Stirred Cell Crossflow Filtration HexaMem

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Manufacturer: Messinger Engineering

1 Stirred Cell Crossflow Filtration – HexaMem

HexaMem is a compact laboratory-scale membrane filtration system designed for crossflow filtration experiments, membrane screening, and process development under controlled operating conditions.

The system enables investigation of membrane performance, permeate flux, retention behavior, concentration polarization, and membrane fouling using only small liquid volumes. Independent control of pressure and hydrodynamic conditions allows reproducible filtration experiments with well-defined operating parameters.

HexaMem is compatible with a wide range of flat-sheet membrane types, including polymeric microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO) membranes, as well as ceramic membranes for demanding chemical and thermal applications.

The stirred crossflow configuration generates controlled tangential flow above the membrane surface, helping to reduce concentration polarization and simulate realistic membrane filtration conditions on a laboratory scale.

The compact stainless steel construction provides high chemical resistance, operational safety, and easy handling in research, educational, and industrial laboratory environments.

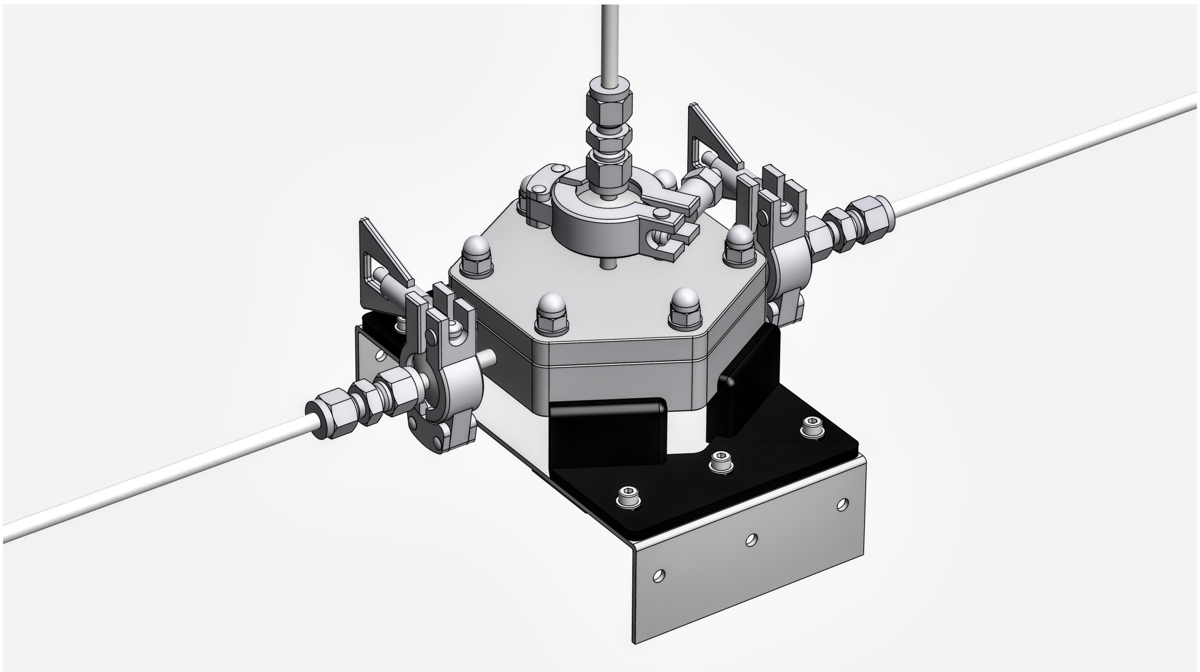

Figure 1: HexaMem stirred-cell membrane filtration system with feed, permeate, and retentate connections.

Typical applications include:

- Flat-sheet membrane screening and comparison
- Crossflow filtration experiments
- Membrane fouling and cleaning studies
- Flux and retention measurements
- Process optimization and feasibility studies
- Small-batch membrane processing
- Enzyme membrane reactor experiments

Key system characteristics:

- Compatible with polymeric and ceramic flat-sheet membranes
- Independent pressure and hydrodynamic control
- Reproducible laboratory-scale filtration conditions
- Low sample volume starting from approximately 50 mL
- Maximum operating pressure up to 40 bar
- Compact stainless steel design for laboratory operation

1.1 Mechanical Assembly

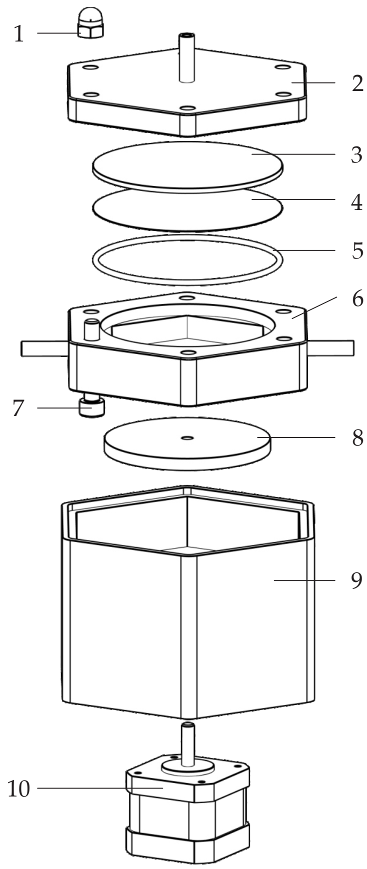

Figure 2: Exploded view of Hexamem.

1. Cap nuts, AISI 304 stainless steel, 6 mm, including washers; used for uniform sealing and mechanical fixation of the membrane cell assembly, 6 pcs.
2. Permeate housing with 6 mm process connection, manufactured from AISI 304 or AISI 316L stainless steel; collects and discharges permeate below the membrane support layer.
3. Porous support disc, diameter 80 mm, manufactured from polypropylene (PP) or stainless steel; provides mechanical support for flat-sheet membranes and enables uniform permeate flow distribution.
4. Flat-sheet membrane, diameter 80 mm; interchangeable membrane disc for MF, UF, NF, or RO filtration experiments.
5. O-ring seal manufactured from EPDM, Viton, or silicone; ensures leak-tight sealing between membrane and housing components under pressurized operating conditions.
6. Main body with 6 mm process connection, manufactured from AISI 304 or AISI 316L stainless steel; forms the feed-side process chamber above the membrane surface.
7. Hex socket screws, 6 mm, 6 pcs.; used for assembly and controlled compression of the membrane cell components.
8. Rotor disc with integrated permanent magnets; generates controlled hydrodynamic shear and tangential flow above the membrane surface during operation.
9. Support structure manufactured from 3D-printed PETG or ABS; provides mechanical support and alignment of the drive and membrane cell assembly.
10. Stepper motor for precise rotational speed control of the magnetic rotor system and adjustment of hydrodynamic operating conditions.

2 How it works

The feed solution is positioned above the membrane. A rotating turbulence promoter generates shear flow across the membrane surface, reducing concentration polarization.

Filtration is driven by transmembrane pressure (TMP), generated either by a pump or by an inert gas supply, typically nitrogen or argon.

Independent control of hydrodynamic and hydraulic parameters allows precise analysis of mass transfer limitations and fouling behavior.

3 Operating Configurations

HEXAMEM systems can be operated either with a pressure-driven pump system or with a pressurized feed vessel using inert gas such as nitrogen or argon. Both configurations enable controlled membrane filtration experiments under well-defined hydraulic and hydrodynamic operating conditions.

The operating mode can be selected depending on the application, sample volume, pressure requirements, and process configuration. Typical applications include membrane screening, fouling investigations, flux measurements, concentration studies, and small-scale process development.

3.1 Operation with Pressure-Driven Pump System

In pressure-driven pump operation, the feed solution is continuously circulated through the membrane cell using an external pump system. This operating mode enables controlled crossflow filtration under well-defined hydraulic and hydrodynamic conditions and is particularly suitable for membrane characterization, fouling investigations, concentration experiments, process optimization, and continuous laboratory-scale filtration studies.

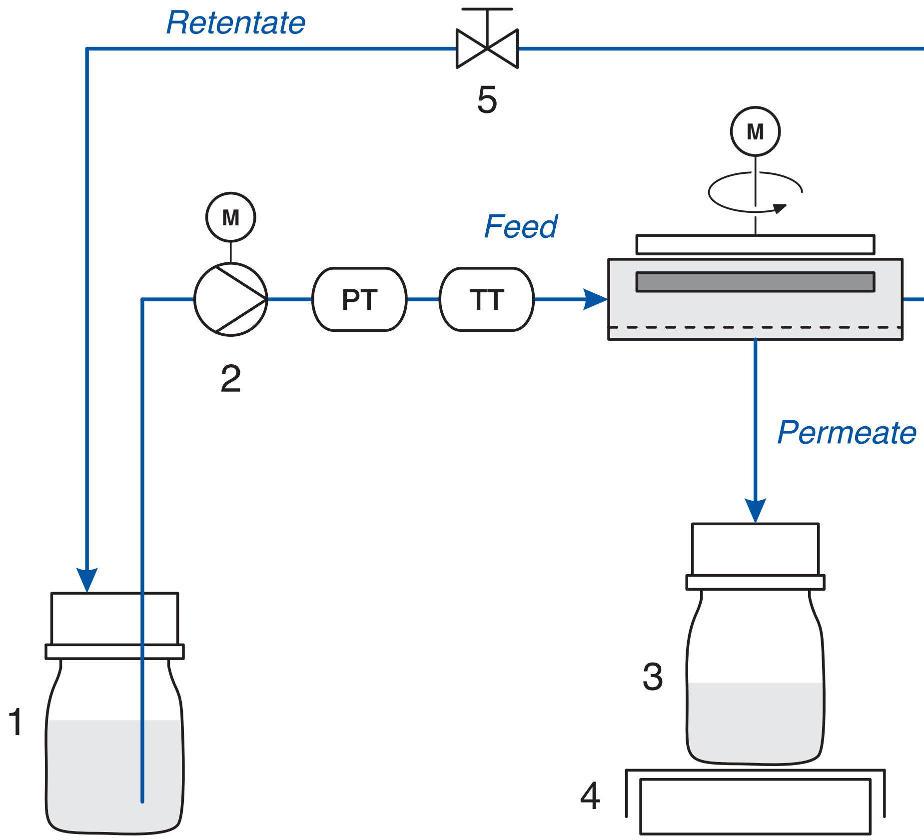

Figure 3: Typical process configuration for operation with a pressure-driven pump system.

A typical process configuration is shown in Figure 3. The feed solution is stored inside a feed reservoir and transported through the membrane cell by a circulation pump. During operation, the liquid flows tangentially across the membrane surface while transmembrane pressure drives permeation through the membrane.

The retentate stream is recirculated back to the feed vessel, enabling continuous operation and stable hydrodynamic conditions throughout the experiment. The permeate stream is collected separately for flux measurements, retention analysis, concentration studies, or downstream analytical investigations.

Compared to simple dead-end filtration systems, pressure-driven circulation operation provides several important advantages:

- Continuous tangential flow reduces concentration polarization
- Improved control of membrane fouling behavior
- More realistic simulation of industrial crossflow membrane processes
- Stable and reproducible operating conditions
- Independent adjustment of pressure and hydrodynamic shear
- Continuous recirculation during long-duration experiments

The circulation pump determines the volumetric flow rate through the membrane cell and therefore directly influences the shear conditions at the membrane surface. Increasing the crossflow velocity generally improves mass transfer, reduces concentration polarization, and decreases accumulation of foulants on the membrane surface.

The average crossflow velocity can be approximated by

$$v = \frac{\dot{V}}{A_c} \tag{1}$$

where v is the average crossflow velocity, $\dot{V}$ is the volumetric circulation flow rate, and A_c is the effective hydraulic flow cross-section above the membrane surface.

At the same time, the transmembrane pressure controls the driving force for permeation through the membrane. Independent adjustment of flow rate and pressure enables systematic investigation of membrane transport phenomena, fouling mechanisms, and mass transfer limitations.

The transmembrane pressure is typically defined as

$$\text{TMP} = \frac{p_{\text{feed}} + p_{\text{retentate}}}{2} - p_{\text{permeate}} \tag{2}$$

where p_{feed} is the feed pressure, $p_{\text{retentate}}$ is the retentate pressure, and p_{permeate} is the permeate pressure.

The permeate flux can be determined using

$$J = \frac{\dot{V}_P}{A} \tag{3}$$

where J is the permeate flux, $\dot{V}_P$ is the permeate volumetric flow rate, and A is the effective membrane area.

The hydrodynamic flow regime can furthermore be characterized using the Reynolds number:

$$\text{Re} = \frac{\rho \cdot v \cdot d_h}{\eta} \tag{4}$$

where ρ is the fluid density, v is the average flow velocity, d_h is the hydraulic diameter, and η is the dynamic viscosity.

For stirred membrane systems such as HexaMem, the rotating magnetic stirrer additionally generates tangential shear flow above the membrane surface. The tangential velocity can be approximated by

$$v_t = \omega \cdot r \tag{5}$$

with

$$\omega = \frac{2\pi n}{60} \tag{6}$$

where v_t is the tangential velocity, ω is the angular velocity, r is the radial distance from the center of rotation, and n is the rotational speed in revolutions per minute.

For laboratory-scale membrane systems such as HexaMem, the combination of adjustable circulation flow rate and independently controlled stirrer speed enables highly flexible investigation of coupled hydraulic and hydrodynamic effects. The system therefore allows differentiation between pressure-limited and mass-transfer-limited operating regimes.

Typical pumps used for this operating configuration include:

- Gear pumps
- Peristaltic pumps
- Diaphragm pumps
- Progressive cavity pumps
- Magnetically coupled centrifugal pumps

Pump selection depends on operating pressure, flow rate, pulsation behavior, viscosity, chemical compatibility, solids content, and shear sensitivity of the process fluid.

Additional process instrumentation may include:

- Pressure transmitters (PT)
- Temperature sensors (TT)
- Flow meters
- Conductivity sensors
- Mass balances for permeate monitoring
- Automated valve systems

The pump-driven configuration is particularly suitable for:

- Crossflow ultrafiltration and nanofiltration experiments
- Long-term fouling investigations
- Membrane cleaning studies
- Concentration experiments
- Process optimization studies
- Simulation of industrial membrane systems
- Continuous recirculation experiments

Compared to gas-pressurized operation, pump-driven systems generally allow higher crossflow velocities and improved hydrodynamic control. However, pulsation effects, pump-induced shear, additional tubing volume, and increased system complexity must be considered during experimental design and interpretation of experimental results.

3.2 Operation with Inert Gas Pressurization

In inert gas pressurization mode, the feed solution is stored inside a closed pressure vessel and pressurized using an inert gas such as nitrogen or argon. The applied gas pressure generates the driving force for membrane filtration and enables highly stable and pulsation-free operating conditions. This configuration is particularly suitable for compact laboratory experiments, small sample volumes, sensitive fluids, and applications requiring precise pressure control.

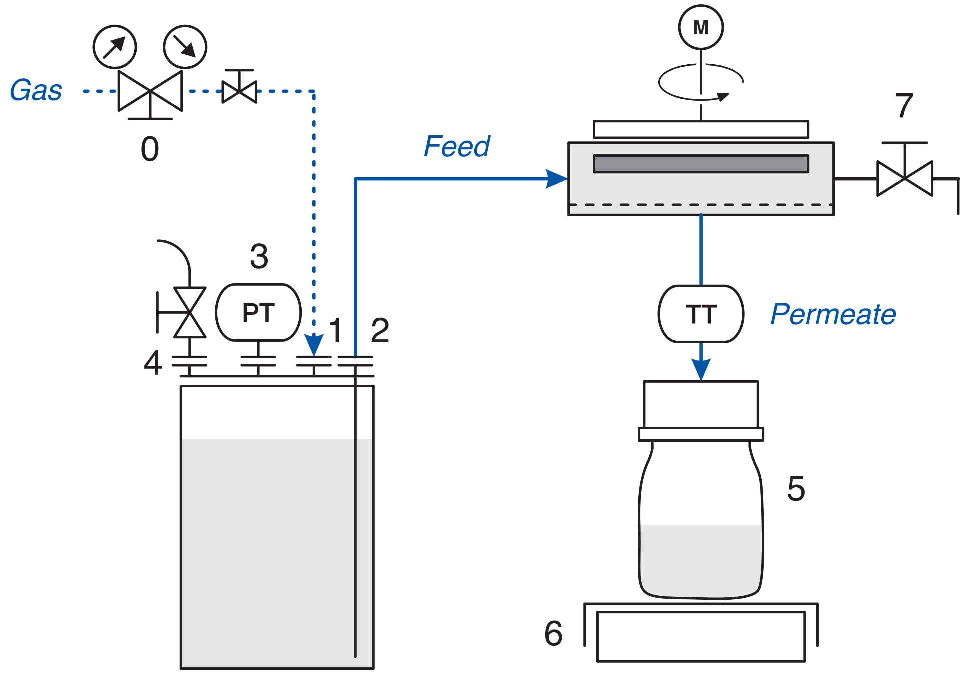

Figure 4: Typical process configuration for operation with inert gas pressurization.

A typical process configuration is shown in Figure 4. The feed solution is placed inside a pressure-resistant dosing vessel connected to an inert gas supply. The gas pressure acts directly on the liquid surface and forces the feed solution through the membrane cell. During operation, the liquid flows across the membrane surface while transmembrane pressure drives permeation through the membrane.

The permeate stream is collected separately for flux measurements, retention analysis, concentration studies, or downstream processing. Depending on the operating configuration, the retentate can either be collected separately or recirculated back into the pressure vessel.

Compared to mechanically pumped systems, inert gas pressurization offers several important advantages:

- Pulsation-free pressure conditions
- Very stable transmembrane pressure
- Low mechanical shear stress
- Simple and compact system design
- Reduced dead volume
- Excellent suitability for small sample volumes
- Low maintenance requirements

The transmembrane pressure is generated directly by the applied gas pressure and can be adjusted precisely using pressure regulators and control valves. For many laboratory applications, the gas pressure approximately corresponds to the feed pressure inside the membrane system.

The transmembrane pressure can be approximated by

$$\mathrm{TMP} = p_{\mathrm{gas}} - p_{\mathrm{permeate}} \tag{7}$$

where p_{gas} is the applied inert gas pressure and p_{permeate} is the permeate-side pressure.

The permeate flux can be determined using

$$J = \frac{\dot{V}_P}{A} \tag{8}$$

where J is the permeate flux, $\dot{V}_P$ is the permeate volumetric flow rate, and A is the effective membrane area.

For stirred membrane systems such as HexaMem, hydrodynamic shear conditions are generated independently by the rotating magnetic stirrer located above the membrane surface. The tangential velocity can be approximated by

$$v_t = \omega \cdot r \tag{9}$$

with

$$\omega = \frac{2\pi n}{60} \tag{10}$$

where v_t is the tangential velocity, ω is the angular velocity, r is the radial distance from the center of rotation, and n is the rotational speed in revolutions per minute.

Independent adjustment of gas pressure and stirrer speed allows systematic investigation of coupled hydraulic and hydrodynamic effects on membrane performance, concentration polarization, fouling behavior, and flux stability.

Typical inert gases used for pressurization include:

- Nitrogen
- Argon
- Compressed air for non-sensitive applications

Inert gas pressurization is particularly suitable for:

- Small-volume membrane experiments
- Membrane screening studies
- Fouling investigations
- Flux and retention measurements
- Concentration experiments
- Shear-sensitive fluids
- Pulsation-sensitive filtration experiments

Compared to pump-driven circulation systems, gas-pressurized operation generally provides simpler system architecture, lower mechanical stress, and highly stable pressure conditions. However, crossflow velocities are typically lower, and continuous recirculation operation is more limited compared to externally pumped systems.

3.3 Operation with Inert Gas Pressurization and Pump

In combined inert gas and pump operation, the membrane system integrates both inert gas pressurization and active liquid circulation. The feed solution is stored inside a pressure vessel pressurized with inert gas, while an external circulation pump generates controlled crossflow conditions across the membrane surface. This operating mode combines the advantages of highly stable pressure conditions with independently adjustable hydrodynamic shear.

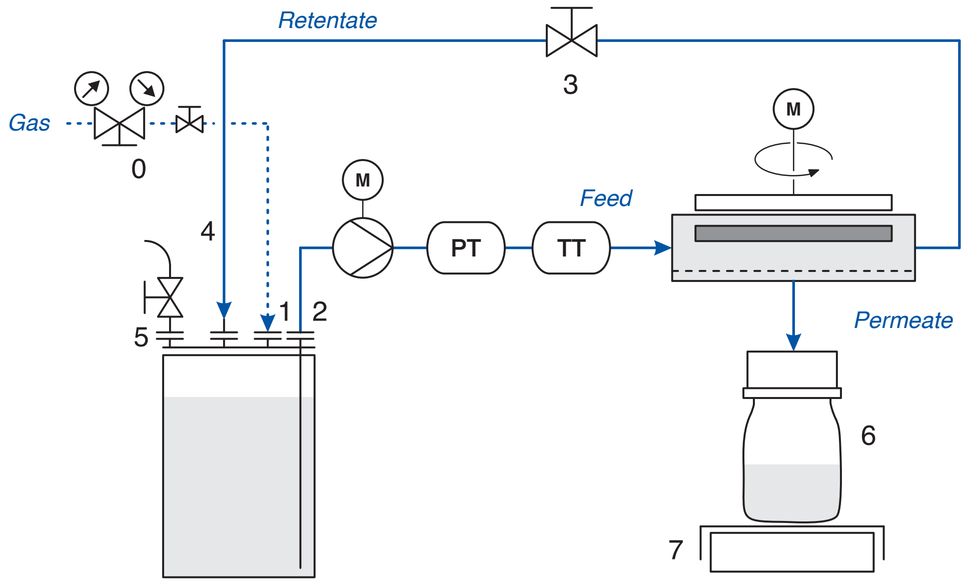

Figure 5: Operation with inert gas pressurization and circulation pump.

A typical process configuration is shown in Figure 5. The feed solution is placed inside a pressure-resistant vessel connected to an inert gas supply. The applied gas pressure provides the hydraulic driving force for membrane permeation, while the external circulation pump continuously transports the liquid through the membrane cell and back into the pressure vessel.

During operation, the liquid flows tangentially across the membrane surface while transmembrane pressure drives permeation through the membrane. The retentate stream is recirculated continuously, enabling stable hydrodynamic conditions and long-duration filtration experiments. The permeate stream is collected separately for flux measurements, retention analysis, concentration studies, or downstream processing.

The combined operating mode offers several important advantages:

- Stable and pulsation-free pressure conditions
- Independent control of transmembrane pressure and crossflow velocity
- Improved hydrodynamic shear conditions
- Reduced concentration polarization
- Enhanced fouling control
- Continuous recirculation operation
- Flexible adjustment of hydraulic and hydrodynamic parameters

The transmembrane pressure is generated primarily by the applied inert gas pressure and can be approximated by

$$\text{TMP} = p_{\text{gas}} - p_{\text{permeate}} \tag{11}$$

where p_{gas} is the applied inert gas pressure and p_{permeate} is the permeate-side pressure.

The circulation pump determines the volumetric flow rate through the membrane cell and therefore directly influences the hydrodynamic shear conditions at the membrane surface. The average crossflow velocity can be approximated by

$$v = \frac{\dot{V}}{A_c} \tag{12}$$

where v is the average crossflow velocity, $\dot{V}$ is the volumetric circulation flow rate, and A_c is the effective hydraulic flow cross-section above the membrane surface.

The permeate flux can be determined using

$$J = \frac{\dot{V}_P}{A} \tag{13}$$

where J is the permeate flux, $\dot{V}_P$ is the permeate volumetric flow rate, and A is the effective membrane area.

For stirred membrane systems such as HexaMem, the rotating magnetic stirrer additionally generates tangential shear flow above the membrane surface. The tangential velocity can be approximated by

$$v_t = \omega \cdot r \tag{14}$$

with

$$\omega = \frac{2\pi n}{60} \tag{15}$$

where v_t is the tangential velocity, ω is the angular velocity, r is the radial distance from the center of rotation, and n is the rotational speed in revolutions per minute.

The combined use of inert gas pressurization, circulation pump, and independently controlled stirrer speed enables highly flexible adjustment of operating conditions. Hydraulic pressure, crossflow velocity, and hydrodynamic shear can therefore be controlled independently over a wide operating range.

Typical applications include:

- Crossflow ultrafiltration and nanofiltration
- Fouling and concentration polarization studies
- Long-duration membrane experiments
- Membrane cleaning investigations
- Concentration experiments
- Process optimization studies
- Simulation of industrial membrane systems

Compared to purely gas-pressurized systems, the combined operating mode enables significantly higher crossflow velocities and improved hydrodynamic control. Compared to conventional pump-driven systems, inert gas pressurization provides more stable pressure conditions and reduced pulsation effects. The combined configuration therefore represents a highly flexible laboratory-scale membrane filtration platform for advanced process investigations under controlled operating conditions.

4 Stepper Motor Control

The HexaMem system uses a stepper motor to generate controlled rotational movement of the magnetic drive plate above the membrane cell. The rotational speed directly influences the hydrodynamic shear conditions at the membrane surface and therefore affects concentration polarization, fouling behavior, and mass transfer characteristics during filtration experiments.

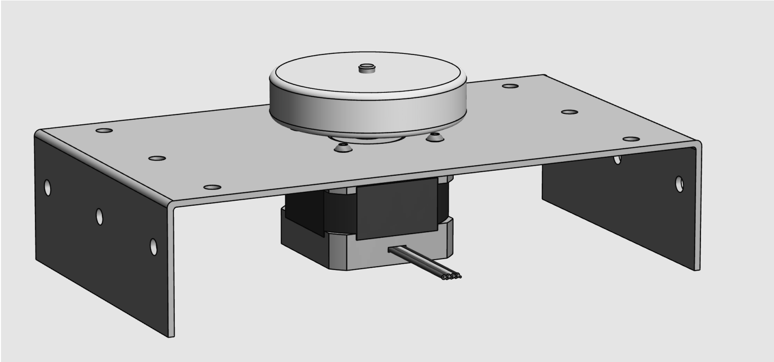

Figure 6: Stepper motor with rotating magnetic drive plate mounting plate.

The stepper motor can be controlled using standard digital pulse signals generated by a microcontroller, programmable logic controller (PLC), laboratory automation system, or dedicated motor controller. Typical control platforms include Arduino, Raspberry Pi, ESP32, industrial PLC systems, or commercial motion controllers.

Motor operation is typically implemented using a separate stepper motor driver with standard STEP and DIR input signals:

- STEP signal: generates individual motor steps and defines rotational speed
- DIR signal: controls rotational direction
- ENABLE signal (optional): activates or deactivates the motor driver

The motor driver provides current regulation, microstepping functionality, overload protection, and thermal protection. Microstepping operation improves rotational smoothness and reduces vibration during operation.

The rotational speed can easily be adjusted over a wide operating range, allowing controlled investigation of hydrodynamic effects on membrane performance. Depending on the selected motor type, driver configuration, and operating conditions, rotational speeds from a few revolutions per minute up to several hundred revolutions per minute can be achieved.

Hydrodynamic shear conditions at the membrane surface are directly related to the tangential velocity generated by the rotating magnetic stirrer. For a rotational system, the tangential velocity can be approximated by

$$v_t = \omega \cdot r \tag{16}$$

with

$$\omega = \frac{2\pi n}{60} \tag{17}$$

where v_t is the tangential velocity, ω is the angular velocity, r is the radial distance from the center of rotation, and n is the rotational speed in revolutions per minute.

v_t	tangential velocity at the membrane surface
ω	angular velocity
r	radial position from the center of rotation
n	rotational speed in revolutions per minute

For the HexaMem system, the tangential velocity at a radius of 35 mm increases approximately linearly with rotational speed. Typical operating conditions range from approximately 0,2 m/s to more than 2 m/s, depending on the selected rotational speed and stirrer geometry.

The use of a stepper motor provides several advantages for laboratory membrane filtration systems:

- Precise and reproducible speed control
- Stable operation at low rotational speeds
- Simple digital integration into laboratory automation systems
- Direct control without feedback sensors in many applications
- Compact mechanical integration
- Low maintenance requirements

For advanced experimental setups, the motor control system can additionally be integrated with pressure sensors, temperature sensors, flow measurement devices, and automated data acquisition systems. This enables fully automated membrane filtration experiments with programmable operating profiles, dynamic shear control, and synchronized process monitoring.

Typical experimental investigations include:

- Influence of shear rate on membrane fouling
- Flux optimization under controlled hydrodynamic conditions
- Concentration polarization studies
- Fouling layer removal investigations
- Membrane cleaning experiments
- Crossflow simulation under laboratory conditions

5 Performance

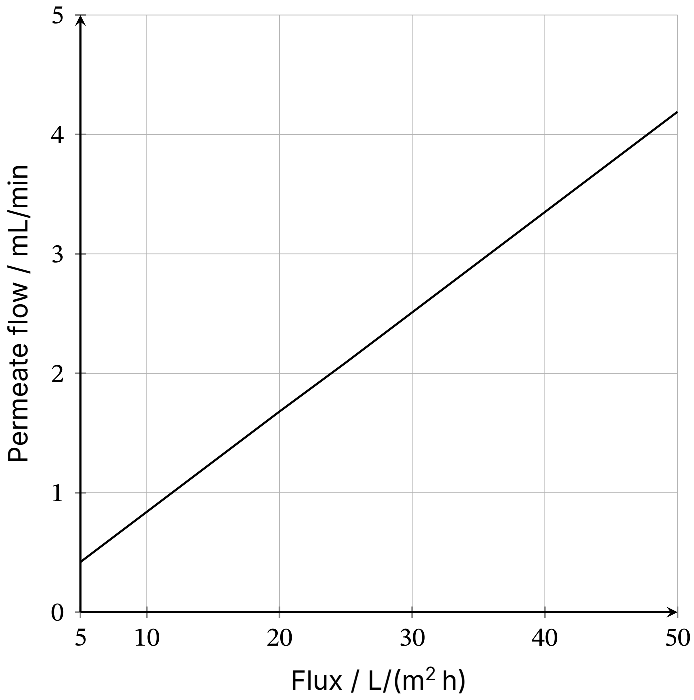

Figure 7: Permeate flow as a function of flux for a membrane with a diameter of 80 mm.

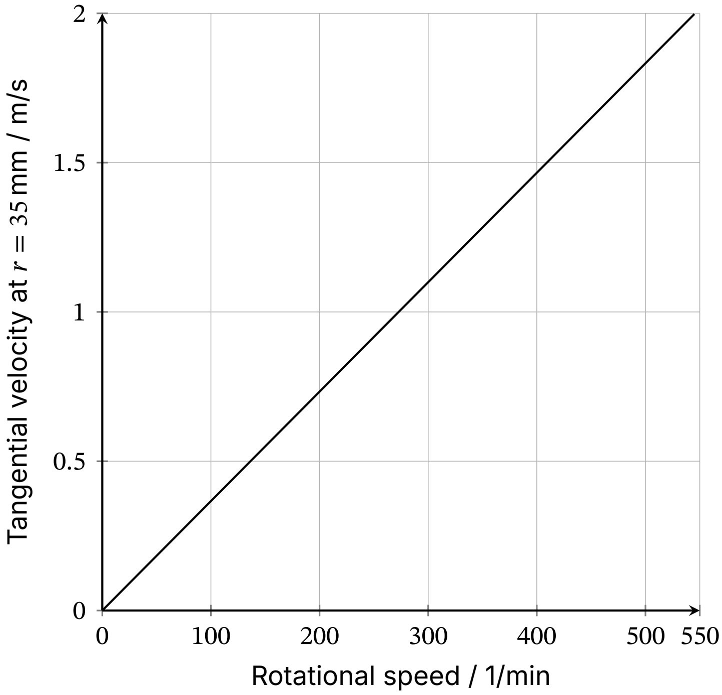

Figure 8: Tangential velocity at a radius of 35 mm as a function of rotational speed.

6 Safety and Handling

To ensure safe operation and reliable system performance, all applicable safety instructions and operating guidelines must be observed. Improper installation, operation, or maintenance may result in personal injury, equipment damage, or reduced process performance. The system must only be operated by qualified personnel familiar with the relevant technical and safety requirements.

- Do not operate the system above the maximum allowable operating pressure (MAOP) under any circumstances.
- Verify the chemical compatibility of all wetted materials with the intended media prior to operation.
- Ensure that only trained and qualified personnel install, operate, and maintain the equipment.
- Fully depressurize and isolate the system before opening the test cell or performing any maintenance.
- Inspect seals and critical components before each use; replace any damaged, worn, or degraded parts immediately.

7 Add-Ons

Messinger Engineering offers a comprehensive portfolio of laboratory and pilot-scale process equipment for membrane filtration and separation technology. Available add-ons include precision pumps, valves, actuators, reservoirs, pressure vessels, and high-quality process instrumentation for flow, pressure, temperature, mass, and conductivity measurement.

The modular system architecture enables rapid configuration of fully customized experimental setups for crossflow filtration, dead-end filtration, electrochemical membrane processes, and specialty membrane applications. Components are selected for maximum chemical compatibility, operational reliability, and seamless integration into laboratory environments.

In addition to proprietary system components, Messinger Engineering provides specification support and integration of qualified third-party equipment from leading manufacturers. This allows customers to implement complete, application-specific membrane process platforms from a single engineering source.

7.1 Pressurized Dosing Tank

Stainless steel pressure dosing tank, diameter DN100 (DIN 32676), variable height, volume 1–3 L. Top connection: Clamp DN100 with configurable 6 mm connections and dip tube 6 mm. Bottom connection: Clamp DN100.

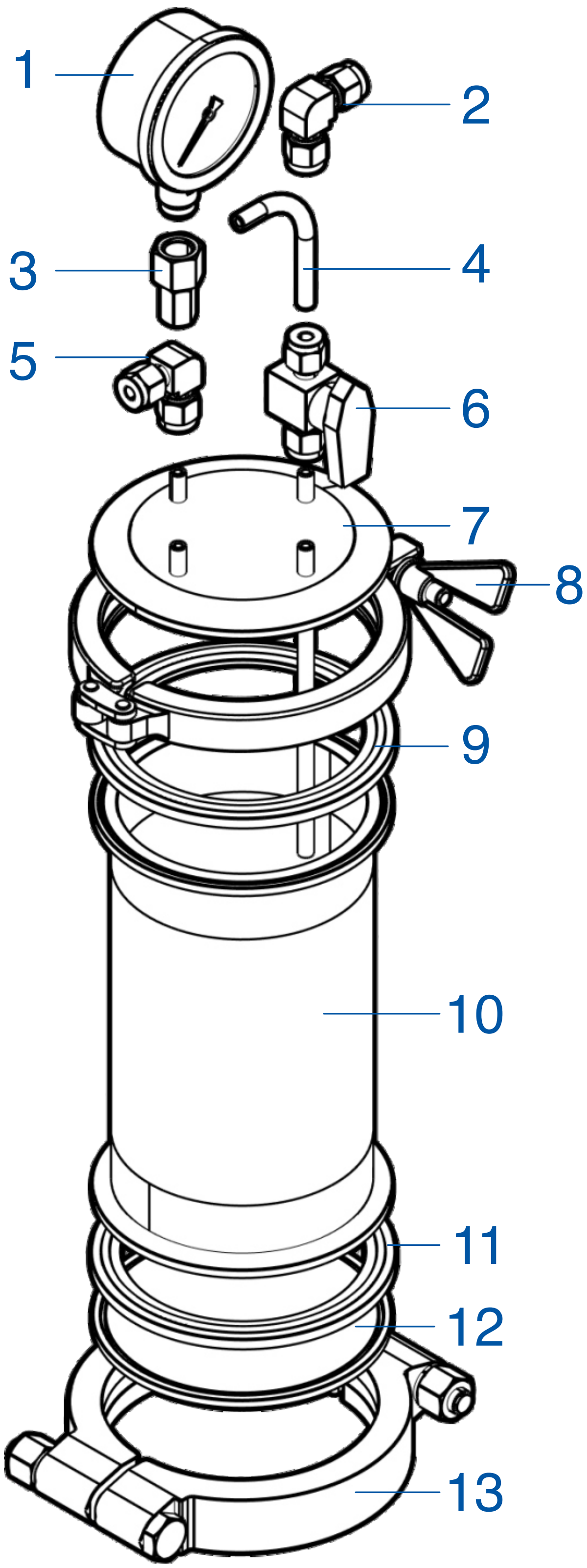

Figure 9: Exploded view of the pressurized dosing tank.

1 Pressure gauge, 0–10 bar, 0–20 bar, 0–30 bar, or 0–40 bar, glycerin-filled, connection 1/4″.
2 Swagelok 90° elbow fitting, 6 mm, SS-6M0-9.
3 Serto pressure gauge connector, 6 mm / 1/4″.
4 90° bend, AISI 304 stainless steel, 6 mm.
5 Swagelok 90° elbow fitting, 6 mm, SS-6M0-9.
6 Swagelok valve, 6 mm, SS-8P6T-MM.
7 Lid for Clamp DN100, AISI 316 stainless steel, with four 6 mm connectors, including one continuous dip tube.
8 Clamp with double hinge, DN100.
9 EPDM, Viton, or silicone gasket for Clamp DN100.
10 Tube with variable length, DN100 diameter, with Clamp DN100 ferrules welded on top and bottom, material AISI 316L or AISI 304 stainless steel.
11 EPDM, Viton, or silicone gasket for Clamp DN100.
12 Clamp blank plate DN100, AISI 304 stainless steel.
13 High-pressure clamp DN100.

8 Membranes

The test cell is compatible with a wide range of flat-sheet membrane types and membrane materials. In addition to conventional pressure-driven membranes for microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO), the system can also accommodate specialty membranes, ion-exchange membranes, functionalized membranes, and ceramic membranes for research and development applications.

Worldwide, numerous membrane manufacturers supply flat-sheet membrane samples for laboratory testing and process development. Typical membrane materials include polyethersulfone (PES), polysulfone (PS), polyvinylidene fluoride (PVDF), regenerated cellulose (RC), polyamide (PA), polypropylene (PP), PTFE, and ceramic materials such as alumina, zirconia, or titania.

Polymeric flat-sheet membranes can easily be prepared using standard membrane punching tools or circular cutting devices, enabling rapid membrane exchange and highly flexible experimental workflows. The simple membrane geometry allows researchers to investigate different membrane materials, pore sizes, molecular weight cut-offs, surface modifications, and operating conditions with minimal preparation effort.

The versatility of the HexaMem system makes it suitable for a broad range of applications in membrane science, process engineering, biotechnology, food processing, water treatment, chemical engineering, and academic research. The system can be used for membrane screening, flux and retention measurements, fouling investigations, cleaning studies, concentration experiments, enzyme membrane reactor applications, and small-scale process development under controlled crossflow conditions.

Type	Model	MWCO [kDa]
Alfa Laval	GR95PP	2
Alfa Laval	GR90PE	5

Alfa Laval	GR90PP	5
Alfa Laval	GR80PE	10
Alfa Laval	GR80PP	10
Alfa Laval	GR61PP	14
Alfa Laval	GR60PP	20
Alfa Laval	GR40PP	100
Kovalus	HFK-328	5
Kovalus	HFK-131	10
Kovalus	HpHT K328	5
Kovalus	HpHT K131	10
Synder	XT	1
Synder	VT	3
Synder	MT	5
Synder	ST	10
Synder	SM	20
Synder	MK	30
Synder	PZ	30
Synder	MQ	50
Synder	V4	70
Synder	LY	100
Synder	PY	100
Synder	LV	200
Synder	LX	300
Synder	PX	400
Unisol	UPS005-P	5
Unisol	UPS010-P	10
Unisol	UPS020	20
Unisol	UPS100	100
Unisol	UPS150-P	150

Table 1: List of flat-sheet membrane samples compatible with the HexaMem stirred-cell membrane system.

9 Membrane Cleaning and Cleaning Experiments

Membrane cleaning is one of the most important aspects of membrane process engineering and strongly influences filtration performance, process stability, operating costs, membrane lifetime, and product quality. During membrane filtration, substances such as proteins, fats, polysaccharides, microorganisms, colloids, salts, minerals, or organic compounds can accumulate on the membrane surface or inside membrane pores. These fouling and scaling phenomena lead to flux decline, changes in selectivity, increased pressure requirements, and reduced long-term process stability. Systematic investigation of membrane fouling and cleaning behavior is therefore essential during membrane selection, process development, optimization, and scale-up. Different feed streams, membrane materials, operating conditions, and hydrodynamic regimes can result in very different fouling mechanisms and cleaning requirements.

9.1 Cleaning Experiments and Fouling Analysis

The HexaMem stirred-cell membrane system is particularly well suited for membrane cleaning experiments and fouling investigations under controlled laboratory conditions. The system allows reproducible generation of fouling layers during filtration experiments, followed by direct cleaning studies using small volumes of cleaning solutions and process liquids. A major advantage of the HexaMem design is the direct accessibility of the membrane. After filtration experiments, the membrane cell can easily be opened and the flat-sheet membrane can be removed for visual inspection and further analysis. This enables direct investigation of fouling layers, deposit structures, discoloration, scaling phenomena, particle accumulation, biofilm formation, and membrane surface changes after operation and cleaning.

The open and accessible system geometry furthermore simplifies membrane exchange, cleaning validation, and comparative membrane studies. The stirred crossflow configuration enables realistic hydrodynamic shear conditions at the membrane surface and allows investigation of the influence of tangential flow, pressure, temperature, concentration, and cleaning chemistry on membrane fouling and flux recovery. Different cleaning procedures can therefore be evaluated systematically under highly reproducible operating conditions.

9.2 Membrane Cleaning Chemicals

Typical membrane cleaning chemicals include alkaline cleaners for removing proteins, fats, and organic deposits, acid cleaners for dissolving mineral scaling and inorganic deposits, and enzymatic cleaners for degradation of proteins, starches, and biological residues under mild operating conditions. Additional cleaning products include oxidative cleaners for reducing microbiological contamination, chelating agents for binding dissolved metal ions, surfactants for improving wetting and cleaning performance, and disinfectants for hygienic cleaning of membrane systems and associated process equipment. Such cleaning chemicals are commonly used to restore membrane flux, reduce fouling, maintain stable filtration performance, and extend membrane service life in MF, UF, NF, and RO membrane systems.

We recommend membrane cleaning chemicals from Halag Chemie AG (Switzerland). Halag Chemie AG (www.halagchemie.ch) offers a broad range of membrane cleaning formulations for polymeric and ceramic membranes used in food processing, biotechnology, dairy processing, beverage production, water treatment, and industrial membrane applications. The HexaMem system is therefore not only a membrane filtration test cell, but also a versatile laboratory platform for systematic fouling studies, membrane cleaning optimization, cleaning chemical evaluation, flux recovery investigations, and membrane process development.

AMC 476 ENZ	Foam- and surfactant-free enzyme additive for use in combination with an alkaline cleaner. Base: proteases. Liquid 0.2–0.5 % within the optimal pH range of 10.0–11.5

AMC 478	Surfactant-free cleaning booster with complexing effect for use in combination with alkaline cleaners. EDTA- and NTA-free. Liquid 0.2–0.5 %
AMC 492	Surfactant-based cleaning booster with complexing action for use in combination with alkaline cleaners on heavily greasy substrates. EDTA- and NTA-free. Liquid 0.2–1.0 %
AMC 556	Acidic cleaner for acid-resistant membranes. Base: phosphoric and nitric acid. Liquid 0.2–0.5 %
AMC 559 plus	Nitric acid additive for reducing nitroso gases and extending membrane service life. Liquid 0.05–0.2 % for diluted solutions, 5.0 % for concentrates
AMC 634	Alkaline, surfactant-free cleaner with active chlorine for membranes resistant to alkalis and active chlorine. Liquid 0.5–2.0 %
Halaplus 6	Surfactant-free cleaning booster based on hydrogen peroxide for peroxide-resistant membranes. Liquid 0.5–1.0 %
Halaplus 12	Surfactant-free cleaning booster based on active chlorine for active-chlorine-resistant membranes. Liquid 0.1–0.2 %
Halades PE	Surfactant-free disinfectant based on peracetic acid and hydrogen peroxide for peroxide-resistant membranes. Liquid 0.3–0.5 %
UF 411 ENZ	Enzyme additive used in combination with an alkaline cleaner. Base: proteases, lipases, and lactase. Liquid 0.35–0.5 % within the optimal pH range of 7.0–10.5
UF 454	Alkaline, buffered cleaner containing surfactants and complexing agents for alkali-resistant membranes. EDTA- and NTA-free. Liquid 0.5–2.0 %
UF 464	Alkaline, buffered, surfactant-free cleaner with complexing agents for alkali-resistant membranes. Can also be used in combination with an enzyme additive. EDTA- and NTA-free. Liquid 0.5–2.0 %

UF 466	Highly alkaline cleaner with surfactants and complexing agents for alkali-resistant membranes. EDTA- and NTA-free. Liquid 0.5–2.0 %
UF 470 ENZ	Enzyme additive used in combination with an alkaline cleaner. Base: proteases. Liquid 0.2–0.5 % within the optimal pH range of 10.0–11.5
UF 480	Highly alkaline, surfactant-free cleaner with complexing agents for alkali-resistant membranes. Can also be used in combination with an enzyme additive. EDTA- and NTA-free. Liquid 0.5–2.0 %
UF 482 Booster	Defoaming cleaning booster with complexing properties for use in combination with alkaline cleaners. EDTA- and NTA-free. Liquid 0.2–0.5 %
UF 490	Mildly alkaline specialty cleaner with surfactants for alkali-resistant membranes in the machinery and automotive repair industries. Liquid 0.5–2.0 %
UF 491	Alkaline, buffered, low-foaming cleaner containing surfactants and complexing agents for use in combination with enzyme additives. EDTA- and NTA-free. Liquid 0.5–2.0 %
UF 557	Acidic, nitrate-free cleaner for acid-resistant membranes. Base: phosphoric acid. Liquid 0.5–1.0 %
UF 558	Acidic cleaner for acid-resistant membranes. Base: nitric and phosphoric acid. Liquid 0.2–0.5 %
UF 635	Alkaline cleaner with active chlorine and surfactants for membranes resistant to alkalis and active chlorine. Liquid 0.5–2.0 %

Table 2: List of liquid membrane cleaning chemicals supplied by Halag Chemie AG (Switzerland) for MF, UF, NF, and RO membrane applications.

10 Ordering Information

HexaMem 304	Membrane cell with 80 mm flat-sheet membrane diameter, manufactured from AISI 304 stainless steel.
HexaMem 316L	Membrane cell with 80 mm flat-sheet membrane diameter, manufactured from AISI 316L stainless steel.
Process connections	Please specify process port configuration: F = feed, R = retentate, P = permeate.

11 Optional Equipment

Seals	Replacement seals and O-rings made of Viton, EPDM, or silicone. O-ring = 75 × 2
Permeate carrier	Replacement permeate carrier materials for membrane support and flow distribution
Connectors	Adapters and connectors from Swagelok, Serto, and other suppliers
Rotors	Rotors with integrated magnets manufactured using 3D printing
Cleaning agents	Cleaning solutions supplied by Halag Chemie AG (Switzerland) for membrane cleaning and system maintenance

12 Manufacturer / Contact

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Special emphasis is placed on a European supply chain. The test cells are manufactured in Europe by a specialized company using modern CNC machines.