

MICRODYN  
Capillary Modules  
User Manual

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# 1 Introduction

MANN+HUMMEL Water & Fluid Solutions (WFS) offers a wide variety of capillary modules under the MICRODYN brand. MICRODYN cross-flow microfiltration (MF) modules are used to separate suspended solids larger than 0.2 micron. The highly porous polypropylene (PP) membrane is backwashable, allowing for stable and efficient filtration with continuously high product flux.

The smart construction techniques employed in the module manufacturing allow them to be used in applications that require highly stable polymer materials, pH stability (0 to 14), and high resistance against abrasive substances.

The advantages of MICRODYN microfiltration modules include:

- Well-defined flow conditions
- High packing density
- Minimized dead zones
- Extremely abrasion resistant
- Strong chemical resistance
- Backwashable
- Low specific energy consumption

Typical applications where MICRODYN capillary modules are used are food applications like wine and vinegar filtration or pharmaceutical applications where specific proteins are concentrated.

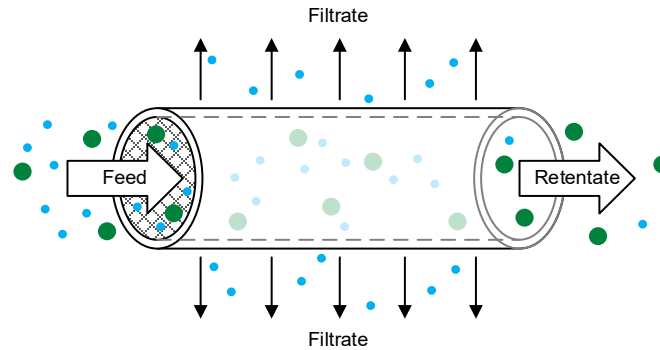
## 2 Product Description

### 2.1 PRODUCT DESIGN

MICRODYN capillary modules contain a bundle of symmetric, hydrophobic polypropylene capillary membranes with a nominal pore size of 0.2 micron. The capillary membranes are potted in polyurethane. MICRODYN capillary modules were developed for cross-flow microfiltration (CMF), a modern filtration procedure for separating suspended solids and for low concentrations of emulsions.

### 2.2 CROSS-FLOW MICROFILTRATION

The feed flows inside the membrane lumen (or inside the membrane fibers) as shown in Figure 1. A part of this feed exits the capillary membrane as filtrate, or clean water, due to a pressure difference across the membrane. The remaining liquid is called the retentate/concentrate.



**Figure 1.** Scheme of lumen function.

### 2.3 PRODUCT CODES & MODULE TYPES

The following coding applies to MICRODYN products:

<b>MD150</b>	-	<b>CP</b>	-	<b>2N</b>	/	<b>DF</b>
Module Type & Size ( $\emptyset$ diameter of housing in mm)		Membrane Geometry & Shell Material		Pore Size (0.2 $\mu$ m) & Module Length		Module Connection
		CP: Capillary membrane with polypropylene housing FP: Hollow fiber membrane with polypropylene housing CS: Capillary membrane with Stainless Steel housing CU: Capillary membrane with Polysulfone housing CV: Capillary membrane with PVC/PVC-C housing		M: medium N: normal		AF: ANSI flange DF: DIN flange JF: JIS flange C: Clamp connection F/R CC: Clamp connection F/R/P AS: Thread connection

Please refer to Appendix 1, Table 1 for an overview of available MICRODYN capillary modules.

For more module-specific data, please refer to the respective datasheet on the webpage ([Capillary & Tubular Modules - MANN+HUMMEL Water & Fluid Solutions \(microdyn-nadir.com\)](https://www.mannhummel.com/en/water-and-fluid-solutions/microdyn-nadir))

## 3 Shipping, Handling & Storage

### 3.1 SHIPPING & HANDLING

Transportation and handling of MICRODYN capillary modules should be done with extreme care as a module may crack or break if dropped. Having proper equipment is also essential for safely handling the modules.

Modules should not come into contact with organic solvents, nor should splicing tape be used as this may lead to the damage of the module casing.

Wipe the module casing with water or ethanol to remove debris from the module casing.

### 3.2 STORAGE CONDITIONS

The following conditions are recommended when storing the modules:

- Store the modules inside a cool building or warehouse out of direct sunlight.
- Temperature limits: between 5°C and 35°C (41°F and 95°F).
- Humidity must not exceed 70%.
- All new modules being stored prior to use should remain in original packaging.

### 3.3 RETURNING A MODULE

If a module is returned for any reason, MANN+HUMMEL WFS must approve the shipment first. Please contact the appropriate MANN+HUMMEL WFS representative before sending the product back. Non-approved return shipments will be rejected.

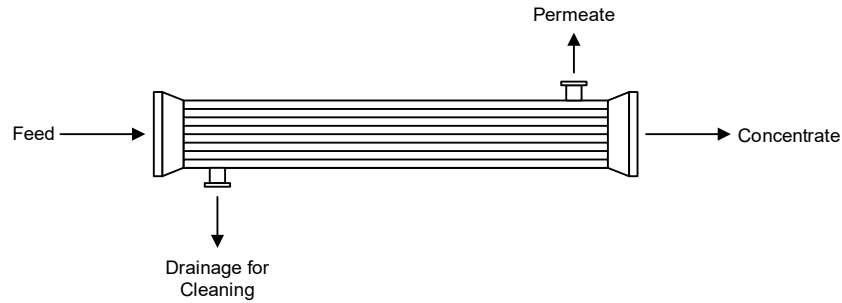
If MANN+HUMMEL WFS approves a return of a module, it must be appropriately cleaned, preserved, packed, and labeled to transport safely and retain the integrity of the materials.

## 4 Installation & Activation

### 4.1 INSTALLATION

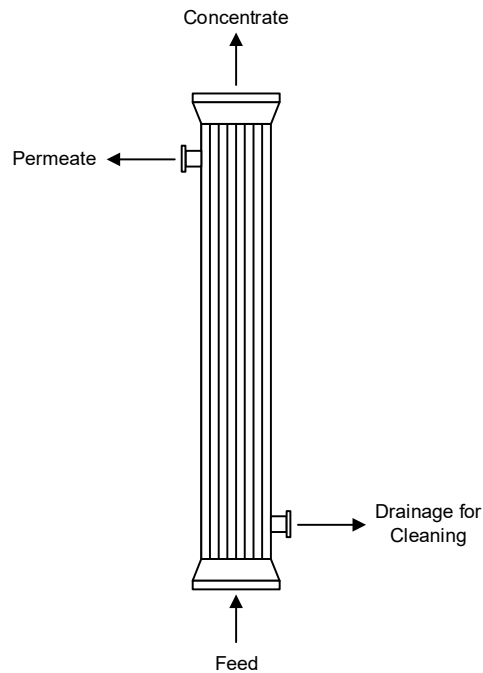
MICRODYN capillary modules may be installed into a system vertically or horizontally.

A horizontal position is recommended for filtration of suspensions with a large quantity of solids (Figure 2). While each module has two permeate outlets, only one is typically used during filtration. In the horizontal position, the permeate port must be facing upwards to allow the module to fill fully with liquid. Additionally, the permeate port should be at the end of the module (low pressure side) if the module is in the horizontal position.



**Figure 2.** Module in the horizontal position.

In the vertical position, the permeate outlet must always be toward the top of the module so that air can be removed completely from the module prior to operation (Figure 3).



**Figure 3.** Module in the vertical position.

## 4.2 ACTIVATION WITH WATER PRESSURE

Typically, activation of the module's membranes is required. The PP membrane is hydrophobic in nature. Liquids like water with high surface tension of 0.072 N/m do not wet the membrane.

A simple and safe way to activate the membrane in the module(s) is the use of water at higher pressure. The first step is to fill the module(s) bubble free with water (25 °C) from both sides (feed and permeate side). A pressure of 6 bar must be applied to the module(s) for 1 minute. Typically, this is the tap line pressure. (Please notice the difference to the max. operating pressure given in the data sheet.)

After this procedure, the pressure must be released to zero. The water must be exchanged, and the procedure must be repeated four to six times. Now the module is activated and can be used for filtration.

## 4.3 ACTIVATION WITH WETTING AGENTS

For all filtration purposes where the module must be tested by a bubble point test for process safety reasons, the module has to be activated by means of water-soluble liquids with a surface tension of less than 0.035 N/m.

Appropriate liquids to be used are:

- a mixture of water and 50 vol. % of isopropanol
- a mixture of water and 25 vol. % tert. butanol (not inflammable)
- surfactants

With this method, it is necessary to run the module in a system for about 30 minutes in cross-flow mode until a sufficiently high flux is reached.

After wetting, the module is flushed either with water or with the solution to be filtered to rinse any remaining agents. As long as it stays in fluid, the membrane is activated. If the membrane dries up, it must be activated again as per the description. The membrane's separation properties will not change by drying.

Heavily gasifying liquids (carbonated beverages or beer) require a counter-pressure on the permeate side (e.g. 1 bar) in order to prevent the release of gases. Gases will deactivate the membranes.

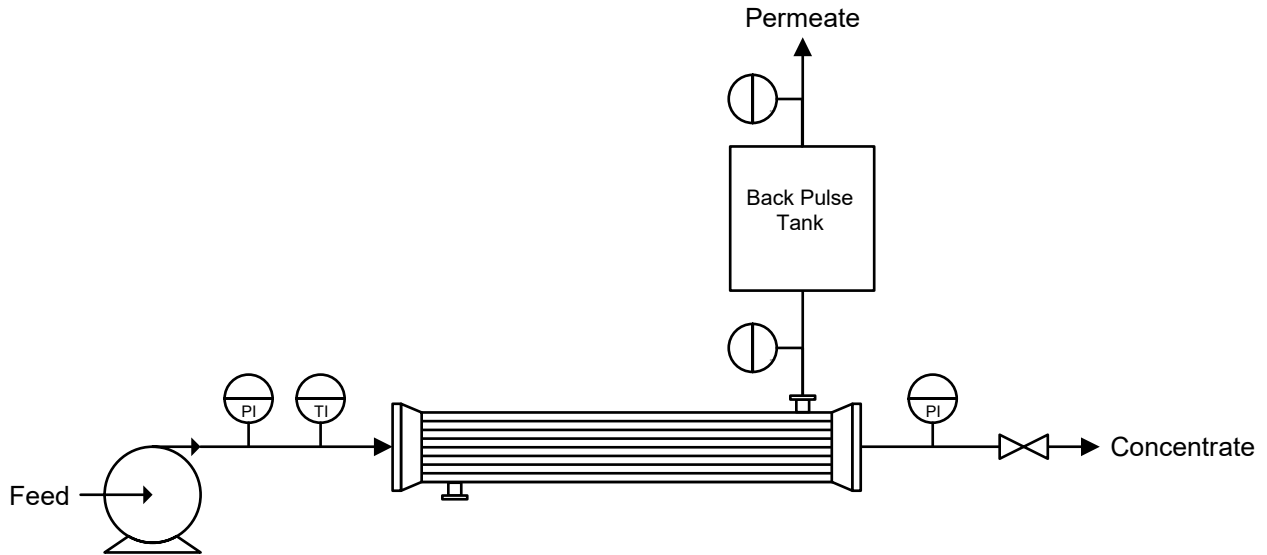
In the PBP process, a part of the permeate is pushed back by compressed gas (e.g. air). Care must be taken so that the gas is not pressed into the membrane. Otherwise, the membranes will be made a partially hydrophobic with reduced flux. A reactivation must then be performed.



## 5 Operation

### 5.1 GENERAL SYSTEM SET-UP

In cross-flow filtration, a liquid is pumped through the modules. A typical arrangement is shown in Figure 4 below. The favorable flow velocity for MICRODYN modules ranges between 1-2 m/s (3.3-6.6 ft/s).

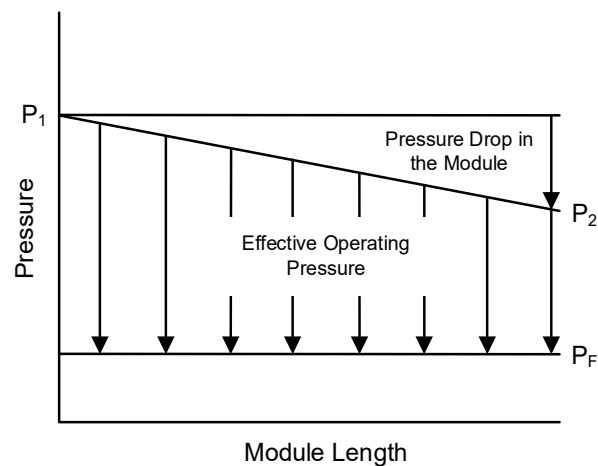


**Figure 4.** Simplified flow diagram using MICRODYN modules.

### 5.2 PRESSURE DROP AND TRANSMEMBRANE PRESSURE

For filtration to occur, the inlet, or feed pressure ( $P_1$ ), must be greater than the outlet pressure ( $P_2$ ) and filtrate pressure ( $P_F$ ), as shown in Figure 5. This difference in pressure, also called pressure drop, is the loss of pressure from the feed end to the concentrate end of a module and occurs due to the resistance of flow.

To achieve stable filtration, begin operation at a low feed pressure and gradually increase the feed pressure until optimal filtration performance is achieved. The driving force for filtration is the transmembrane pressure, which is defined by the difference of the pressure on the filtrate side and the averaged pressure on the feed/concentrate side (see also below equations). The allowable operating pressure is listed on the respective product data sheet.



**Figure 5.** The pressure drop along the length of the module.

To calculate the pressure drop and transmembrane pressure, please refer to the below equations.

Pressure drop:

$$\Delta P = P_1 - P_2$$

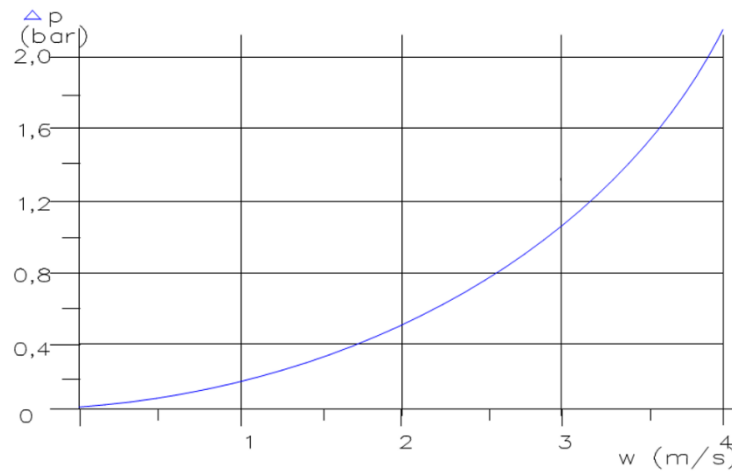
Transmembrane (operating) pressure:

$$P_{TMP} = \frac{P_1 - P_{2t}}{2} - P_F$$

The energy consumption of a cross-flow microfiltration system is determined mainly by the circulating volume and the pressure losses of the module. The pressure loss is affected by:

- The properties of the circulating fluid (e.g. rheological behavior, viscosity, and the concentration of suspended particles)
- The velocity resistance in circulation (modules, fittings, piping system)
- Operating conditions (flow velocity)

The greatest resistance to velocity in circulation occurs when the modules are operated in parallel or in series. Figure 6 shows the relationship between pressure drop and the mean linear velocity of water through MICRODYN capillary modules at 20°C.

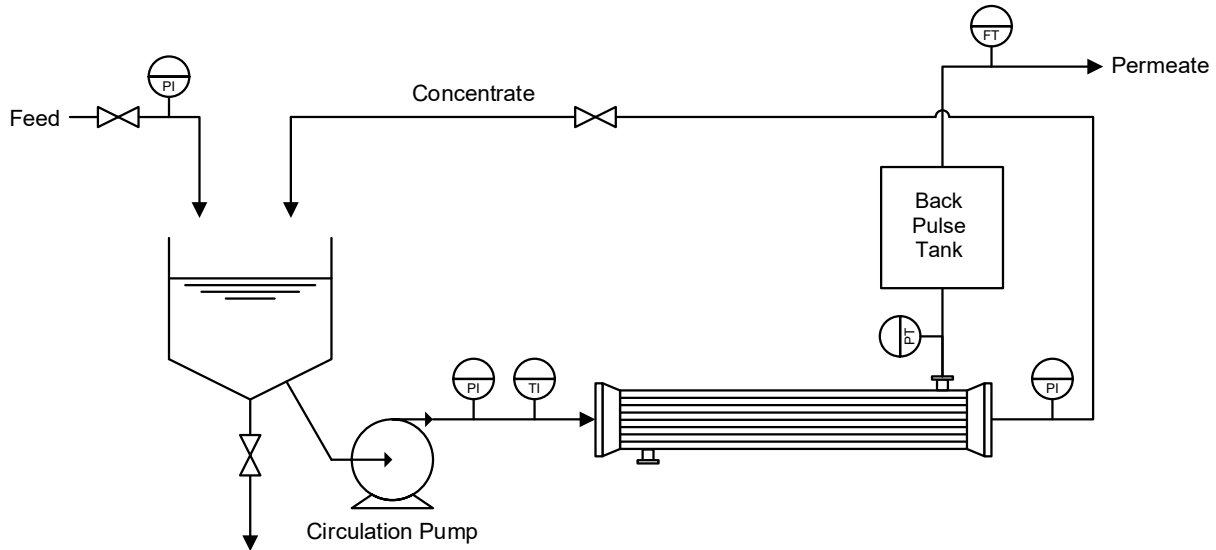


**Figure 6.** Relationship between pressure drop and velocity of water at 20°C measured in a MD 150 CP 2N.

## 5.3 OPERATION PROCESSES

### 5.3.1 Open Loop Operation

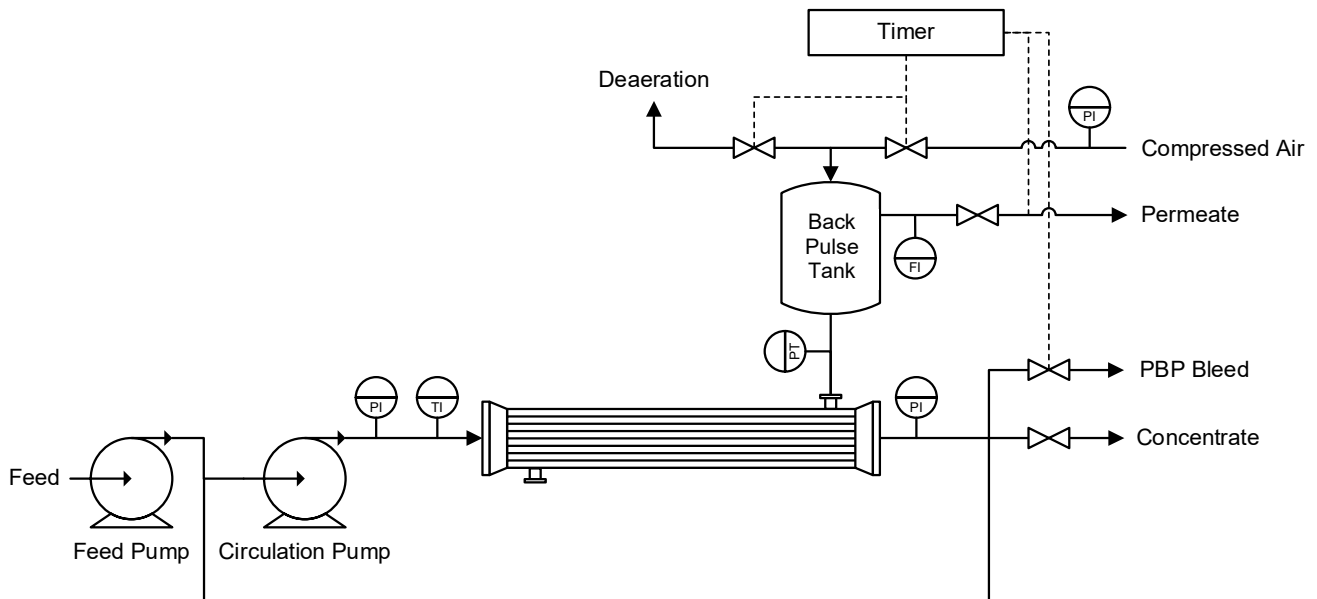
An open loop design is commonly used for batch processes, where a highly concentrated retentate is desirable. In an open loop design, the retentate is sent back to the feed tank for further concentrating. A continuous operation is possible with an open loop by continuously sending raw feed to the system and with concentrate bleeding.



**Figure 7.** Simplified flow diagram for open loop operation.

### 5.3.2 Closed Loop Operation

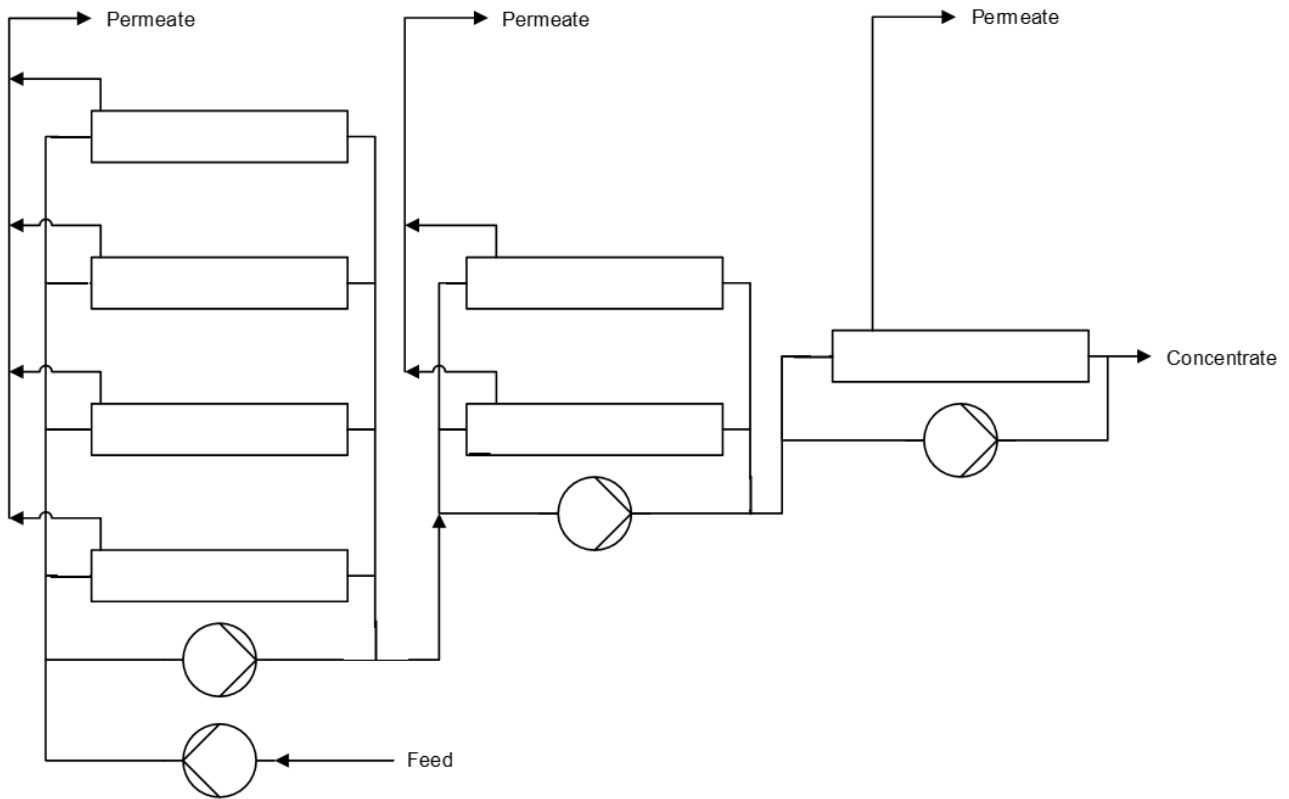
In a closed loop operation, the concentrate stream is sent back to the circulation pump ahead of the module. The advantage with this design is that the circulation pumping pressure is reduced. The feed pump is what supplies the system pressure. Overall, the pumping volume only includes the filtration flow rate and the bleed concentrate. The concentration of the concentrate is based on the mixing ratio of feed and bleed flow. It is important to keep the periodic back pulse (PBP) valve wide open to bleed the high amount of back pulsing water and to protect the feed side for a pressure increase.



**Figure 8.** Simplified flow diagram for closed loop operation.

### 5.3.3 Multistage operation

If the filtrate flow rate decreases with increasing feed concentration, it is possible to operate in a multistage configuration. In this configuration, the concentrate from the first stage is fed to the second stage. This means that the flow rate is higher in the first stages and only lower in the later stages. This configuration allows for fewer modules for a system.



**Figure 9.** Simplified diagram (without control devices and back pulsing system) of a multistage system.

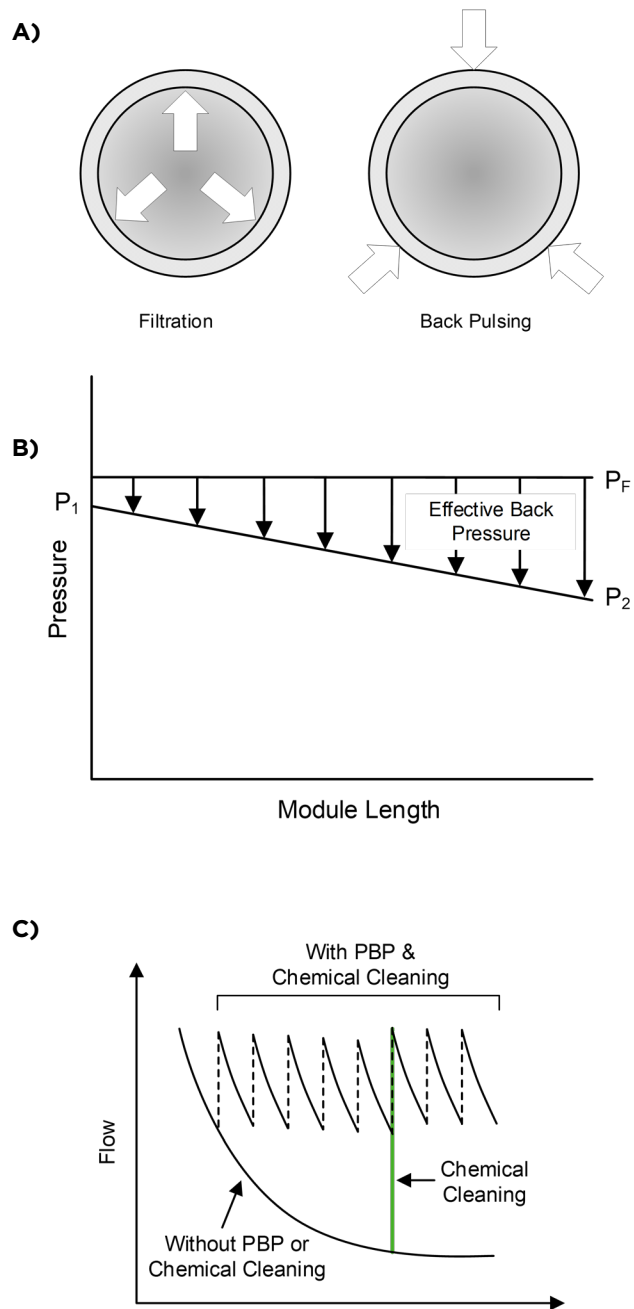
## 5.4 PERIODIC BACK PULSE (PBP)

During filtration, some particles will settle down on the surface of the membrane. This decreases the performance of the membrane. The purpose of the periodic back pulse (PBP) system is to remove these particles from the surface of the membrane, which helps restore the performance of the membrane. PBP may also decrease the system's overall energy consumption.

During PBP, a small amount of the filtrate is sent through the backside of the membrane (reversed flow) and is forced toward the feed side of the membrane. Figure 10A shows how the flow direction changes from normal filtration to back pulsing. In this moment, the filtrate pressure is higher than the feed pressure ( $P_F > P_1$  and  $P_2$ ), as shown in Figure 10B.

When filtrate is sent through the backside of the membrane and gets pushed through the feed side of the membrane, the fouling and scaling materials are loosened and removed from the membrane surface. Typically, a back pulse is done every 5 – 30 minutes, but trials may be done to determine how frequently a back pulse should be performed so that the system runs most efficiently. Figure 10C shows how important it is to perform regular PBP and chemical cleanings to help maintain membrane performance for extended periods of time.

It is recommended to install a PBP overflow for the concentrate because of the high backflow volume (nearly 1 L per 1 m<sup>2</sup> of installed membrane area, or 0.26 gal per 10.8 ft<sup>2</sup> of membrane area, in a range of 2-5 seconds).



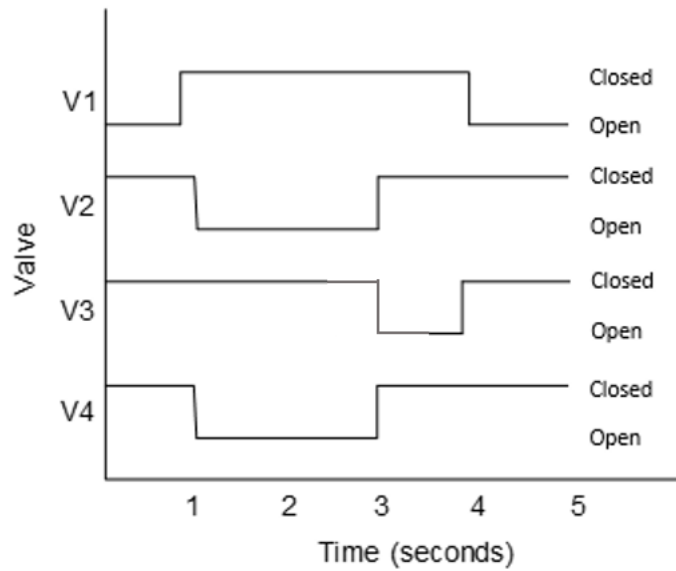
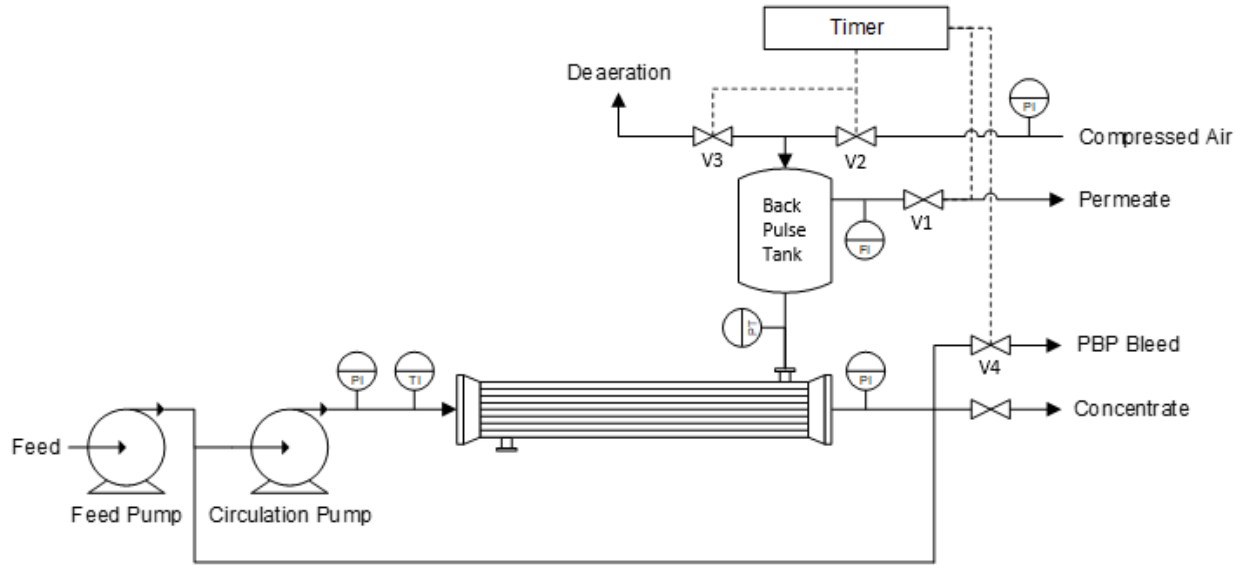
**Figure 10. A)** Diagram showing the difference in flow direction in the capillary membranes during filtration and back pulsing.

**B)** During PBP, the filtrate pressure must be higher than the feed pressure.

**C)** A simplified graph showing the decline in membrane performance without PBP or chemical cleaning. PBP and chemical cleanings help restore membrane performance by removing particles from the membrane surface.

### 5.4.1 PBP with Compressed Air

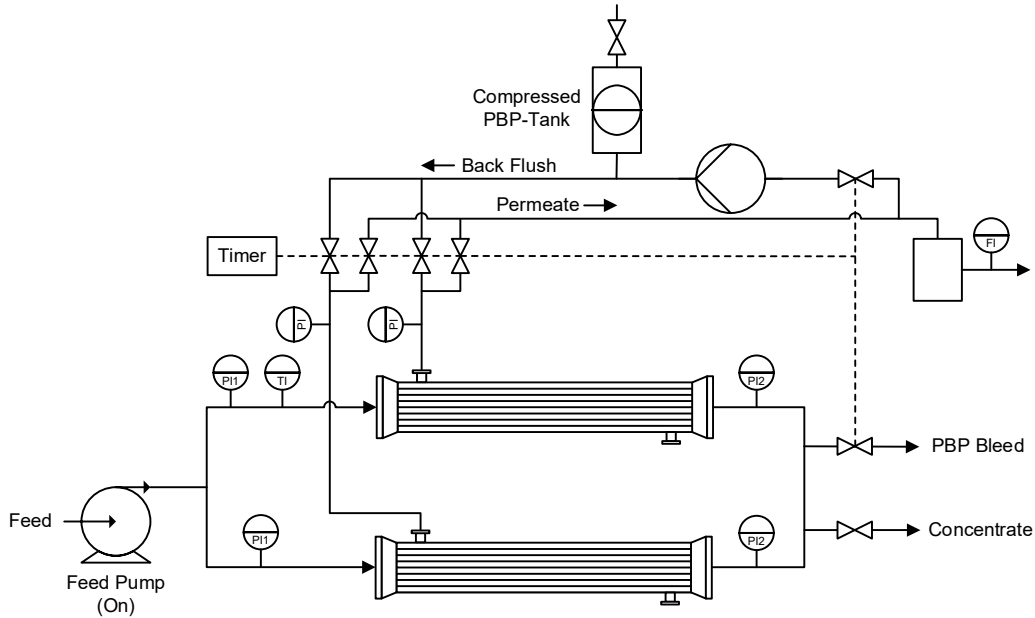
Figure 11 shows the closed standard loop with a switch diagram of the pressurized back pulse. The compressed air (or compressed gases like N<sub>2</sub>) is not used as a cleaning substance. The air is only used to pressurize the back pulse tank to push the liquid backwards through the membrane.



**Figure 11.** Simplified flow diagram with PBP using compressed air, along with the switch diagram for the valves.

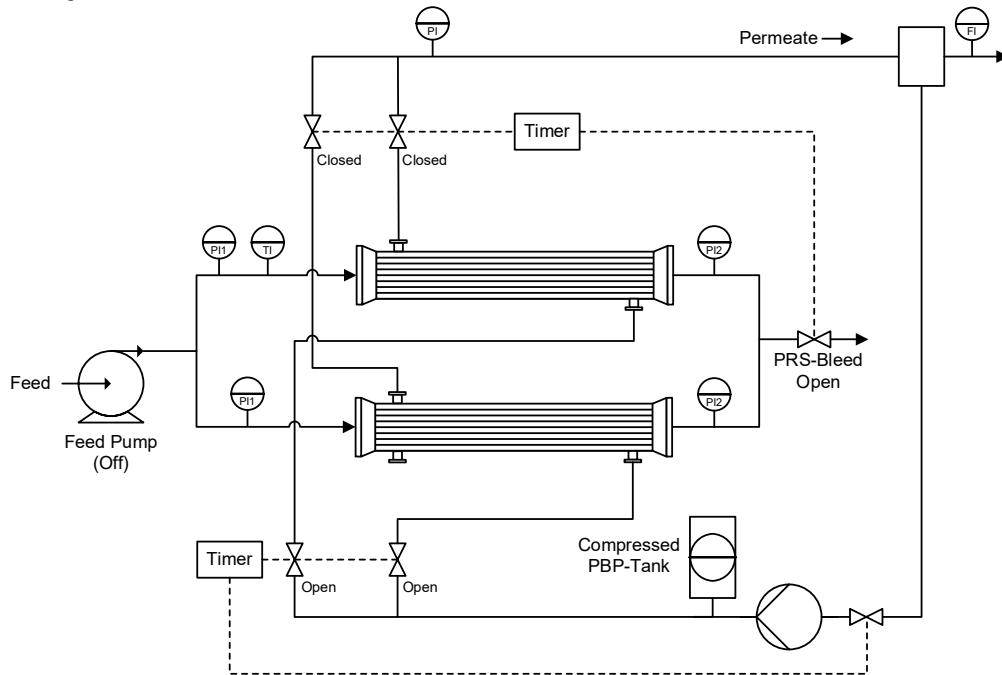
### 5.4.2 PBP with Pump Pressure

In large systems, it is possible to back pulse the modules individually or in groups. In this case, it is best to use a pressure-controlled pump. To keep the pump small and to get the necessary flow volume, it is possible to use a pressure vessel with a rubber membrane for the storage of pressurized filtrate. The pump will pressurize this filtrate in the vessel up to the regulated pressure. The vessel needs to be big enough to store the back pulsing volume of 1 L per installed m<sup>2</sup> of membrane area (or 0.26 gal per 10.8 ft<sup>2</sup> of membrane area).



**Figure 12.** Simplified flow diagram of PBP with pump pressure.

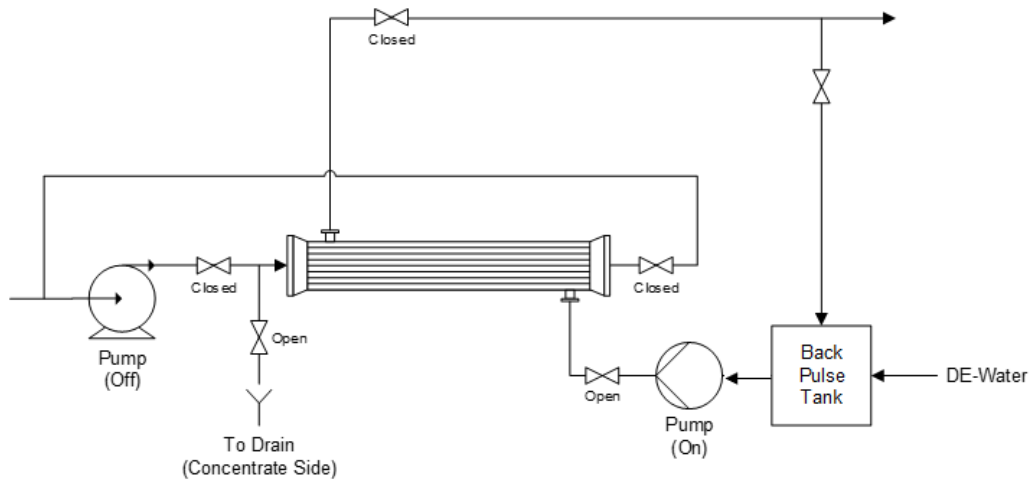
Usually, the outlet on the upper, downstream side is used for the filtrate due to the module's automatic ventilation. However, it is also possible to use the outlet on the other side of the module for back pulsing, especially when it is used for chemical cleaning with automatic valving.



**Figure 13.** Flow diagram of PBP with the second filtrate socket.

### 5.4.3 Backwashing with Special Pump & Disconnected Feed Pump

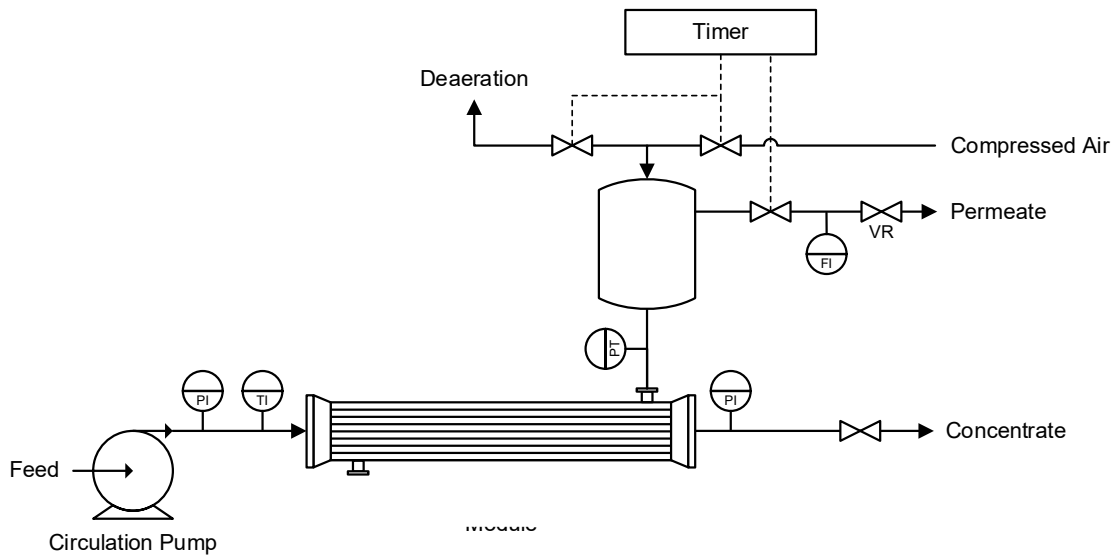
In some cases, backwashing is better than back pulsing. It is not used often – typically performed once every hour, but for a longer period of time (between 10 – 60 seconds). Backwashing is also done with the feed pump disconnected. For this procedure, a bigger filtrate storage vessel is needed and may require a sterile air vent filter.



**Figure 14.** Flow diagram of PBP with the second filtrate socket.

### 5.5 ADJUSTMENT OF FILTRATE FLOW

At very high filtrate flow (high membrane permeability) there is a high potential for mechanical blocking or fouling of the membranes. To maintain good membrane performance, it is best to limit and control the flow of filtrate by throttling the regulator valve (VR).



**Figure 15.** Flow diagram showing the adjustment of filtrate flow with regulator valve VR.



## Resistance to chemicals

Most MICRODYN capillary modules are made of polypropylene (PP) capillary membranes potted in polyurethane, with a plastic casing made of polypropylene. The below content is only valid for modules with PP housing. For resistance of modules with housings made of stainless steel, polysulfone, or PVC/PVC-C, please contact your MANN+HUMMEL WFS representative.

Aromatic and aliphatic hydrocarbons with low boiling points – such as petrol ether, benzene, and carbon tetrachloride – diffuse into the polymers of the membrane and will cause swelling and decrease mechanical strength. Before filtration of these substances, please consult with your MANN+HUMMEL WFS representative. Exceptions include low volatile substances such as grease, oil, and wax; these substances cause negligible swelling and little reduction to mechanical strength.

Peroxides may be used in small quantities and for short periods of time for cleaning purposes. Before applying, please consult your MANN+HUMMEL WFS representative.

The chemical resistance of MICRODYN capillary modules is listed in the following table. The resistance depends on many factors such as temperature, concentration, and intensity of mechanical stress. The data in the table is for reference only.

The symbols in the below table are as follows:

- + resistant at operating conditions as per data sheet
- / limited resistance, swelling (only limited operating conditions)
- not resistant

**Table 1. Chemical Resistance**

Chemical	Module		O-Rings (Viton Material)
	20°C (68°F)	60°C (140°F)	
Acetone	+	/	+
Ethanol, 96%	+	+	+
Ethyl acetate	/	-	-
Ethyl ether	+	+	/
Ethylene glycol	+	+	+
Formic acid (diluted)	+	+	-
Amylic alcohol	+	+	+
Aniline dye	+	+	+
Petrol ether, K <sub>P</sub> 100-140 C	/	-	+
Benzene	/	-	/
Succinic acid (diluted)	+	+	+
Beer	+	+	+
Bromic water, cold saturated	-	-	+
Butanol	+	/	+
Butyl	/	-	/
Butyl glycol	+	+	+
Calcium chloride sol. aqueous	+	+	+
Chlorobenzene	+	/	+
Chloroform	+	-	+
Chlorosulfonic acid	-	-	/
Chloric water (short time)	+	/	+
Cyclohexane	+	+	+
Cyclohexanol	+	/	+
Cyclohexanon	/	+	/
Diethanol amine	+	+	+
Dichloroethylene	/	+	/
Dichlorobenzene, cold saturated	/	N/A	/
Dimethyl amine	/	-	+
Ferric chloride (III), saturated	+	+	+
Vinegar	+	+	+
Acetic acid, 10%	+	/	+
Hydrofluoric acid, 10%	+	+	+
Formaldehyde, 30%, aqueous	+	+	+

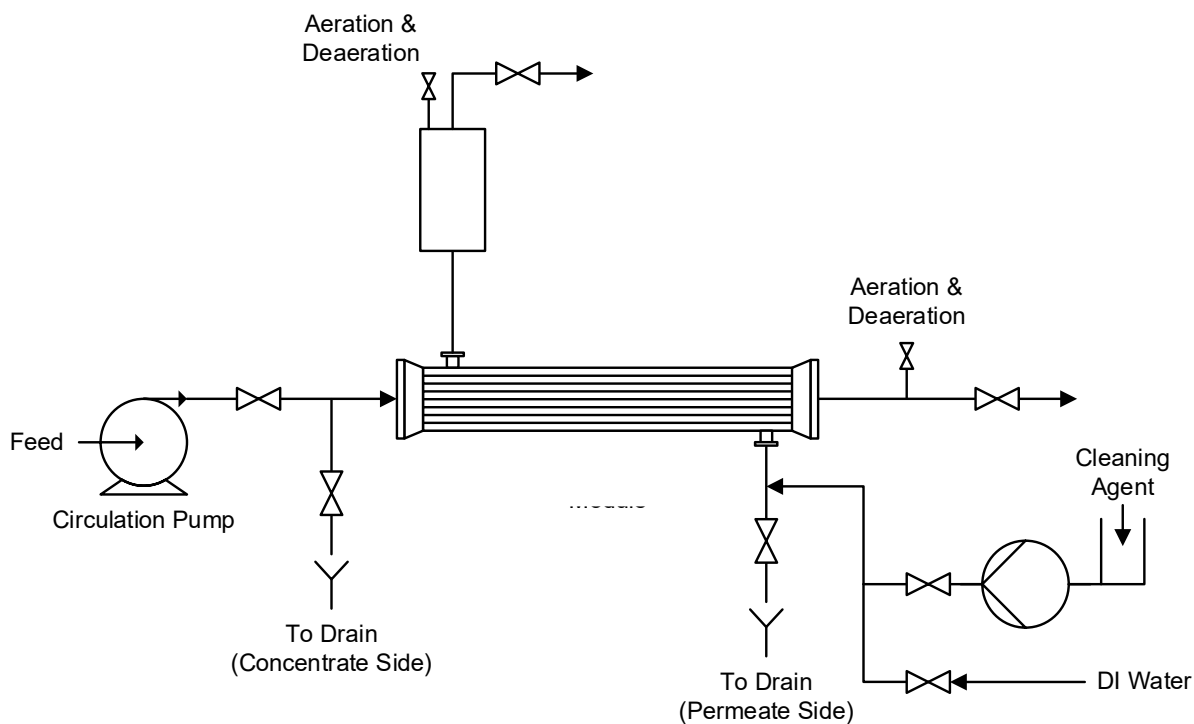
Chemical	Module		O-Rings (Viton Material)
	20°C (68°F)	60°C (140°F)	
Juices, aqueous	+	+	+
Fructose, aqueous, cold saturated	+	+	+
Galvanic baths	+	+	+
Gelatin	+	+	+
Glucose, aqueous	+	+	+
Glycerol	+	+	+
Glycol	+	+	+
Hexane	+	/	/
Isopropanol	+	+	+
Potassium hydroxide, aqueous	+	+	+
Potassium permanganate (2N)	-	-	+
Saline, saturated	+	+	+
Linseed oil	+	+	+
Machine oil	+	/	+
Sea water	+	+	+
Methanol	+	+	+
Methylene chloride	+	-	/
Molasses	+	+	+
Milk	+	+	+
Lactic acid, aqueous, 10%	+	+	+
Mineral oils	+	/	+
Mineral water, commercial qual.	+	+	+
Natrium sulfite, 40%	+	+	+
Sodium hydroxide solution (2N)	+	+	+
Sodium hydroxide solution, 52%	+	+	+
Nitrobenzene	/	/	/
Fruit juices	+	+	+
Oleum, 100%	-	-	/
Olive oil	+	+	+
Petrol ether	+	+	+
Peracetic acid, 0.2% (see note)	-	-	+
Plant oils	+	/	+
Pyridine	/	-	/
Nitric acid (2N), aqueous	/	-	+
Chloric acid, 30% ig, aqueous	+	/	+
Sulfuric acid (2N), aqueous	+	/	+
Soap solution	+	+	+
Silicon oil	+	+	+
Sodium carbonate solution	+	+	+
Soybean oil, cold saturated, aqueous	+	+	+
Starch solution	+	+	+
Turpentine	-	-	-
Carbon tetrachloride	-	-	-
Toluene	/	-	/
Trichloro ethylene	+	+	/
Trichloro acetic acid	+	/	+
Water	+	+	+
Tartaric acid, aqueous, 10%	+	+	+
Whisky	+	+	+
Xylol	-	-	/
Citric acid, aqueous, 10%	+	+	+

## 5.6 CHEMICAL CLEANING

Regular chemical cleanings are recommended to help maintain the module over time. Chemical cleanings require acidic or caustic solutions with a pH within the range of 0.5 to 14. The cleaning chemical solutions may be flushed through the membrane from the permeate side. Employing a cross-flow along the membrane surface at low pressure also has a favorable effect on the cleaning process; it is very effective and saves cleaning agents. In fact, unspent chemicals may be pumped down for further use.

The following steps describe how to properly clean the modules:

1. Uncouple the filtration system from other systems
2. Empty the system on both sides of the membrane (feed and filtrate)
3. Flush the system with clean water and drain again
4. Fill the system completely with the cleaning solution (e.g. sodium hydroxide) from the filtrate side
5. The cleaning chemicals must soak in the module for 30 minutes to 1 hour
6. Drain the complete system
7. Flush the system with clean water to remove residual cleaning agents
8. Repeat steps 4-7 with another cleaning solution (e.g. citric acid) if required
9. Connect the filtration system to the other systems.



**Figure 16.** CIP flow diagram

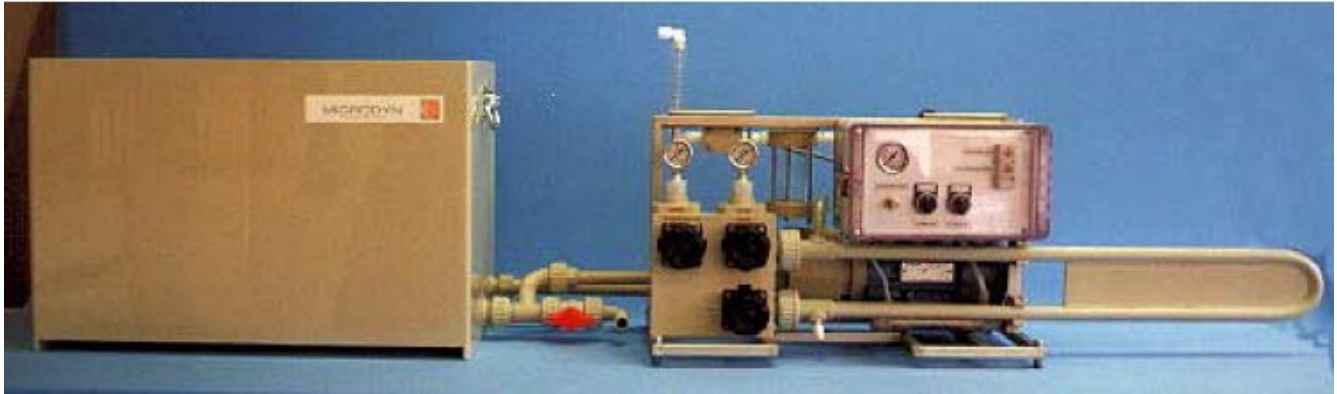
Notes to be considered during cleaning:

- Cleaning temperatures must not exceed those listed on the product data sheets.
- Detailed cleaning instructions must be determined on-site and are depending on the application.
- Organic fouling of the membrane is predominantly cleaned by using alkaline cleaning agents. Typically, 1-5% NaOH is used at a temperature of 20-60°C (68-140°F).
- Cleaning aids (e.g. surfactants) speed up the dissolution of oily and greasy substances.
- Inorganic fouling (e.g. mineral salts, ferrous compounds) is removed using acidic agents. Organic acids like citric acid, oxalic acid, or mixtures of hydrochloric acid and oxalic acid have proven favorable.
- For more information about cleaning, please consult MANN+HUMMEL WFS.

## 6 Piloting

Pilot testing is usually required to determine the feasibility and process parameters of the filtration/concentration process utilizing MICRODYN.

Please note that MANN+HUMMEL WFS offers compact pilot units (see Figure 17) and supervision of piloting. For more details, please contact your MANN+HUMMEL WFS representative.



**Figure 17.** Picture of compact MICRODYN pilot unit.

### 6.1 FILTRATION WITH CONSTANT CONCENTRATION

A typical pilot test starts with filtration at a constant concentration. The permeate and the concentrate flow back into the feed tank, so there is no increase in concentration. Once the flux is not changing any more, the concentration step can start.

### 6.2 DETERMINING MAX CONCENTRATION FACTOR

By concentrating the feed, the influence of the growing filter cake can be seen and assessed for the process. The permeate flows into a separate tank, the concentrate goes back to the feed tank. Please consider the increasing viscosity during concentration as well as an increase in temperature. The max. temperature for MICRODYN modules is 60°C (140°F). Additionally, the pressure drop - inlet pressure to outlet pressure - is increasing, so a pressure adjustment might be necessary.

### 6.3 SETTINGS FOR PERIODIC BACK PULSE

The tangential flow along the membrane surface reduces the speed of a cake build-up on the membrane but does not avoid the cake formation itself. At some point, the filtration performance hits its limit, and the filter cake must be disturbed to stop further compaction.

During the periodical back pulse (PBP) a part of the permeate is pressed back through the membrane. For each application, the desired frequency and extent of the PBP needs to be determined to guarantee a stable process. As a starting point, a frequency of every 5-15 minutes can be chosen. The default duration of the PBP is 2-3 seconds.

### 6.4 CLEANING TESTING

Depending on the fluid processed, a slow blockage of the filter modules takes place. A chemical cleaning might be necessary. The chemicals to be used for the cleaning are related to the substances that are forming the cake on the membrane. In general, alkaline or acids in combination with detergents, enzymes, etc. are good cleaning chemicals.

In principle, there are two different ways of cleaning, (a) cleaning in filtration direction and (b) cleaning from permeate side to feed side. Please refer to section 5.6 for more details.

## 7 Appendix

**Table 2.. Available MICRODYN capillary modules with key data.**

Type	Housing Material	Fiber ID	Membrane Area	Max TMP @25°C	Max TMP @40°C	Max TMP BP @25°C	Max TMP BP @40°C	Temp	Flow*	Max housing pressure
		[mm]	m2	[bar]	[bar]	[bar]	[bar]	[°C]	[l/h]	[bar]
MD020 CP 2N	PP	1,8	0,1	1,6	1,4	1,5	0,5	5-40	360	3
MD020 FP 2N	PP	0,6	0,2	2	1,5	1,5	1	5-40	250	3
MD063 CP 2N	PP	1,8	0,75	1,6	1,4	1	0,5	5-40	1440	3
MD150 CP 2N	PP	1,8	10	1,6	1,4	1	0,5	5-40	16400	3
MD150 CS 2N	SS 1.4571	1,8	10	1,6	1,4	1	0,5	5-40	16400	3
MD150 CU 2M	PS	1,8	6,3	2,2	2,2	1	0,5	5-40	16400	3
MD150 CU 2N	PS	1,8	9	2,2	2,2	1	0,5	5-40	16400	3
MD200 CV 2N7CC	PVC-C	1,8	14	1,6	1,4	1	0,5	5-40	22000	6

\*Flow rate for 1 m/s velocity with water @25°C