SEPRODYN®
Tubular Modules

User Manual

MANN+HUMMEL

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1 Introduction

MANN+HUMMEL Water & Fluid Solutions (WFS) offers a wide variety of tubular modules under the SEPRODYN® brand. SEPRODYN cross-flow microfiltration (MF) modules are used to separate suspended solids larger than 1.0 micron. The highly porous polyethylene (PE) 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. Feeds with high solids content are not a problem for SEPRODYN due to the self-supporting and extremely robust tubular membranes with a large inner diameter of 5.5 mm. These tubular membranes are made of ultra-high molecular weight polyethylene, in a patented process.

The advantages of SEPRODYN microfiltration modules include:

- Well-defined flow conditions
- High packing density
- Minimized dead zones
- Extremely abrasion resistant
- Chemically backwashable
- Low specific energy consumption

Typical applications where SEPRODYN modules are in use:

Chemical Processes	• Acid/caustic recycling • Filtration of suspended matter from heterogeneous reactions • Concentration after diafiltration
Metal Processing	• Treatment of rinse baths • Acid recovery • Treatment of phosphating baths • Heavy metal separation of solids from galvanic wastewater • Recycling of water used in grinding

How SEPRODYN modules can increase the economy and capacity of a process can be shown in the exemplary use case “filtration of pickling baths”.

Pickling of stainless steel is a very important production step in the steel industry. By using a pickling bath, the steel is cleaned of tinder and re-passivated. The pickling bath is a mixture of 150 g/l HNO_3 and 50 g/l HF. During the process, the concentration of suspended solids and heavy metal ions increases in the bath. The solids, and especially the heavy metal ions, decrease the pickling speed. By removing the metals and the solids from the bath, the pickling speed can be stabilized and the economy of the process and the lifetime of the bath can be improved. The process of the lifetime extension contains a 2-step membrane filtration process of microfiltration (with SEPRODYN) and nanofiltration.

2 Product Description

2.1 PRODUCT DESIGN

SEPRODYN® modules contain a bundle of symmetric, hydrophobic polyethylene tubular membranes with a nominal pore size of 1.0 micron. The tubular membranes are welded together with an end cap made of polyethylene, which is tightly pressed in the casing (Figure 1). SEPRODYN modules were developed for cross-flow microfiltration (CMF), a modern filtration procedure for separating suspended solids and for low concentrations of emulsions.

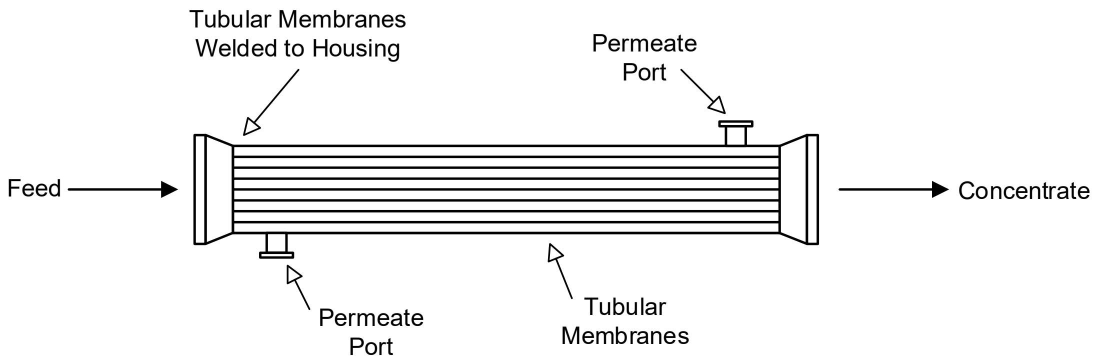


Figure 1. Schematic of SEPRODYN MF module.

2.2 CROSS-FLOW MICROFILTRATION

The feed flows inside the membrane lumen (or inside the membrane tubes), are as shown in Figure 2. A part of this feed exits the tubular membrane as filtrate, or clean water, due to a pressure difference across the membrane. The remaining liquid is called the retentate/concentrate.

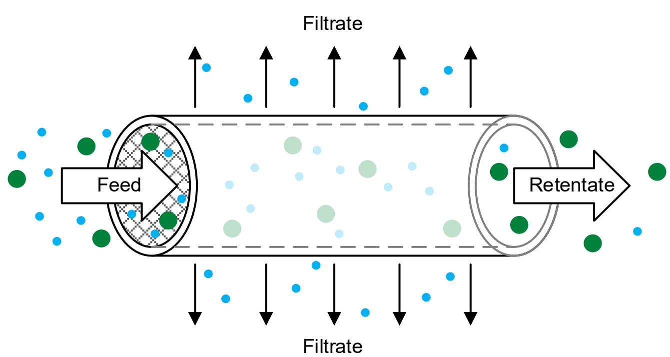


Figure 2. Scheme of lumen function.

2.3 PRODUCT CODES & MODULE TYPES

The following nomenclature identifies SEPRODYN products:

SE150	-	TP	-	1N	/	DF
Module Type & Size		Membrane Geometry & Shell Material		Pore Size (1µm) & Module Length		Module Connection
(Ø diameter of shell in mm)		TP: Tubular membrane with polypropylene shell TO: Tubular membrane without shell		M: medium N: normal L: long		AF: ANSI flange DF: DIN flange

For more module specific data, please refer to the respective datasheet on the webpage (Tubular & Capillary Modules - MANN+HUMMEL Water & Fluid Solutions (microdyn-nadir.com).

3 Shipping, Handling & Storage

3.1 SHIPPING & HANDLING

Transportation and handling of SEPRODYN® 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. Appropriate gloves, shoes, and safety glasses should always be worn.

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 appropriate cleaned, preserved, packed, and labeled to transport safely and retain the integrity of the materials.

4 Installation & Initial Flushing

4.1 INSTALLATION

SEPRODYN® modules may be installed into a system vertically or horizontally.

A horizontal position is recommended for filtration of suspensions with a large amount of solids (Figure 3). 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.

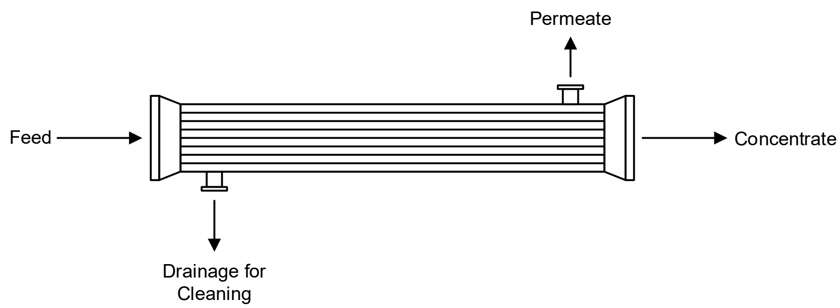


Figure 3. Module in the horizontal position.

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 4).

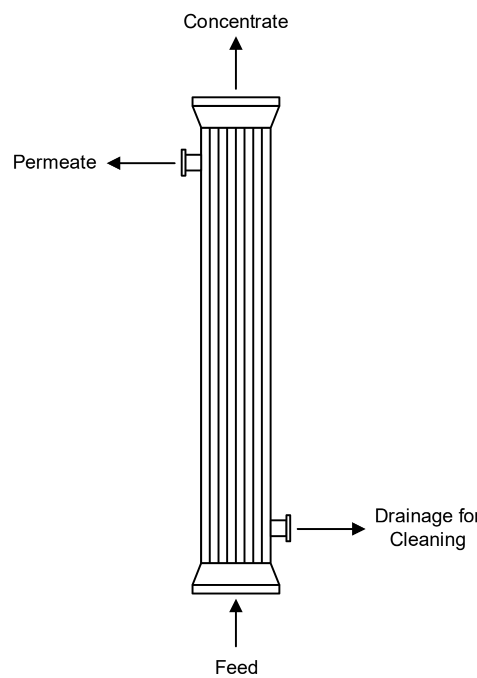


Figure 4. Module in the vertical position.

4.2 ACTIVATION & INITIAL FLUSHING

An activation of the modules membranes is typically not required as the membrane is activated just by the normal filtration pressure. If there are issues, however, a pressure increase to 2 bar will help to activate the membrane.

Please note that the tubular PE membrane may have small amounts of residual surfactants and organic oil. Initial module operation can generate foam. Once surfactants are washed out, no more foam will be generated. In some applications residuals of organic oil may lead to distorted results.

Please first flush the module thoroughly to wash out residual surfactants before operating with original feed media.

If residuals of organic oil cause complications, the following initial cleaning procedure can be applied:

1. Prepare a NaOH cleaning solution with a target concentration of 5% NaOH.
2. Circulate the solution for 30-60 minutes. Make sure to adjust the feed pressure to a value that allows the cleaning solution to penetrate the membrane to the permeate side.
3. Leave the solution soaking for 30-60 minutes.
4. Drain and flush the system with water. Please note that NaOH and residual oil can generate white foam (oil will be saponified).
5. Repeat steps 2 to 4 until no more foam is generated (usually after 2-3 repetitions).

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 5 below. The favorable flow velocity for SEPRODYN® modules ranges between 2 and 4 m/s (6.6 – 13.1 ft/s).

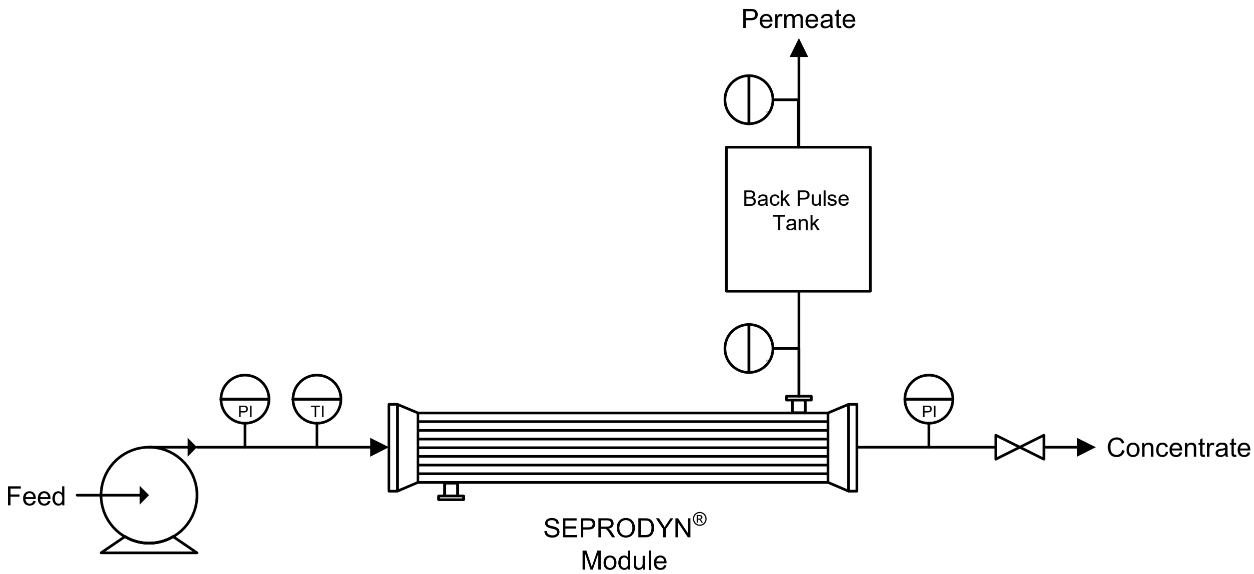


Figure 5. Simplified flow diagram using SEPRODYN modules.

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 6. 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.

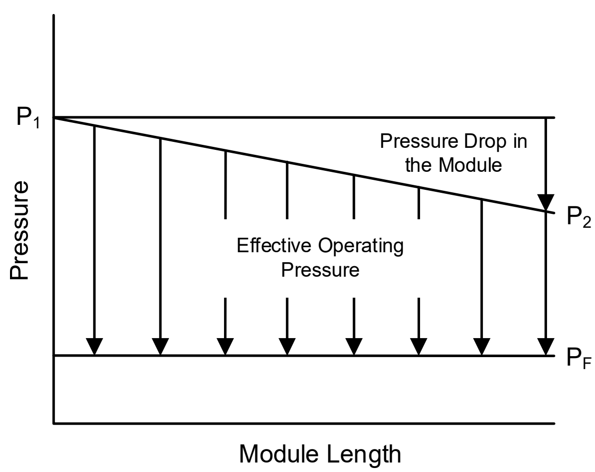


Figure 6. The pressure drop along the length of the module.

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

Pressure drop:

$$\Delta P = P_1 - P_2$$

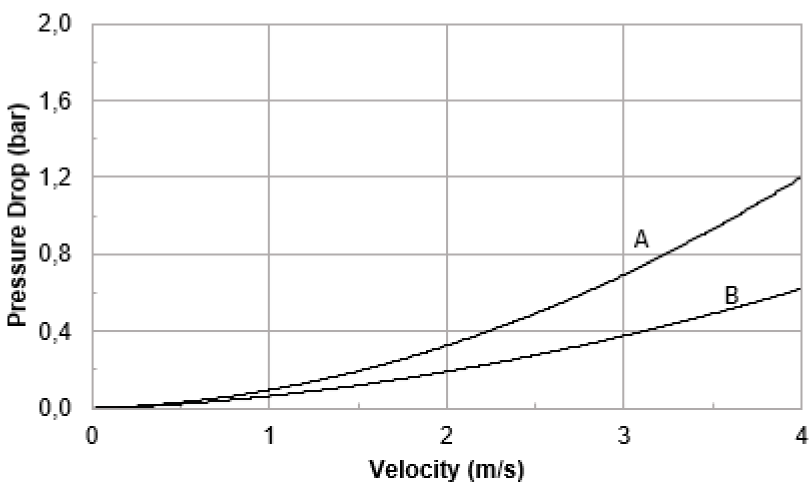
Transmembrane (operating) pressure:

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

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 7 shows the relationship between pressure drop and the mean linear velocity of water through SEPRODYN® modules at 20°C.



Curve A represents 3.0 m long modules with tubular membranes with an inner diameter of 5.5 mm.

Curve B represents 1.5 m long modules with tubular membranes with an inner diameter of 5.5 mm.

Figure 7. Relationship between pressure drop and velocity of water at 20°C.

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.

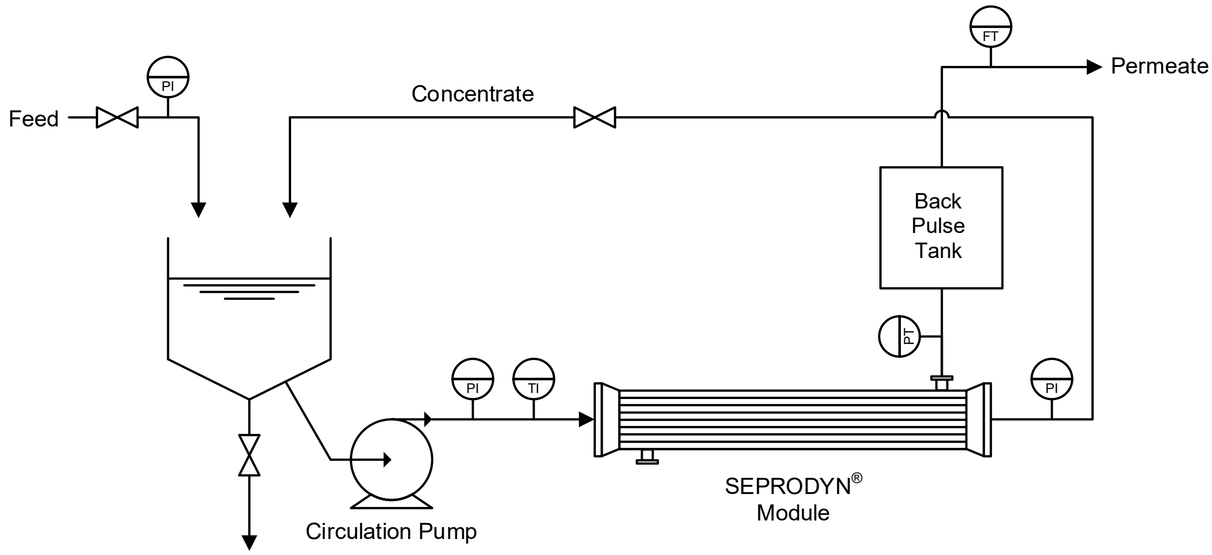


Figure 8. Simplified flow diagram for open loop operation.

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.

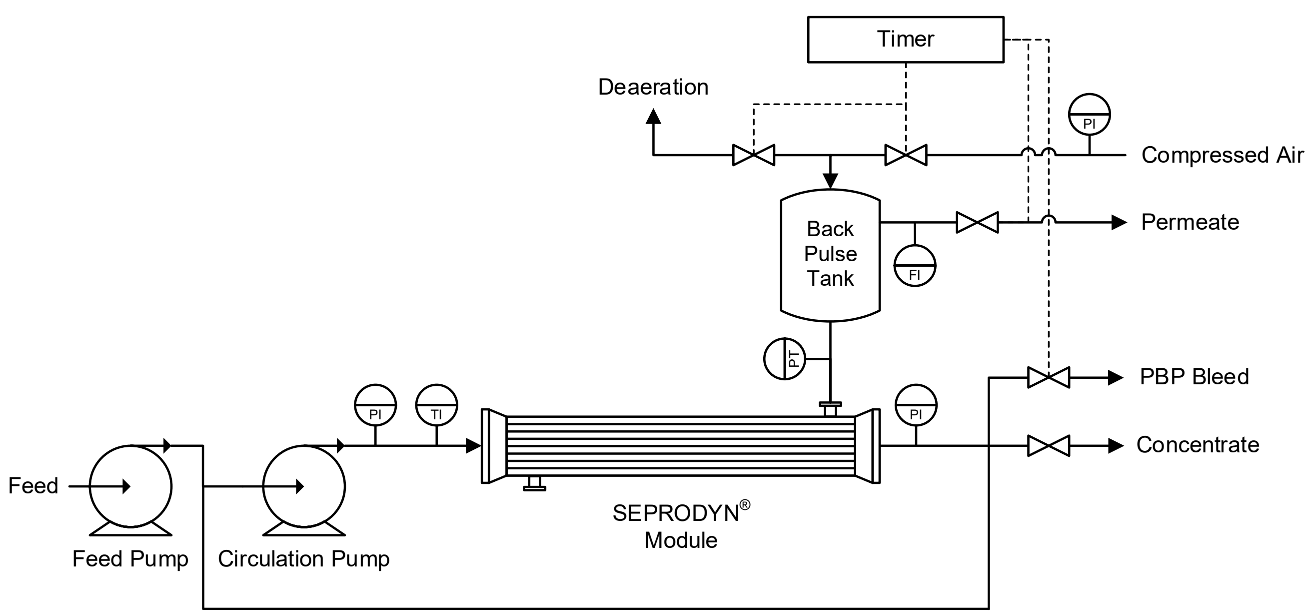


Figure 9. Simplified flow diagram for closed loop operation.

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.

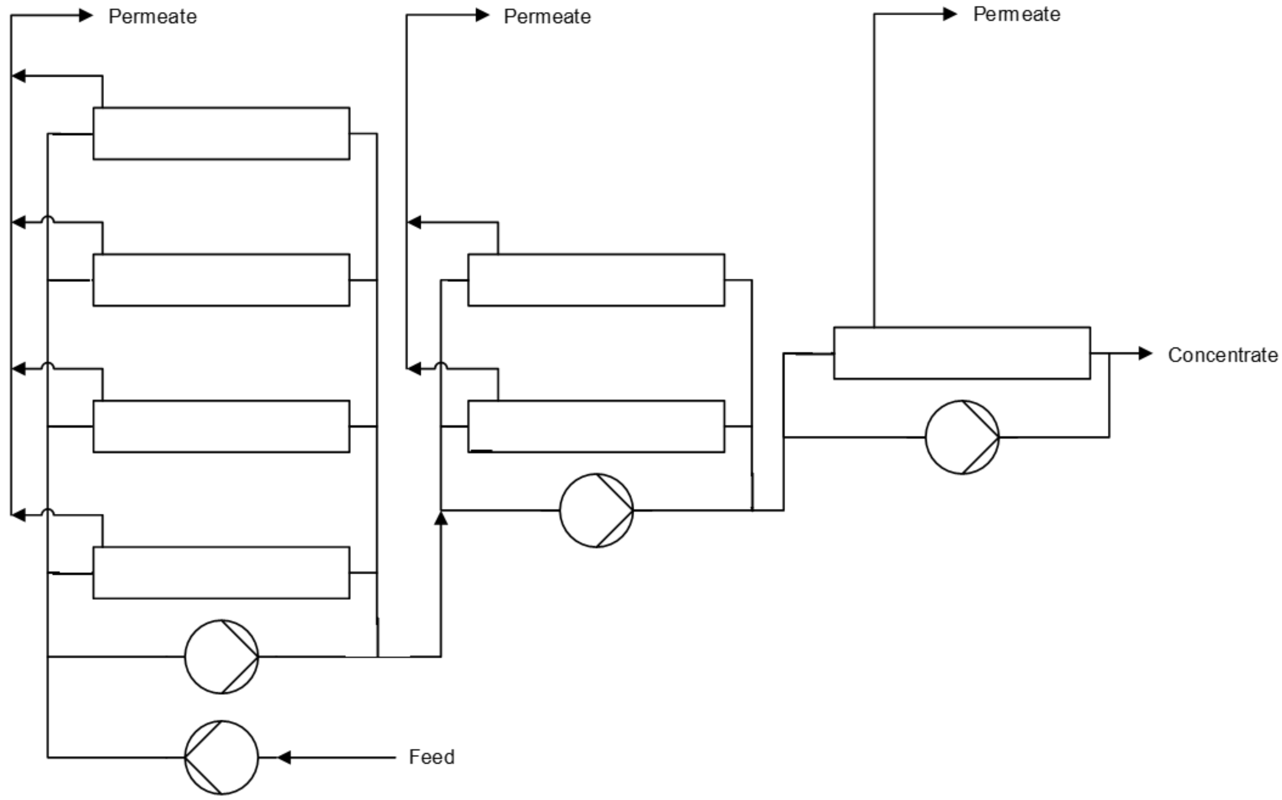


Figure 10. Simplified diagram (without control devices and back pulsing system) of a multistage system.

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 and 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 11A 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 11B.

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 11C 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 back flow volume (nearly 1 L per 1 m^2 of installed membrane area, or 0.26 gal per 10.8 ft^2 of membrane area, in a range of 2-5 seconds).

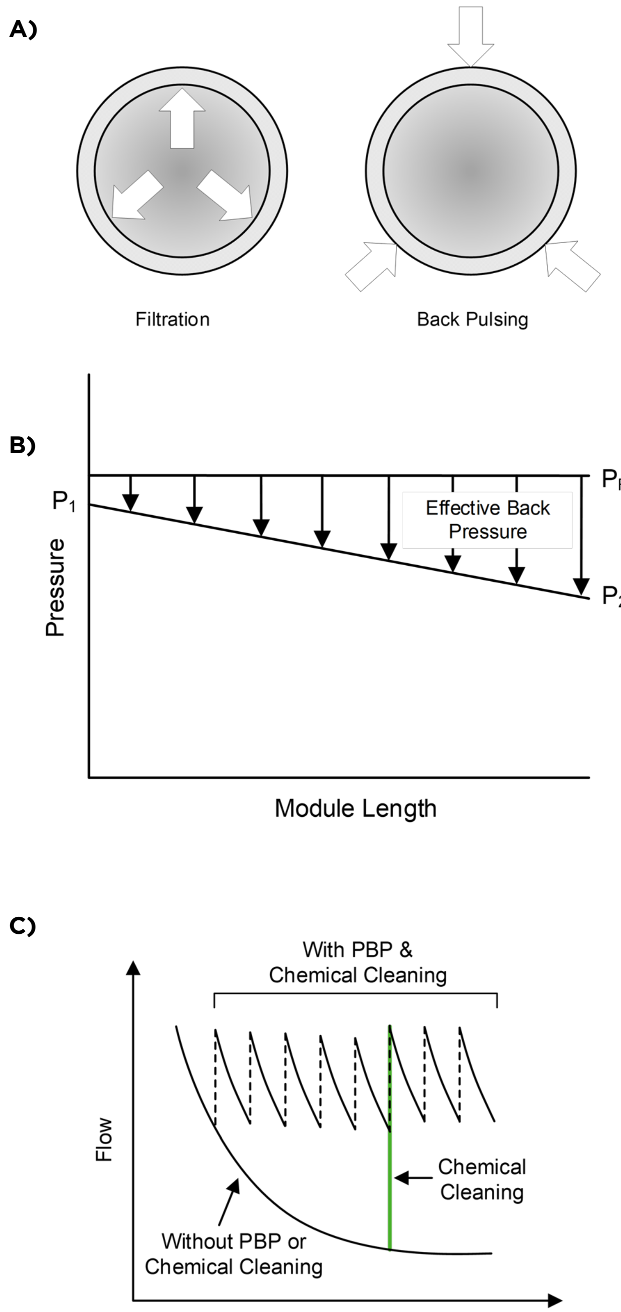
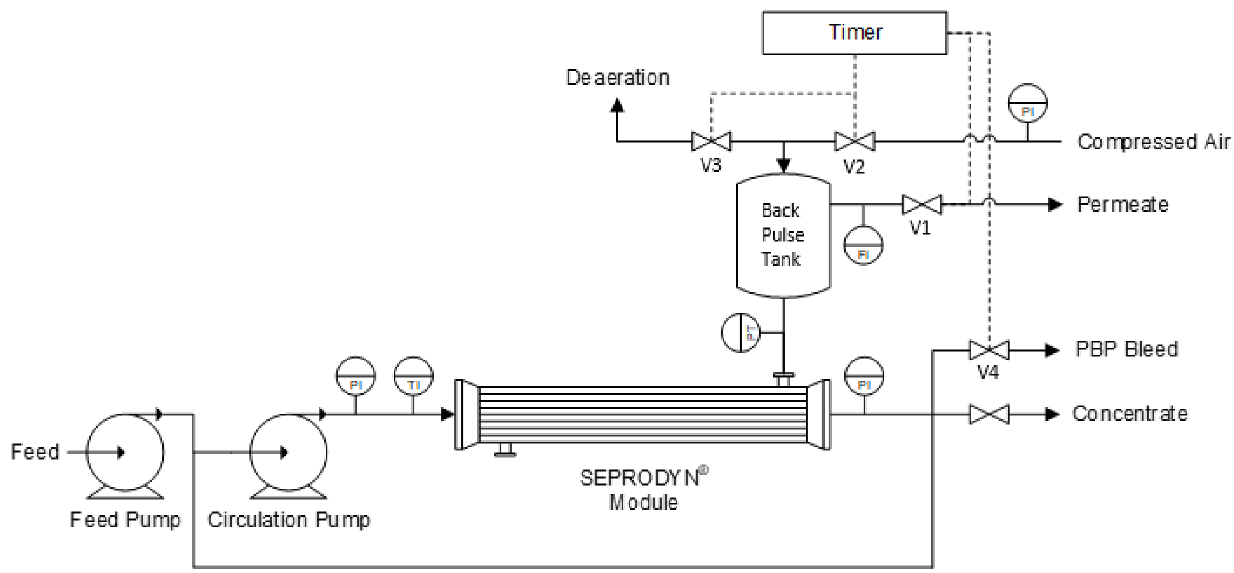


Figure 11. A) Diagram showing the difference in flow direction in the tubular membranes during filtration and back pulsing.
B) During PBP, the filtrate pressure must be higher than the feed pressure.
C) A simplified graph showing the decline in membrane performance without PBP or chemical cleaning. PBP and chemical cleanings help restore membrane performance by removing particles from the membrane surface.

5.4.1 PBP with Compressed Air

Figure 12 shows the closed standard loop with a switch diagram of the pressurized back pulse. The compressed air (or compressed gases like N_2) 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.



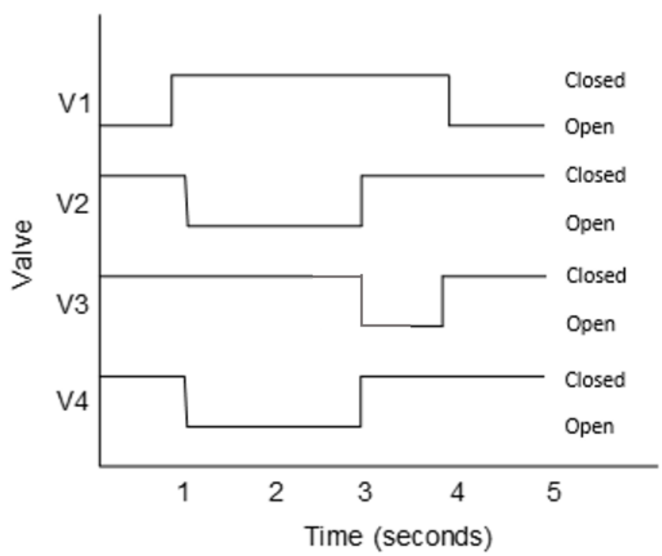


Figure 12. Simplified flow diagram with PBP using compressed air, along with the switch diagram for the valves.

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^2 of membrane area (or 0.26 gal per 10.8 ft^2 of membrane area).

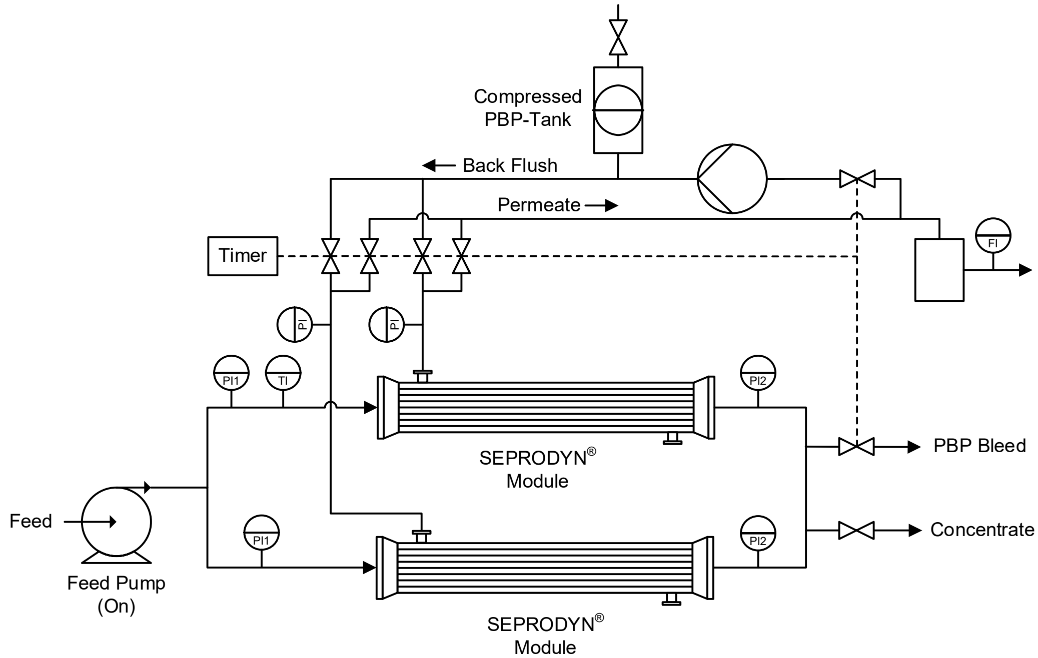


Figure 13. Simplified flow diagram of PBP with pump pressure.

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.

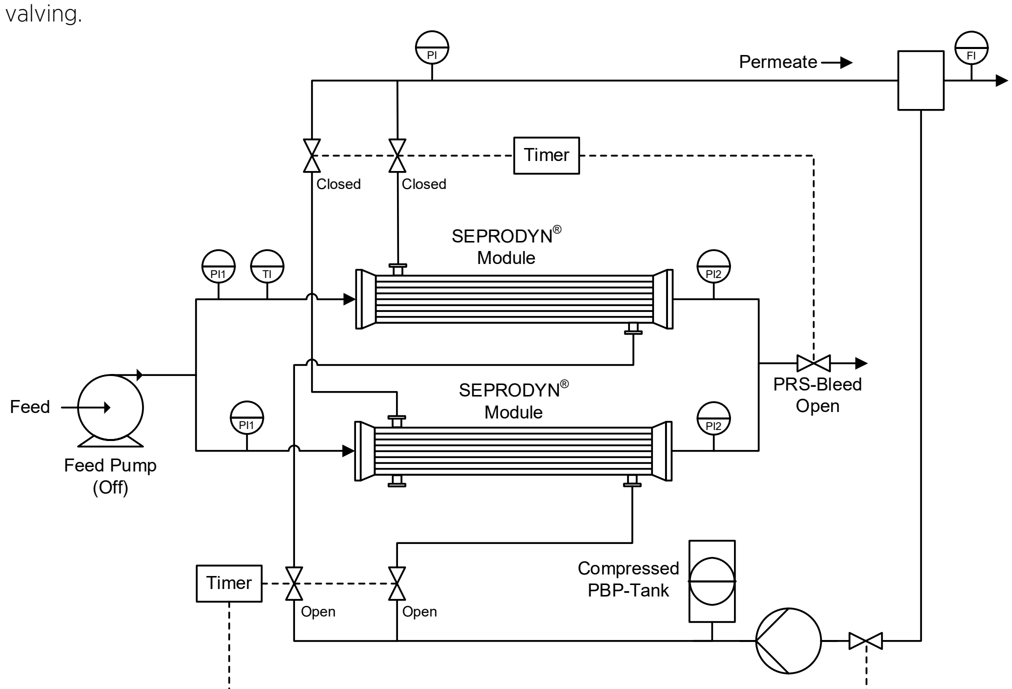


Figure 14. Flow diagram of PBP with the second filtrate socket.

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.

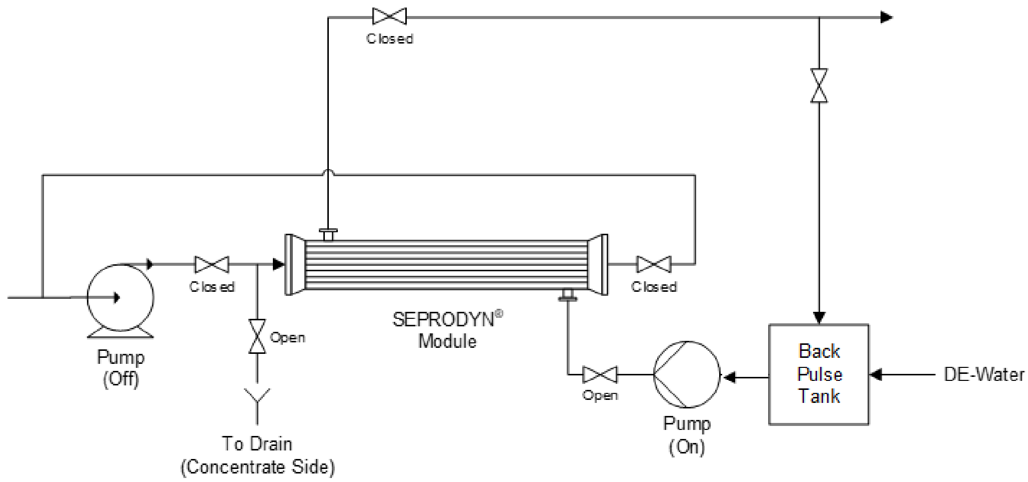


Figure 15. Flow diagram of PBP with the second filtrate socket.

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).

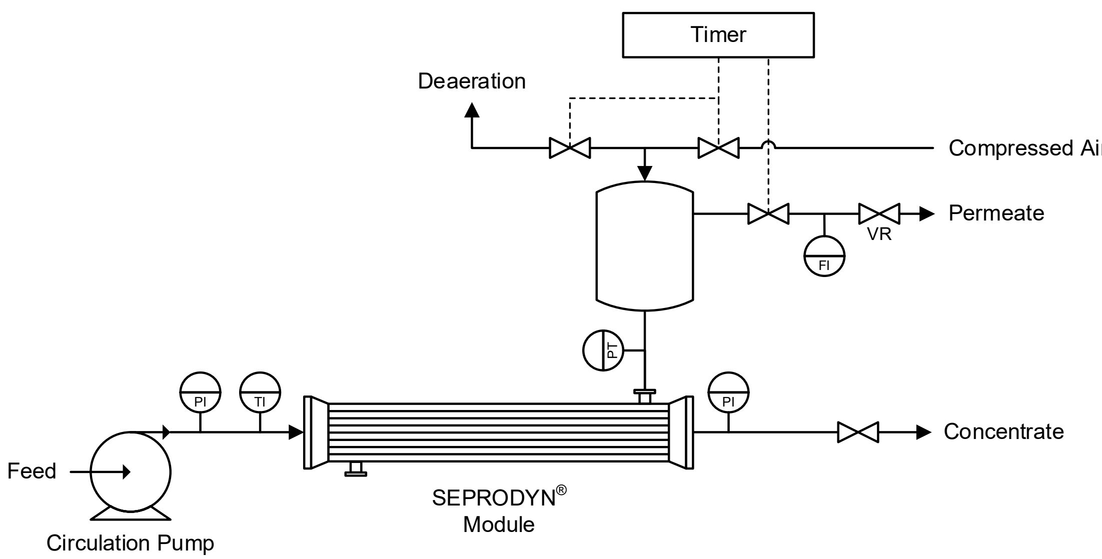


Figure 16. Flow diagram showing the adjustment of filtrate flow with regulator valve VR.

Resistance to chemicals

SEPRODYN® modules are made of polyethylene (PE) tubular membranes and a plastic casing made of polypropylene.

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 SEPRODYN 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_P 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	+	+	+
Juices, aqueous	+	+	+
Fructose, aqueous, cold saturated	+	+	+

Chemical	Module		O-Rings (Viton Material)
	20°C (68°F)	60°C (140°F)	
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 crossflow 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

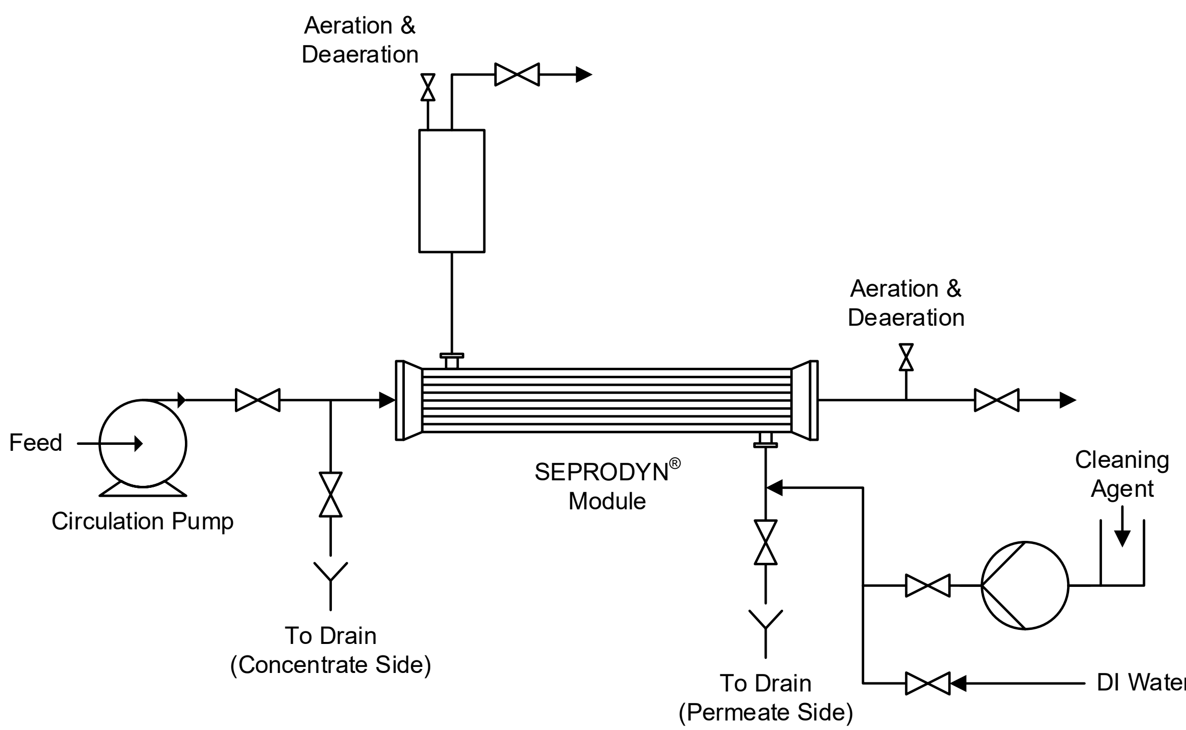


Figure 17. CIP flow diagram

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 SEPRODYN®.
Please note that MANN+HUMMEL WFS offers compact pilot units (see Figure 18) and supervision of piloting. For more details, please contact your MANN+HUMMEL WFS representative.

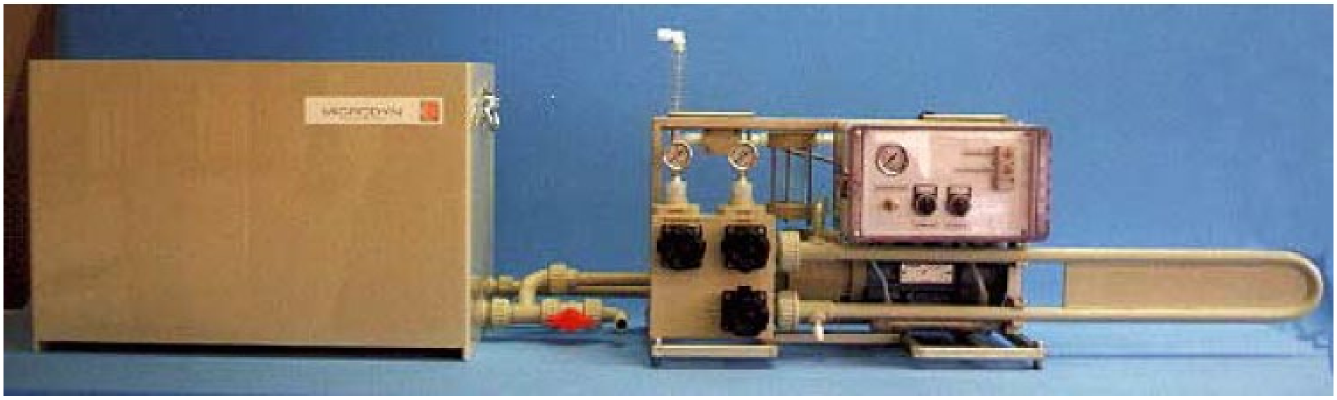


Figure 18. Picture of compact SEPRODYN pilot unit.

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 SEPRODYN 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 PBW 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 PBW 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, cleaning in filtration direction (a) and cleaning from permeate side to feed-side (b). Please refer to section 5.6 for more details.