ULTRADYN™ Hollow Fiber Modules

User Manual

MANN+HUMMEL

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1 Introduction

MANN+HUMMEL Water & Fluid Solutions (WFS) offers a wide variety of hollow fiber modules under the ULTRADYN™ brand.

This user manual is intended to provide general information only. For further details, please contact your local MANN+HUMMEL WFS representative. Please read the following instructions carefully before handling all ULTRADYN hollow fiber elements; inappropriate handling, operating, or cleaning of the modules may lead to decreased performance or even damage.

This information is based on our latest knowledge and is intended to provide only general notes on our products. At any time, we reserve the right to make modifications due to new developments. Any existing property rights must be observed. Our products are sold under our General Conditions of Purchase and Sale. MANN+HUMMEL WFS does not accept any warranties other than these stated in our General Conditions of Purchase and Sale. Explicitly, we do not give performance or lifetime warranties.

Our products are intended for use by specially trained personnel only. We do not accept liability for any inquiry or damages to people, equipment, or products caused directly or indirectly by the use of the products offered herein. Any warranty for product delivered in a defective state is limited to replacement of said product only.

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2 Description of ULTRADYN™ Hollow Fiber Modules

ULTRADYN™ hollow fiber elements are made for sanitary process and water applications. MANN+HUMMEL WFS offers ULTRADYN modules with a wide range of backwashable membrane types, all with high mechanical strength. ULTRADYN hollow fiber modules are suitable for all applications requiring a high level of purification and high packing density. ULTRADYN modules are available with polyethersulfone (PES), polyacrylonitrile (PAN), and cellulose triacetate (CTA) hollow fiber membrane types. Additionally, the modules are available in a configuration that can be sterilized with hot water up to 98°C (208.4°F), eliminating bacterial growth and preventing fouling.

Table 1. Features & Applications of ULTRADYN Hollow Fiber Modules

Membrane Material	Type	Feature	Application
Polyethersulfone (PES)	FUS	High chemical resistance, double-layered	Pathogenic removal from pure water for pharmaceuticals and electronics; wine, vinegar, and juice filtration
Polyacrylonitrile (PAN)	FUY	Hydrophilic, double-layered	Juice filtration, pharmaceuticals
Cellulose Triacetate (CTA)	FUC	Very hydrophilic, double-layered	Surface water treatment

When determining which module type is best suited for a particular application, preliminary tests using a pilot system are strongly recommended.

2.1 PRODUCT CODE

ULTRADYN hollow fiber modules are available in different sizes as well as different membranes.

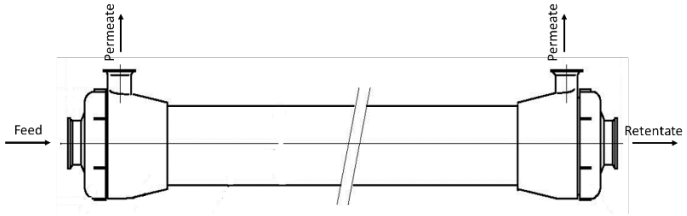
Product Code:

FS 10	FS / FC	FUS	0353
Module Type	Arrangement Permeate Outlet	Membrane Polymer	Characteristics of Membrane
	FS: Ferrule, S-Position permeate ports face opposite sides FC: Ferrule, C-Position permeate ports face the same side	FUS: polyethersulfone FUY: polyacrylonitrile FUC: cellulose triacetate	

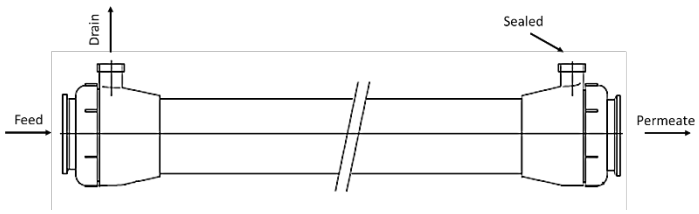
2.2 MODULE TYPE

Many different ULTRADYN modules are available. The feed runs inside the hollow fibers of the FB02, FS03, FS10, and FE10 modules, and the permeate is collected on the outside of the fibers (inside-out filtration). FG10 modules operate outside-in, meaning the feed runs on the outside of the fibers, and the permeate is collected on the inside of the fibers. The permeate flows through one or both permeate outlets, while the concentrate leaves the module through the concentrate outlet.

FB02: inside-out
FS03: inside-out
FS10: inside-out
FE10: inside-out



FG10: Outside-in



2.3 MEMBRANE POLYMER

Polyethersulfone (FUS)

The FUS series are made of heat-sanitazible polyethersulfone (PES) ultrafiltration (UF) membrane. Ideal for ultrapure water polishing.

Polyacrylonitrile (PAN)

The FUY series are UF modules using hydrophilic polyacrylonitrile (PAN) membrane UF membrane. Ideal for various applications including food processing, enzyme purification, and much more.

Cellulose Triacetate (CTA)

The FUC series are UF modules using cellulose Triacetate (CTA) membrane, which demonstrates high hydrophilicity. Ideal for (surface) water filtration purposes.

Tables 2- 4 outline the chemical resistance of the three available membrane polymers. In general, the chemical resistance depends highly on the chemicals in use, applied concentration, exposure time, temperature, and installed membrane material. For questions on chemicals other than mentioned in below tables, please contact MANN+HUMMEL WFS.

Table 2. Chemical Resistance of FUS Series

Chemicals	Concentration	Temperature	Exposure Time	Judgment
Hydrochloric Acid	0.1N 0.5N	80ºC 80ºC	30 Days 30 Days	○ ×
Sulfuric Acid	0.1N	60ºC	30 Days	○
Nitric Acid	0.1N	60ºC	30 Days	○
Citric Acid	1N	60ºC	30 Days	○
Sodium Hypochlorite	1% 1%	25ºC 60ºC	30 Days 30 Days	○ △
Formalin	3% 35% 35%	80ºC 25ºC 80ºC	30 Days 30 Days 30 Days	○ ○ ×
Ethanol	100% 70% 70%	25ºC 25ºC 25ºC	30 Days 30 Days 30 Days	○ ○ ×

Judgment: ○ No Influence; △ Slightly Influenced; × Damaged

Table 3. Chemical Resistance of FUY Series

Chemicals	Concentration	Temperature	Exposure Time	Judgment
Hydrochloric Acid	0.1N	20ºC 40ºC	7 Days 2 Days	○ ○
Acetic Acid	1N	20ºC 40ºC	7 Days 2 Days	○ △
Sodium Hydroxide	0.1N 1N 0.1N	20°C 20°C 40°C	7 Days 7 Days 2 Days	○ × △
Ethyl acetate	1N	40℃	2days	○
Hexane	1N	40℃	2days	△
Sodium Hypochlorite	500ppm 1%	45℃ 45℃	1day 1day	○ ×
Formalin	3% 35%	45℃ 45℃	7days 7days	○ ○
Ethanol	100%	45℃	7days	○

Judgment: ○ No Influence; △ Slightly Influenced; × Damaged

Table 4. Chemical Resistance of FUC Series

Chemicals	Concentration	Temperature	Exposure Time	Judgment
Ultrasil 53	1%	NA	250 Days	○
Citric Acid	1%	NA	250 Days	○
Oxalic Acid	0.1N	NA	10 Days	○
Sodium Hypochlorite	10ppm 100ppm 500ppm	25°C	10 Days	○ △ ×
Hydrogen Peroxide	500ppm	NA	20 Days	×
Sodium Hydroxide	0.01N	NA	1 Day	×

Judgment: ○ No Influence; △ Slightly Influenced; × Damaged

3 Shipping, Handling & Storage

3.1 SHIPPING & HANDLING

Transportation and handling of ULTRADYN™ 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 to avoid direct contact with the preservative solution.

Modules should not come into contact with organic solvents or use splicing tape as this may lead to the damage of the module casing. To remove debris from the module, the casing should be wiped with water or ethanol.

3.2 PRESERVATION

The module is shipped with a preservation liquid (about 4L for the larger modules) to prevent bacteria propagation inside the module. When handling the module, wear plastic gloves, safety glasses, etc., and pay attention to prevent the solution from touching skin or going into the eyes or mouth. Provide ventilation to avoid direct inhalation of the steam from the mounting medium.

The used preservation varies with the type of installed membrane and targeted application. The three preservation liquids in use are:

- Pure water (heat sterilized)
- Pure water (sterilized with 0.005 % w/v sodium hypochlorite)
- 3 % w/v Glycacil

Please refer to the specific module's data sheet to see the preservation used in the purchased product.

3.3 STORAGE CONDITIONS

ULTRADYN modules should always be stored under the following conditions:

- No exposure to direct sunlight
- Storage temperature must be between 5°C and 35°C (41°F and 95°F)
- Humidity must not exceed 70%
- All new modules being stored should remain in original packaging

3.4 CAUTION

3.4.1 Anti-Freezing Measures

Freezing of the module may cause damage to the membranes and the case. Do not allow the modules to freeze under any circumstance. If there is a risk of freezing, make sure to take anti-freezing measures, such as heat insulation for the module. At temperatures below 5°C, water can crystalize and harm the membrane structure. Ensure that the element is well tempered when placed in operation.

3.4.2 Anti-Drying Measures

The module is packed to prevent drying of the fibers. Take caution to prevent drying of the inside of the module. After unpacking the module, seal each tie-in point. If the sealing is insufficient, the filtration performance of the membranes may significantly deteriorate. As mentioned in Section 3.3, sealing of each tie-in point is also necessary for prevention of bacterial contamination.

3.4.3 pH Control Feed Water

For stable use of the module, the appropriate pH range of the feed water is:

- pH 1 - 13 for FUS series
- pH 4 - 8 for FUC series
- pH 2 - 11 for FUY series

Usage with pH outside this range, or other conditions such as the feed water temperature, operation pressure, etc., may shorten the expected life of the module. Pay attention to the pH of the feed water while taking necessary measures to adjust pH whenever necessary.

3.4.4 Temperature Control of The Feed Water For Module Usage

For stable use of the module, the upper limit of the feed water temperature is:

- 98°C for the FUS series
- 40° for the FUC series
- 45°C for the FUY series

Please note that the applicable operation condition (applicable pressure) differs depending on the temperature of the used feed water. For operating conditions, see Section 8.

3.4.5 Protection for the Module

The modules are shipped with a protection cap on each port for feed water and permeate water to protect the flange surface. Do not use these caps except for transport or storage of the module.

3.4.6 Handling of the Module

If any impact due to a tumble or fall occurs, it may cause damage. The membranes inside may break, even if there is no apparent damage in the appearance. Take care when handling the module.

3.5 RETURNING A MODULE

If a module is to be returned for any reason, MANN+HUMMEL WFS must approve. 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, the module must be appropriate cleaned, preserved, packed, and labeled to transport safely and retain the integrity of the materials.

4 Installation

While designing and installing the piping for a system using ULTRADYN™ hollow fiber modules, please consider that the module must be installed free of any mechanical stress. Please pay attention to avoid piping weight and ensure that any force applied on the piping is not applied directly to the module. This may cause damage of the tie-in point or main body of the module, or may cause water leakage. There may be a relatively big pressure fluctuation or temperature change. Vibration and expansion/contraction of piping and module must be taken into consideration.

If possible, flexible tubing should be used to compensate for any vibrations and thermal expansion of the pipes and the module. The following steps are recommended to install a module safely:

1. Remove the module from its packaging and ensure that the module has not been damaged during transportation.
2. Drain the preservative solution from the module before mounting. Do not leave the module drained of preservative for long periods of time as this may cause the fibers to dry out.
3. Before mounting the module to the rack, clean the system to ensure that residual foreign matter and oily materials from the system do not enter the module.
4. Use a clamping ring to attach the module to the rack. Attach the module so that the liquid will flow in the direction of the arrow on the module's label.
5. Connect the feed clamp. *
6. Connect the concentrate clamp. *
7. Connect the permeate outlets. *

* Avoid excessive stress on the module, especially at the ports. Please do not overtighten the connectors as this may cause the connectors to break. Lastly, be sure to prevent slipping of the seals when mounting the modules.

NOTE: If ULTRADYN elements are shipped or stored under cold conditions, the elements should rest and acclimate before being mounted.

4.1 PIPING AND CONNECTION

Please note that mounting ULTRADYN modules requires tension-free connection to the manifold piping. If the module is fixed with a U-band or similar connection, do not excessively tighten. Rather, tighten it so that it touches the module lightly. Otherwise, the module may be damaged.

Ensure a piping design that allows degassing of the system. If necessary, apply degassing devices or air vents.

In case of heat sanitization, polysulfone housing of ULTRADYN modules may elongate during heat sanitization. Compensational parts are recommended to be installed.

Please refer to the following example to project thermal elongation of ULTRADYN modules:

α = 5.6 x 10^{-5} [1/°C]
l_0 = Original Length [mm]
T_{min} = Starting Temperature [°C]
T_{max} = Maximum Temperature [°C]
EF = Elongation Factor [mm]

$$\mathrm{EF} = \mathrm{l}_0\,(T_{max} - T_{min}) \times \alpha$$

Example 1: ULTRADYN™ FS10 at ΔT = 88°C (e.g. 98°C – 10°C)

$$\mathrm{EF} = 1129\mathrm{mm} \times 88°\mathrm{C} \times \left(5.6 \times 10^{-5}\frac{1}{°C}\right) = \mathbf{5,6mm}$$

Example 2: ULTRADYN™ FS10 at ΔT = 70°C (80°C – 10°C)

$$\mathrm{EF} = 1129\mathrm{mm} \times 70°\mathrm{C} \times \left(5.6 \times 10^{-5}\frac{1}{°C}\right) = \mathbf{4,4mm}$$

5 Start-Up Procedure & Integrity Testing

The following procedure is to ensure a successful start-up of the system using ULTRADYN™ hollow fiber modules.

1. To remove the remaining preservative solution from the module, rinse the module using pure water (e.g. demineralized water) for 20 minutes, sending both the permeate and concentrate to drain. Be sure no leaks are present at the connecting ports. If leaks are present, stop operation and fix the clamps.

2. It is crucial that residual air is removed from the system via low pressure operation to avoid water or air hammer. Gradually increase the pressure and flow rate to the specified conditions for operation.

3. Once all the preservative has been rinsed out of the modules, it is time to start operation. When starting operation, avoid rapidly increasing the flow and pressure. Gradually adjust the pressure and flow rate to operating conditions. Continue to check the system for leaks. If leaks are present, stop operation to fix the leaks. If no leaks are present, the system is ready for normal operation.

If the module or system integrity needs to be verified, the following procedure can be applied (please refer to Figure 1):

1. Put the module in the vertical direction and fill up with water. V1, V2, V3 open.
2. Close V1, V2, V3, and V5. Open V4.
3. Adjust air pressure to 3 bar.
4. Open V5 little by little. Drain the residual water at the feed side (inside of hollow fibers) of the module.
5. For a module installed in a rack (and connected to feed and permeate header), wait for 10 minutes after opening V5 and V4. For a single module that is disconnected from the headers, wait for 90 seconds before opening V5 and V4. Measure the amount of water coming out of the hose connected to V4. The measured flow rate is equal to the diffusion or ai leakage flow. The specified allowed leakage rate of FS10-FUST653 is ≤ 10 ml/min.

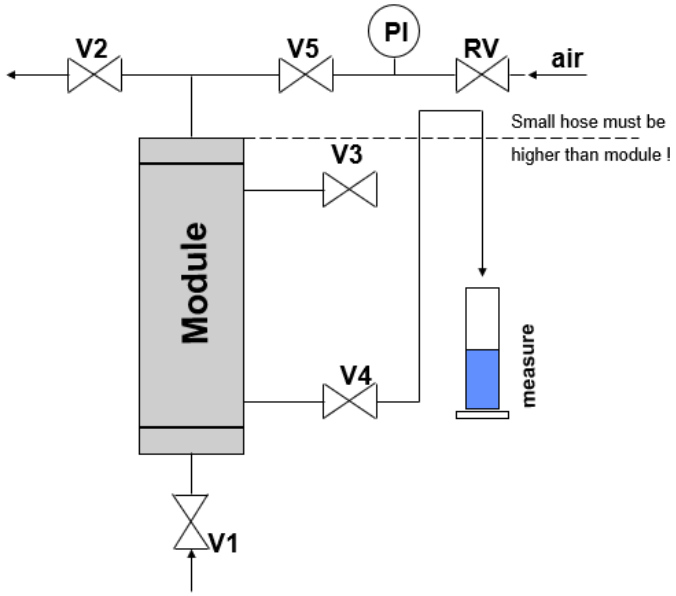


Figure 1. Integrity test set-up for a FS10-FUST653.

6 Operation

6.1 GENERAL SYSTEM SET-UP

To control the flow rate and pressure of the system, it is necessary to equip the membrane system with flow rate regulating valves, pressure regulating valves, and other measurement instruments as shown in Figure 2 below:

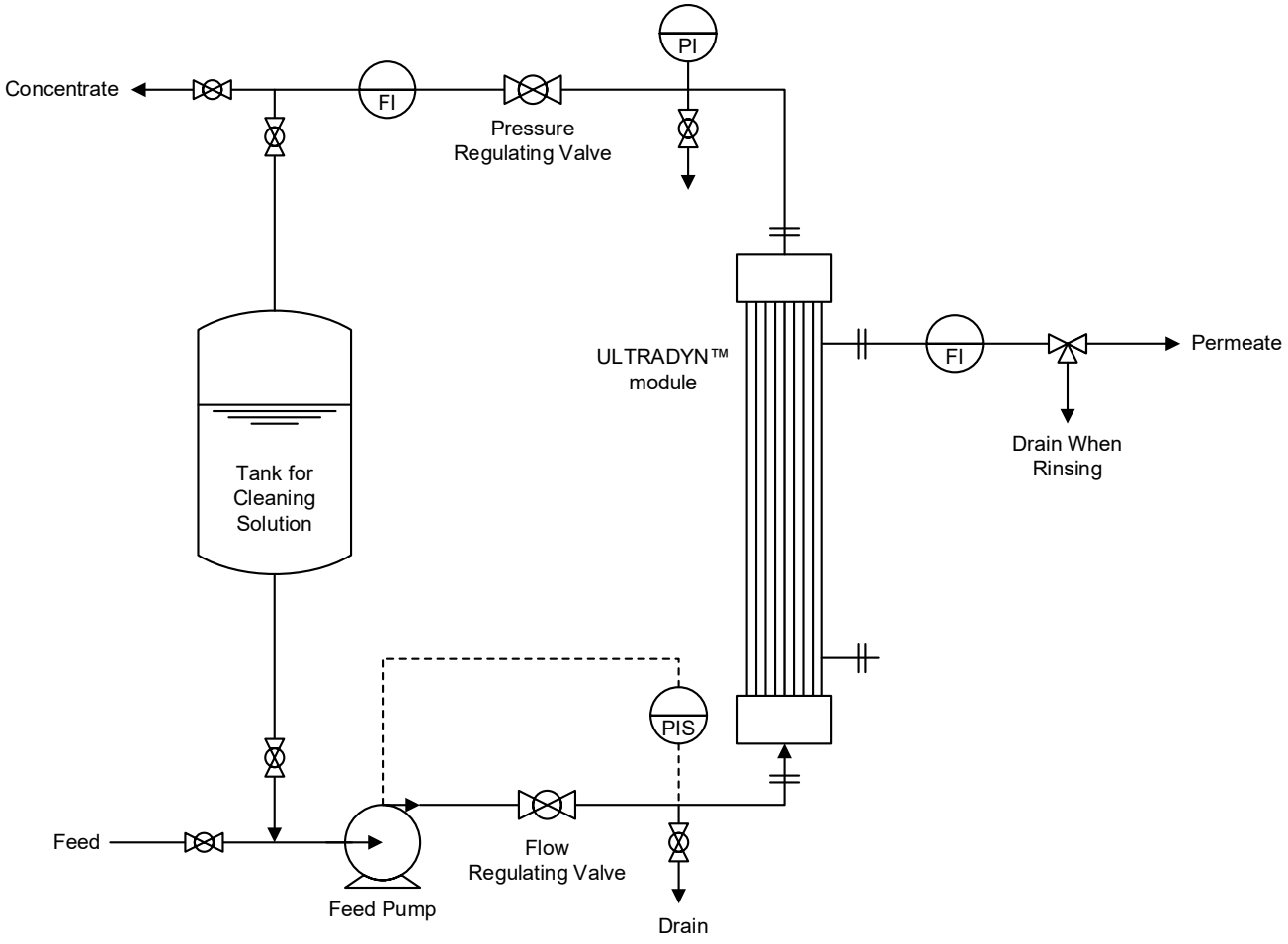


Figure 2. Basic flow diagram of a system using ULTRADYN™ modules.

While the operating conditions for each module type are listed on the respective product data sheets, the optimal operating flow rate largely depends on the application and feed source. As such, it is highly recommended to perform some preliminary tests to determine the optimal flow rate and transmembrane pressure. Please be sure to increase flow rate and pressure gradually to avoid water hammer.

A high flow rate limits the formation of the fouling layer and results in a high operational flux. However, the permeate flux also depends on the transmembrane pressure. High filtration pressures increase the thickness and density of the fouling layer and may result in a decline in permeate flux.

To calculate the pressure drop and transmembrane pressure, please refer to the below equations as well as Figure 3 below.

Pressure drop:

$$\Delta P = P_{in} - P_{out}$$

Transmembrane (operating) pressure:

$$P_{TMP} = \frac{P_{in} - P_{out}}{2} - P_{Permeate}$$

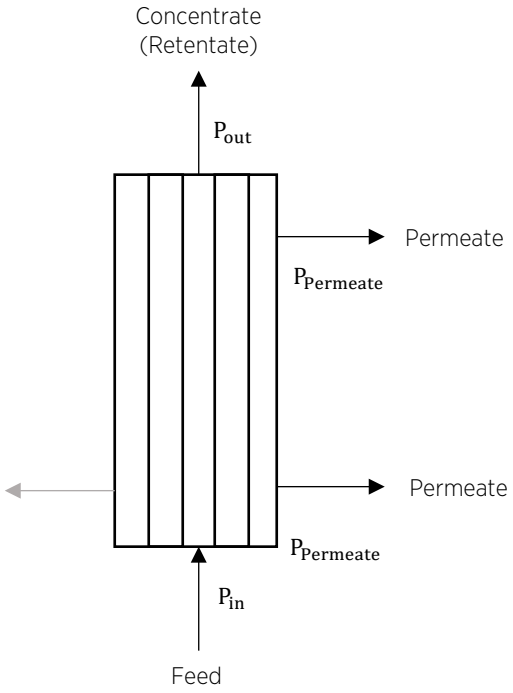


Figure 3. Diagram showing the different streams and pressures entering and exiting the UF module.

6.2 FLUX RATES

Applicable flux rates are highly dependent on the application. Factors like feed water composition, applied transmembrane pressure, temperature, and membrane type influence the applicable flux rates. It is recommended to run the modules with a sustainable flux rate that results in a slow transmembrane increase with time.

Ideally pilot tests are done beforehand to determine the optimal process conditions for the specific application. However, pure water polishing applications show usually more or less equivalent conditions where specific recommendations on flux rates and applied transmembrane pressure can be given. ULTRADYN™ FS10-Series modules with FUST653 or FUS0353 membrane are often operated with the residual system pressure at ~0.5bar and water temperatures in a range of 10°C – 15°C. Within these parameters, it is recommended to design the water flux per module between 1500l/hr*module and 2000l/hr*module, as per Figure 4.

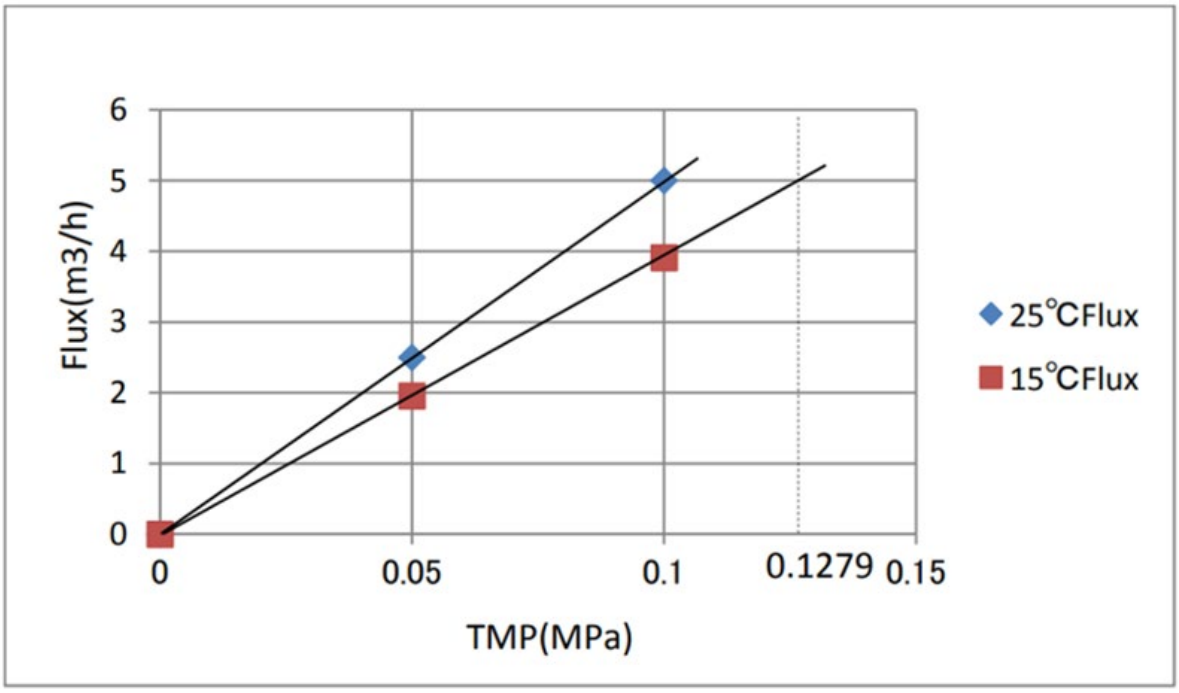


Figure 4. Diagram showing the different streams and pressures entering and exiting the UF module.

7 Cleaning & Regeneration

During operation, the surface of a membrane is subject to fouling by mineral scale, biological matter, colloidal particles, and insoluble organic constituents. The term “fouling” includes the build-up of any type of material on the membrane surface, including mineral scaling. Membrane surface fouling results in lower permeate flow rate, increased pressure drop between the feed and concentrate, and/or higher solute passage. In these situations, it is necessary to recover the module’s performance by periodic cleaning. A few different cleaning methods are described in the following sections.

7.1 CLEANING BY CIRCULATING WATER

In pure water polishing applications, the system is cleaned by circulating the water through the UF system. Please refer to the following procedure and Figure 5.

1. Stop the feed supply.
2. Drain the feed tank as well as the whole system.
3. Fill the feed tank with pure water.
4. Prior to circulation, a short rinse should be performed to rinse out any residual liquid remaining in the module, replacing it with pure water. Be sure to send the concentrate to drain.
5. After the rinse, switch the valves so that the permeate and concentrate will return to the feed tank (cleaning mode).
6. Circulate the pure water using the feed pump for about 20 minutes.
7. Drain the feed tank as well as the whole system and then return to filtration mode.

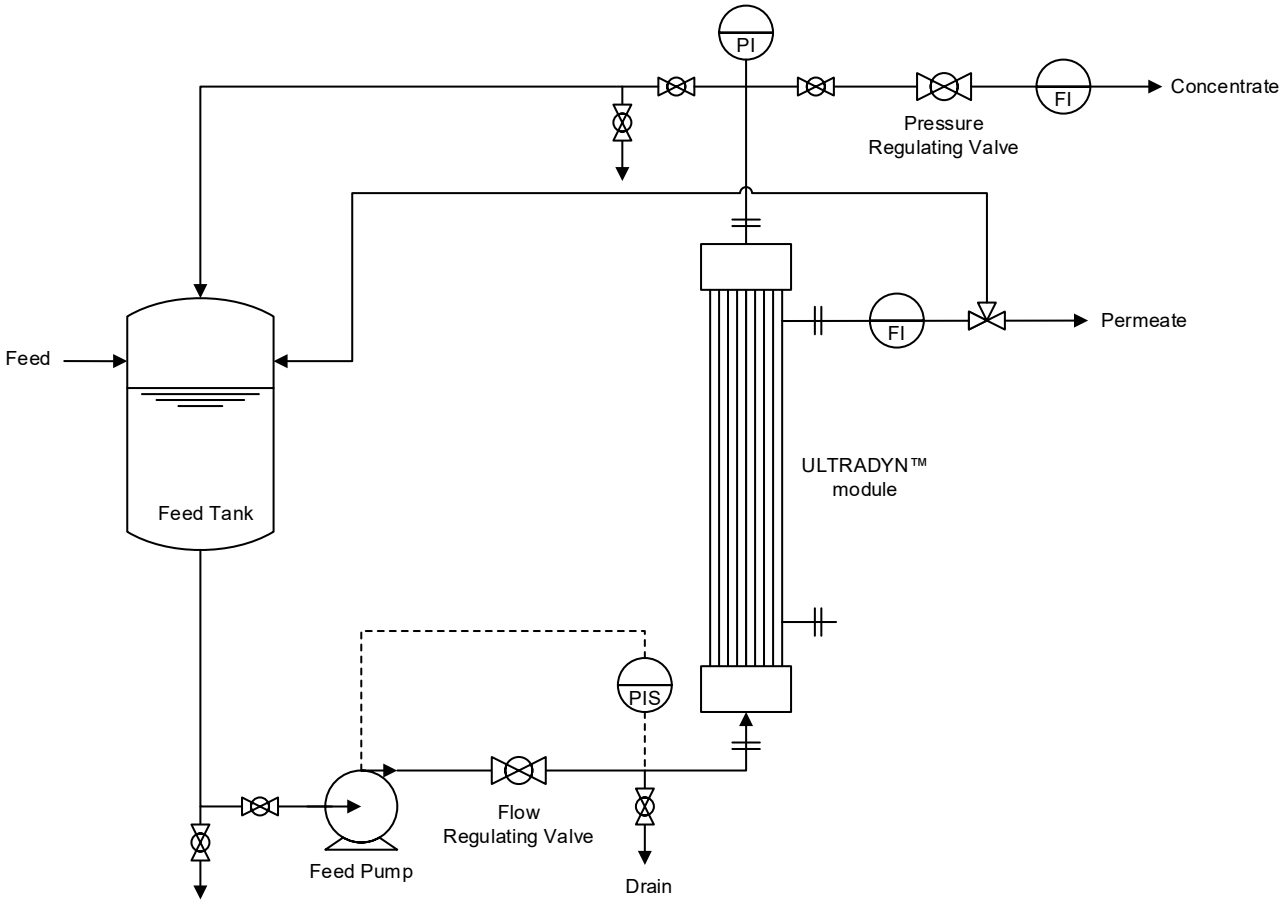


Figure 5. Flow diagram of circulation without backwashing.

7.2 CLEANING BY FORWARD / BACKWARD SWITCHING

This cleaning method is mainly used for process hollow fiber UF modules. The feed flow is switched between the forward or backward direction (Figure 6). This cleaning procedure is effective in removing any particles or constituents that are clogging the back side of the module. This method, combined with cleaning by backwashing, is expected to have a high cleaning effect.

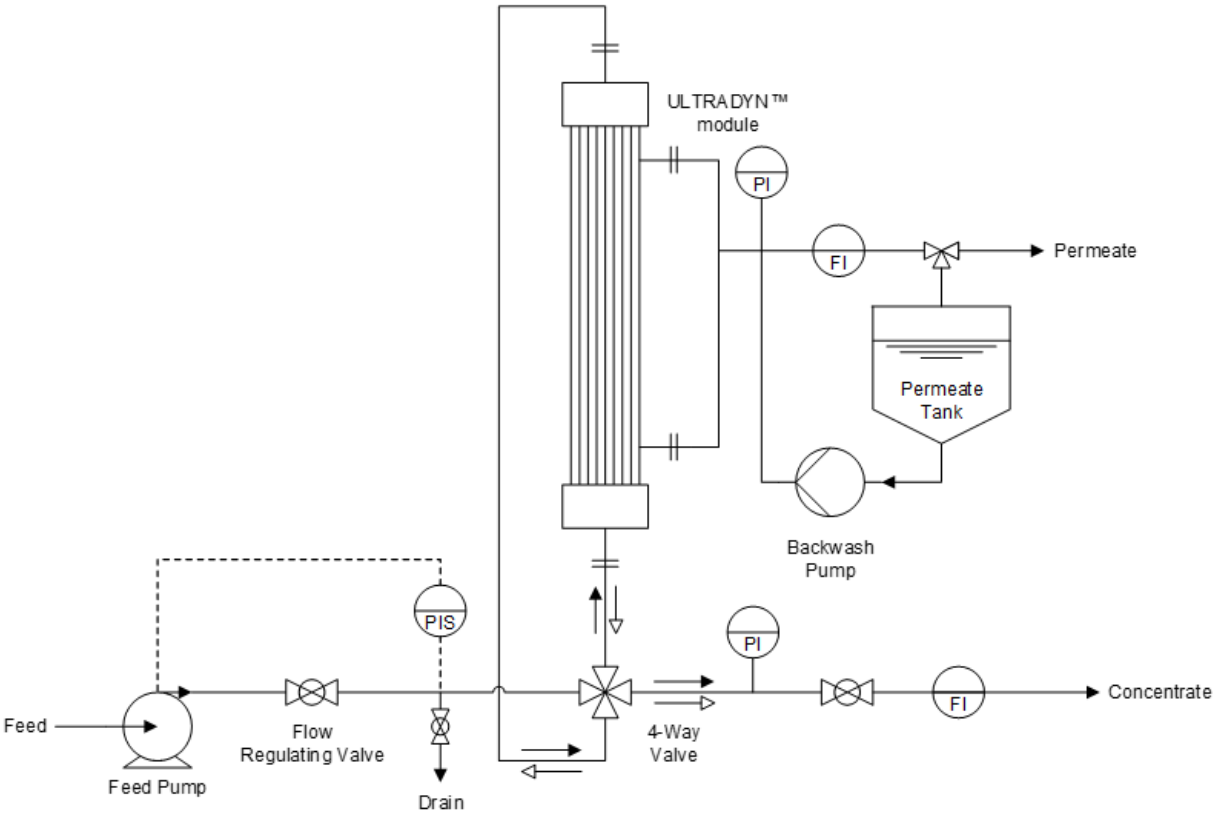


Figure 6. Cleaning by forward and backward flushing.

7.3 CLEANING BY BACKWASHING

This cleaning method is mainly used for process hollow fiber UF modules. The feed pump is stopped and the valve on the permeate side is closed (refer to Figure 7). The permeated liquid is pushed by the backwashing pump through the permeate port at a low pressure and low flow rate. The permeate runs through the pores of the membrane in the opposite direction, removing the fouling layer on the membrane surface. This liquid is then discharged from the system through the concentrate outlet. The duration and frequency of backwashing largely depends on the application.

* *Note*: Only permeate is suitable for backwashing!

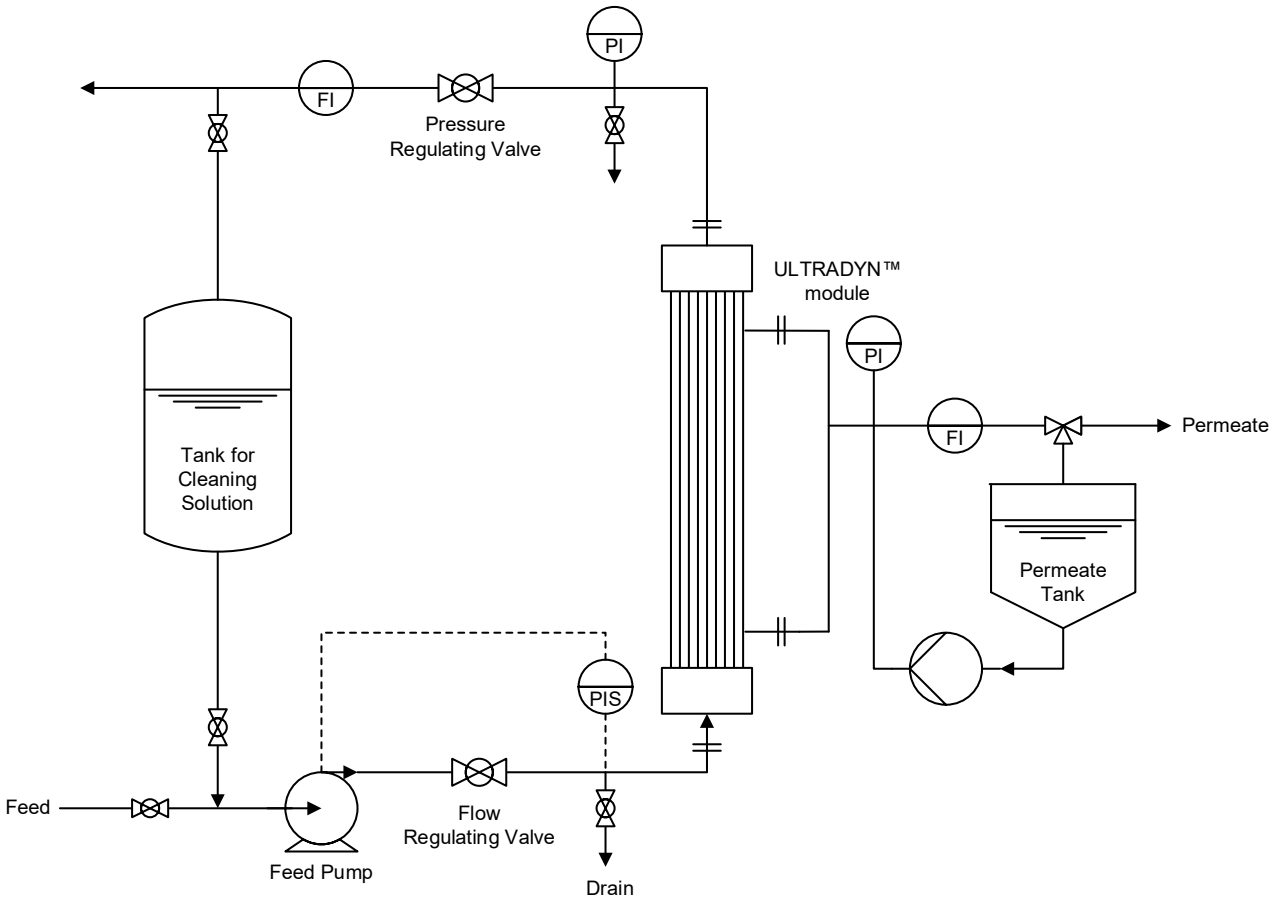


Figure 7. Backwashing flow diagram.

7.4 CLEANING WITH CHEMICALS

The filtration performance is deteriorated gradually over time due to contamination of the membrane surface. Most contaminants on the membrane surface can be removed by chemical cleaning. There is no all-purpose cleaning method that can be applied for any application, operation method, or feed water quality to ensure the module filtration performance after chemical cleaning. The best cleaning method for each case depends on the hollow fiber type, application, operation method, and feed water quality. Please refer to Tables 2-4 when using chemicals to ensure compatibility with the installed membrane type.

The following cleaning procedure has been successful in common applications with FUS membrane series and may be used as a guideline.

Cleaning to Remove Inorganic Soiling:

- 1-2% citric acid or
- 1-2% oxalic acid

Cleaning to Remove Organic Soiling:

- 0.05-0.5% NaOH
- 100-500 ppm (effective chlorine) NaOCl

To clean the modules, mix the cleaning chemicals in the cleaning tank. Circulate the solution through the modules using ordinary operating conditions so that the permeate and concentrate are led back to the cleaning tank. Continue this circulation operation for 30-60 minutes. Discharge chemical solution from the system and rinse with pure water for 20 minutes.

8 Sanitization

Please note, only ULTRADYN™ Elements with FUS-type membranes can endure a hot water sanitization. Please check the data sheet of ULTRADYN module in use to confirm ability of hot water sanitization. Before sanitizing a module, please perform one of the described cleaning methods in Section 7.

8.1 HOT WATER SANITIZATION

Some applications like ultrapure water polishing require chemical-free sanitization. ULTRADYN modules with FUS-membrane may be sanitized with hot water. These modules endure thermal sterilization up to 98°C. The applicable pressure to be used, however, is dependent on the temperature of the feed water.

Table 5. Heat Resistance of FUS Series for Different Temperatures and Pressure Ranges

Temperature [°C]	TMP [bar]	Max Feed Pressure [bar]	Max Permeate Pressure [bar]
5 - 49	3	6	4
50 - 79	2	4	3
80 - 98	1	2	1.5

Gradually heat up the ULTRADYN FUS module by no more than 10°C/min. After heating, cool the module gradually at the same rate. Any drastic change in the temperature within the module will generate strong stress, and thus may damage the module. Repetition of heating and cooling also may damage the hollow fibers or other parts of the module.

Any sterilization operation outside the above indicated condition range may damage the module and result in breakages of the hollow fibers or module parts.

Thermal shock due to rapid heating or cooling may break the module.

The following procedure is recommended to sanitize a system with hot water:

1. Stop the feed supply.
2. Drain the feed tank as well as the whole system.
3. Fill the feed tank with pure water.
4. Prior to circulation, a short rinse should be performed to rinse out any residual liquid remaining in the module, replacing it with pure water. Be sure to drain the retentate.
5. After the rinse, switch the valves so that the permeate and retentate will return to the feed tank (cleaning mode).
6. Circulate the pure water using the feed pump.
7. Gradually heat up the circulating water by no more than 10°C/min up to 85°C (185°F). Please make sure to stay within the recommended limits as noted on the product data sheet. Ensure that there are no rapid changes in flow rate or pressure.
8. Circulate with hot water for one hour. Avoid passing raw steam directly through the module.
9. After cleaning, slowly decrease the temperature (max. 10°C/min) and discharge the concentrate.

8.2 CHEMICAL SANITIZATION

Chemical sanitization is an option to sanitize ULTRADYN elements that are not qualified for hot water sanitization.

The following methods of sanitizing the module are recommended:

- Circulate cleaning chemicals for 30 minutes using a 200ppm sodium hypochlorite (NaOCl) aqueous solution.
- Continue circulating for 80 minutes using 1% formaldehyde aqueous solution.

9 Long-Term Storage

Thoroughly clean the module and keep it in a wet state. Use either of the following preservatives to prevent biofouling during storage:

1. 0.5% formaldehyde
2. 1% sodium bisulfite ($NaHSO_3$)

Close the module with the original caps and store the module in a horizontal position. Prevent the module from being in direct sunlight and store within the temperature range of 5 - 30°C (4 - 86°F).

10 Module Lifetime

When the separation characteristics of a module cannot be restored by cleaning, or when the permeate flux has degraded and can no longer be restored, the module has most likely reached the end of its lifespan. Please contact your MANN+HUMMEL WFS representative for replacements.