane exposed to flow.

Feed

Material or solution that is fed into the filtration system.

Feed Pressure

The pressure measured at the inlet port.

Flow Path Length, Nominal Flow Path Length

The total length that a feed solution travels from inlet to outlet. Flow path length is an important parameter to consider when doing any process development, system design or scale-up or scale-down experiments.

The flow path length and other fluid channel geometries such as lumen diameter or channel height can affect the fluid dynamics of the system and will directly affect pump requirements and differential pressure of the filtration step.

Flux

Flux represents the volume of solution flowing through a given membrane area during a given time. Expressed as LMH (liters per square meter per hour).

Fouling

Membrane fouling is a process whereby a solution or a particle is deposited on a membrane surface or in membrane pores in processes such as reverse osmosis, forward osmosis, membrane distillation, ultrafiltration, microfiltration, or nanofiltration so that the membrane’s performance is degraded. It is a major obstacle to the widespread use of this technology. Membrane fouling can cause severe flux decline and affect the quality of the retentate. Severe fouling may require intense chemical cleaning or membrane replacement. There are various types of foulants: colloidal (clays, flocs), biological (bacteria, fungi), organic (oils, polyelectrolytes, humics) and scaling (mineral precipitates).

Fouling can be divided into reversible and irreversible fouling based on the attachment strength of particles to the membrane surface. Reversible fouling can be removed by a strong shear force or backwashing. Formation of a strong matrix of fouling layer with the solute during a continuous filtration process will result in reversible fouling being transformed into an irreversible fouling layer. Irreversible fouling is the strong attachment of particles which cannot be removed by physical cleaning.

Hold-up Volume

Volume of fluid in the system tubing and filter.

Hollow Fiber

A tube of membrane, sealed inside a cross flow cartridge. The feed stream flows into the lumen of one end of the hollow fiber and the retentate (the material that does not permeate through the walls of the hollow fiber) flows out of the other end. The material that passes through the membrane (walls of the hollow fiber) is called the permeate.

Housing

The mechanical structure that surrounds and supports the membrane or filter element. The housing normally has feed, retentate and permeate ports that direct the flow of process fluids into and out of the filter assembly.

Inlet Pressure

The pressure of a fluid at the feed port of a membrane filter.

Membrane Recovery

The degree to which the original performance of a membrane can be restored by cleaning.

Microfiltration

The process of removing particles from a liquid by passing it through a porous membrane under pressure. Microfiltration usually refers to removing submicron-sized particles.

Minimum Process Volume

Also called minimum operating volume. The least amount of fluid able to be handled effectively by a filtration system.

Nominal Molecular Weight Cut Off (NMWC)

The pore size designation, usually in kilo Daltons (kD). No industry standard exists; hence the NMWC ratings of different manufacturers are not always comparable.

Normalized Water Permeability (NWP)

The water flux at 20°C divided by operating pressure. Common units LMH/psi, LMH/bar.

Permeate

The components of the feed solution that passes through the membrane

R

Membrane salt rejection (%), which is defined as the percentage of solutes/particles that have been removed from the membrane filtration process.

Retentate

The portion of the feed solution that does not pass through the membrane. Any component that does not pass through the membrane flows out of the filter and back to the feed container.

Shear Rate

The ratio of velocity and distance expressed in units of s-1. The shear rate for a hollow fiber cartridge is based on the flow rate through the fiber lumen and is used to control crossflow.

Size Exclusion

The mechanism for removing particles from a feed stream based strictly on the size of the particles. Retained particles are held back because they are larger than the pore opening.

Tangential Flow Filtration (TFF)

See Crossflow filtration.

Transmembrane Pressure

The pressure drop across the membrane

Ultrafiltration

The separation of macrosolutes based on their molecular weight or size.

STERLITECH

Company Background

Founded in 2001 in Kent, WA, Sterlitech Corporation manufactures and markets filtration-focused laboratory products to a broad spectrum of scientific and industrial sectors. Its line of flat sheet membranes and tangential flow cells deliver industry-leading performance and reliable results. Configured for reverse osmosis, nanofiltration, ultrafiltration, and microfiltration applications, Sterlitech's benchtop cross flow membrane test system provides the versatility required to innovate.

Sterlitech's comprehensive line of products is supported by the expertise of its technical specialists who can assist with application-specific product selection and provide customized solutions where necessary. Unique problem-solving approaches, flexibility, and consistent quality have made Sterlitech Corporation a renowned global provider of filtration products and equipment.

Sales Inquiries

sales@sterlitech.com

Accounts Payable

AP@sterlitech.com

Accounts Receivable

AR@sterlitech.com

Press Inquiries

PR@sterlitech.com

STERLITECH

4620 B Street NW, Suite 101
Auburn, WA 98001 USA
Tel: 877-544-4420 or 1-253-437-0844
Fax: 1-253-437-0845
Email: info@sterlitech.com