PureULTRA II Hollow Fiber UF Modules

Product Manual

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1 Introduction

Water resources continue to be one of the top environmental concerns around the world, leading to increased water recycling efforts in water and wastewater treatment facilities globally and reducing the consumption of fresh water. Ultrafiltration (UF) has shown demonstrated success in water reuse applications, as well as in removing harmful pathogens and suspended solids from drinking water.

UF is a process using a physical barrier to separate water and suspended solids, turbidity, silt, bacteria, and viruses from the feed water. In a system using pressurized PureULTRA II hollow fiber modules, the feed water may come from different sources such as surface water, groundwater, secondary or tertiary treated industrial wastewater, or other sources like tertiary treated municipal wastewater. PureULTRA II hollow fiber UF membrane modules feature an "outside-in" hollow fiber membrane that has a nominal pore size of 0.025 µm. This hollow fiber membrane is made using an innovative modified phase separation method for membrane production, which gives higher membrane surface porosity, smaller nominal pore size and robust mechanical properties.

PureULTRA II hollow fibers produced using the modified phase separation method combines both the advantages of DIPS and TIPS using the same materials. Features of the PureULTRA II hollow fiber UF modules include:

- **Longevity:** PureULTRA II hollow fiber UF modules are produced using an advanced membrane formation technique and a robust module structure providing superior filtration efficiency and durability.

- **Robust membrane:** PureULTRA II membrane is made using the advanced technology, which provides the membrane with highly crystalline structure. As a result, the membrane has high chemical resistance, outstanding mechanical strength, and lasts longer.

- **Permanently hydrophilic membrane:** The stabilized operating flux of most UF or microfiltration (MF) membrane products is much lower than initial / start-up flux, which is a result of loss in membrane hydrophilicity by polymer reconfiguration. PureULTRA II PVDF UF membrane remains permanently hydrophilic, and thus, offers a steady flux.

- **Oxidation-inert membrane:** PureULTRA II membrane modules can be cleaned thoroughly with strong oxidants because of the chemical inertness of the PVDF polymer.

- **Highly efficient fluid distribution:** MANN+HUMMEL Water & Fluid Solutions' (WFS) unique designed distributor ensures even distribution of feed water or air during the filtration and air scouring steps respectively. The distributor diffuses the water or air evenly both on vertical and horizontal direction along with the module tube, which reduces the energy consumption during filtration, and maximizes the air scouring efficiency.

- **Dual layer potting protection:** Dual layer centrifugal potting (Epoxy & PU) implemented, offers dense glue layers with less internal defects, even glue surface and high-pressure resistance. The soft PU layer protects the fiber roots, which is the weakest point of the hollow fiber inside the module, guarantees extremely low fiber breakage rate during its entire lifetime of our PureULTRA II module.

- **Low operating pressure:** Typically, PureULTRA II membrane is designed to run at pressures as low as 0.02 Mpa (3.0 psi) to produce desired filtrate.

2 Shipping, Handling, & Storage

Proper handling of the modules is necessary to maintain the chemical and mechanical integrity of the membrane modules.

2.1 SHIPPING

Every PureULTRA II module undergoes a stringent quality check before leaving the membrane manufacturing site. The membrane module is preserved for storage. All open ports are sealed with caps or plugs.

Upon receipt, and prior to installation, the modules must be inspected for any physical damage. Ensure that the correct product was received. MANN+HUMMEL WFS, or its representative, must be notified in writing immediately if damage or leaks have been found, or if the product identification (model name, part number, or serial number, etc.) does not match the shipping documents. If damage has occurred during third party transportation, damages must be reported and documented to the freight forwarding company, as well.

2.2 HANDLING

Only remove the membrane module from its original packing when ready for commissioning. The membrane module should be handled with care at all times to avoid damage. Personnel handling the membrane module should use the appropriate Personal Protective Equipment (PPE) and proper lifting guidance. Do not use the connectors to lift the module. Please ensure proper safety guidelines are followed when handling the membrane modules.

Avoid contacting the membrane module with any solvents or substances that may be harmful to the membrane modules, unless agreed upon and specified by MANN+HUMMEL WFS. The module must be kept wet all the time, as the fibers may dry out and become damaged. Always handle the module with care and protect it from impact or shock to prevent damage to both the membrane and module.

2.3 STORAGE

The shelf life of each membrane module is one year from the date of delivery if stored at the recommended storage conditions and without additional preservation measures.

For uninstalled membrane modules, it is recommended to store the modules in their original packaging and in a cool, dry, and well-ventilated area protected from direct sunlight at an ambient temperature between 5 and 45°C (41-113°F).

The connection ports of the membrane modules are sealed with caps and plugs from the factory and should be checked for tightness and leakages. Please keep these caps and plugs until it is time to install the modules.

Membrane modules that have been installed onto a rack but are offline (i.e., not in operation) may be stored in place if the previously mentioned storage conditions are followed. It is also possible to remove used membrane modules from the rack and put them into storage. To prevent membrane damage, please be sure to follow the shutdown procedure (see Chapter 6.5). For storage exceeding one year, fresh preservative must be added, as described in Table 1.

TABLE 1. STORAGE CONDITIONS

<table>
<tr><th>Duration</th><th>Recommended Procedures</th></tr>
<tr><td><1 year</td><td>No action required</td></tr>
<tr><td>>1 year</td><td>Drain out the existing preservative and replace the preservative with the following:
• Add the preservative liquid consisting of:
<table>
<tr><th rowspan="2">Module</th><th rowspan="2">Preservative Liquid Volume (L)</th><th colspan="2">Preservative Liquid Formulation</th></tr>
<tr><th>SMBS* (g)</th><th>Potable Water (L)</th></tr>
<tr><td>PHF-60-V</td><td>5</td><td>50</td><td>5</td></tr>
<tr><td>PHF-80-V</td><td>6</td><td>60</td><td>6</td></tr>
<tr><td>PHF-107-V</td><td>7</td><td>70</td><td>7</td></tr>
</table>
*SMBS = Sodium Meta bisulphate
• Pour in the chemicals from the reject port at the top of the membrane module
• Subsequently replace the preservatives every 3 months</td></tr>
</table>

3 Fundamentals

3.1 WHAT IS ULTRAFILTRATION?

Ultrafiltration (UF) is a membrane filtration process using pressure as a driving force to remove a large majority of contaminants including particulate matter, bacteria, viruses, and high molecular substances from water or process feed streams. Depending on the pore size of the UF membrane and the size of the particles suspended in the feed water, certain particles will pass through the membrane (typically low molecular weight solutes and dissolved solids) while others are rejected (e.g. suspended solids, bacteria, viruses, and high molecular weight substances). This separation process is widely used in water treatment, industry, and research for purification and concentration of solutions.

Ultrafiltration is not fundamentally different from microfiltration, except in terms of the size of the molecules it retains. The basic process of membrane filtration is shown in Figure 1. The process is pressure driven and typically operates with a feed pump, pushing the water through the membrane.

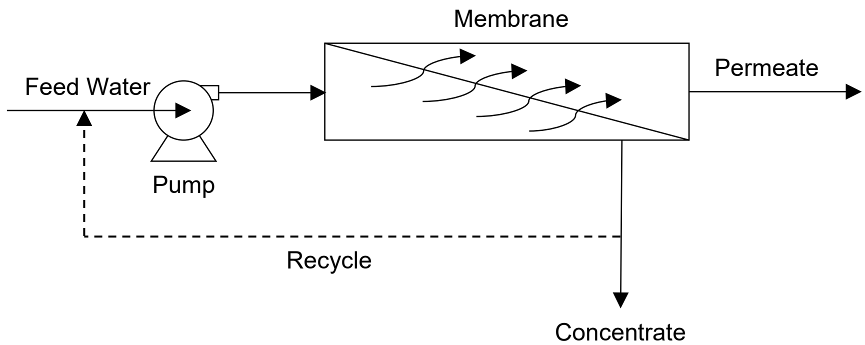


Figure 1. Schematic representation of membrane filtration process

The filtration spectrum and the selectivity of various filtration methods are shown in Figure 2. Because UF membranes reject particles based on size exclusion principles, they are often classified according to the size of the separated components. UF membranes may be classified by molecular weight cutoff (MWCO) in Daltons (1 Dalton is equivalent to 1 atomic mass unit) or by pore size (the nominal diameter of the openings or micro pores) in microns. The MWCO of the membrane refers to the molecular weight (in Daltons) of the molecule or solute that is 90% retained by the membrane.

Typically, UF membranes are classified by a range from about 1,000 to 500,000 Daltons (Da). But as the membrane becomes more open (greater than 100,000 Da), it is common to see UF membranes classified by pore size.

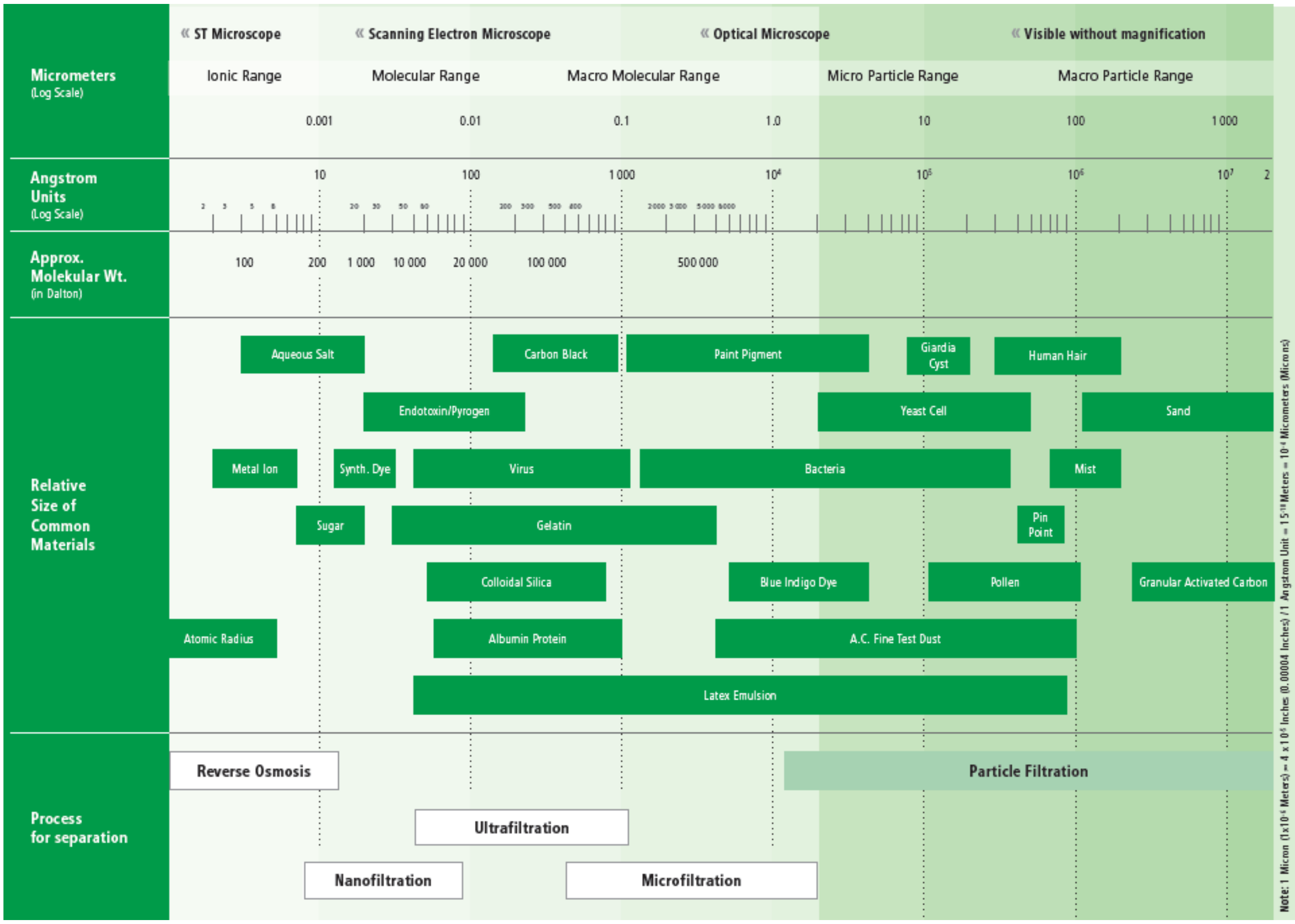


Figure 2. Membrane Filtration Spectrum

3.2 DEFINITIONS

The following section describes common terms used in UF operations.

Hollow Fiber (HF)

Ultrafiltration membrane is commercially available in a variety of configurations including hollow fiber, flat sheet (or plate and frame), spiral-wound, and tubular modules. The advantages of hollow fiber membrane modules include high membrane packing density, backwash ability, high permeability, and good mechanical strength.

Hollow fiber membrane modules consist of numerous very thin (1-3 mm in diameter) and long fibers (Figure 3). These fibers are fixed at one or both ends of the module in a potting material with one end of the module open for permeate collection.

There are two modes of filtration depending on the direction of permeate flow: inside-out or outside-in. For inside-out, the feed water is fed into the lumen (interior) of the fibers and the permeate comes out into the shell (exterior of the fibers) of the membrane module. For outside-in, the feed water is fed to the shell and the permeate is collected in the lumen of the fibers. The most common operation mode is outside-in.

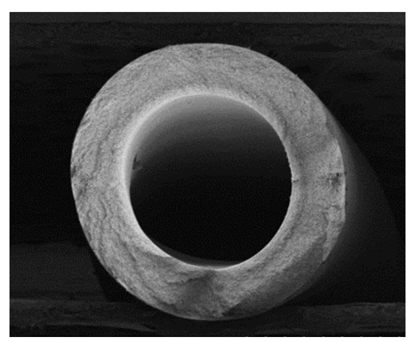


Figure 3. An SEM (scanning electron microscope) image featuring the cross section of a hollow fiber membrane.

During outside-in filtration, the fibers are surrounded by feed water, facilitating a very even flow distribution along the entire length of the fiber and among all fibers within a module. The permeate is collected inside the fibers.

The inside-out operation is the exact opposite, with the feed water distributed to the inside of the fiber and the permeate surrounding the fibers. This operation mode allows for low pressure operation and frequent and efficient backwash, as the volume on the feed side is much smaller compared to the outside-in operation. However, this mode is very sensitive to higher solids load or peak solids load in the feed water.

Dead-End vs. Cross-Flow Filtration Mode

Membrane systems can operate either through dead-end filtration or through cross-flow filtration.

1. **Dead-End Filtration**

   Dead-end filtration is the most basic form of filtration and is used in many filtration processes. In dead-end filtration, the feed water is forced through the filter surface via an applied pressure. Retained particles stay behind on the filter surface while water flows through (Figure 4A). The retained particles accumulate on the filter surface and, consequently, the water experiences a greater resistance to passing through the filter. This may result in a decrease in flux. Because the removed solids accumulate on the surface of the filter, filters and/or screens require cleaning to restore performance.

   Dead-end filtration is a batch process and can be a very useful technique for concentrating compounds. It has two streams: the feed (raw water going through the filter or screen) and permeate (treated water free of solids).

2. **Cross-Flow Filtration**

   Cross-flow filtration (also known as tangential-flow filtration) is a filtration technique in which the feed solution passes along the surface of the membrane (Figure 4B). The constant turbulent flow along the membrane surface prevents the accumulation of matter on the membrane surface. A pressure difference across the module drives water through the membrane (permeate) while particles that are retained (concentrate) by the membrane continue to pass along the membrane surface. The process is referred to as "cross-flow" because the feed (and concentrate) flow(s) and permeate flow are perpendicular (90°) to one another.

   Whereas dead-flow has two streams, cross-flow filtration has three streams: feed (raw water going through the module), permeate (treated water), and concentrate (water with retained particles).

   Cross-flow filtration is an excellent way to filter liquids with a high concentration of filterable matter. The feed and concentrate flows help keep the membrane surface clean and free of accumulated matter so the membrane may continue to perform with less frequent cleanings.

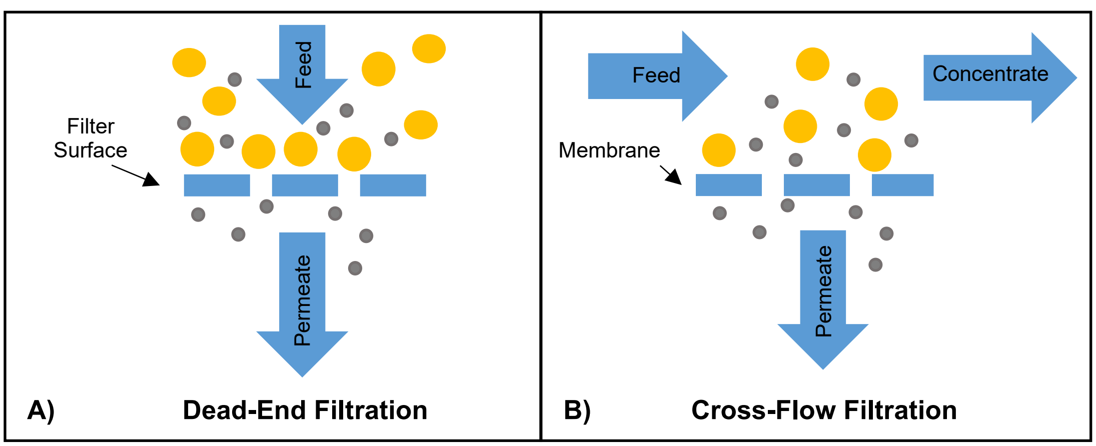


Figure 4. Diagrams showing the difference between crossflow and dead-end filtration.

Transmembrane Pressure (TMP)

Transmembrane pressure (TMP) is the pressure difference between the feed pressure and the permeate pressure. This pressure difference is the driving force for filtration; it describes how much force is needed to push water through a membrane. A low TMP typically indicates a clean, well-functioning membrane while a high TMP indicates a fouled membrane with reduced filtering abilities.

TMP is measured by pressure sensors in the feed and permeate headers. Generally, TMP is calculated as follows:

$$\mathrm{TMP} = \mathrm{Feed\ Pressure} - \mathrm{Permeate\ Pressure} + \mathrm{CF}$$

If there is any height difference between the locations of the feed pressure and permeate pressure sensors, the above calculation is corrected using a correction factor (CF). For example, if the feed pressure sensor is located 50 cm higher than the permeate pressure sensor, then CF = + 0.05 bar. In the event the permeate pressure sensor is located 80 cm higher than the feed pressure sensor, then CF = - 0.08 bar.

Gross Flux

The flux presents the absolute hydraulic flow in relation to the active membrane area that is used for filtration. Increasing the flow also increases the flux. Reducing the active membrane area (e.g., by isolating a module) also increases the flux. See the formula below:

$$\mathrm{Gross\ flux} = \frac{\mathrm{Feed\ Flow}\left[\frac{\mathrm{L}}{\mathrm{h}}\right]}{\mathrm{Membrane\ Area}\ [\mathrm{m}^2]}\left[\frac{\mathrm{L}}{\mathrm{m}^2 \cdot \mathrm{h}}\ \mathrm{or\ LMH}\right]$$

The gross flux is the instantaneous, "real" flux through the available membrane surface area. For feed pump flow rate sizing, the gross flux is used and multiplied by the total (maximum) membrane area.

Net Flux

The net flux (NF) is the average flux dependent on net permeate production flow (considering permeate production stops during backwash and chemical cleaning periods). The net flux depends on the filtration time, air scouring, backwash flow, backwash time, and cleaning frequency and duration. The formula below can be used to calculate the net flux:

$$\mathrm{Net\ Flux} = \frac{\mathrm{Net\ Permeate\ Production\ Flow}\left[\frac{\mathrm{L}}{\mathrm{h}}\right]}{\mathrm{Membrane\ Area}\ [\mathrm{m}^2]}\left[\frac{\mathrm{L}}{\mathrm{m}^2 \cdot \mathrm{h}}\ \mathrm{or\ LMH}\right]$$

Average Flux

The average flux is defined as the specific flux over a longer period (e.g., over a week, month, or even a year). The average flux can be calculated using the following formula (the example is for an operating period of one week):

$$\mathrm{Average\ Flux\ (week)} = \frac{\mathrm{Filtered\ Water\ During\ One\ Week}}{\mathrm{Total\ Membrane\ Area\ Used} \cdot\ 168\ \mathrm{hours}}\ [\mathrm{LMH}]$$

Permeability

Permeability is a membrane's ability to allow fluids to pass through it and is an important factor to evaluate the membrane's performance. The permeability is expressed as the ratio of gross flux to the TMP.

$$\mathrm{Permeability} = \frac{\mathrm{Gross\ Flux}}{\mathrm{TMP}}\left[\frac{\mathrm{L}}{\mathrm{m}^2 \cdot \mathrm{h} \cdot \mathrm{bar}}\right]$$

Normalized Permeability

Permeability is strongly related to the viscosity of the medium, which in turn, depends on the temperature. Usually, permeability is normalized to a temperature of 25˚C to compare membrane modules operated at different temperature conditions. The following equation can be used for that purpose. T is the actual temperature of the medium:

$$\mathrm{Normalized\ Permeability} = \frac{\mathrm{Gross\ Flux}}{\mathrm{TMP}} \cdot\ 1.024^{(25-\mathrm{T})}\left[\frac{\mathrm{L}}{\mathrm{m}^2 \cdot \mathrm{h} \cdot \mathrm{bar}}\right]$$

Recovery

Recovery, recovery rate, or percent recovery is the percentage of feed water that becomes permeate. The longer the time frame that the recovery is measured in, the more accurate the recovery calculation is. This is because all water losses and nonproductive time for backwashes and chemical cleanings are accounted for.

$$\text{Recovery} = \frac{\text{Net Product Flow}}{\text{Feed Flow}} \cdot 100\%$$

3.3 TYPES OF MEMBRANE FOULING

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, effectively plugging the membrane. The three general types of fouling include particulate or colloidal; inorganic or scaling; and organic fouling.

3.3.1 Particulate or Colloidal Fouling

Particulate or colloidal fouling is caused by suspended solids, colloids, and turbidity in the feed water (e.g., dirt, silt, clay, etc.). This fouling is controlled by hydraulic cleanings through regular air scouring and backwashing.

3.3.2 Inorganic Fouling / Scaling

Most inorganic fouling or scaling occurs when filtering ground water or alkaline industrial wastewater. Scaling may occur if the concentration of certain dissolved (inorganic) compounds are concentrated beyond their solubility limits and precipitate on the membrane surface as scale. Scale may be removed by acid cleaning. Citric is a commonly used acid for acid (low pH) cleanings. The concentration depends on the nature of the inorganic precipitate, how severe, and how long the fouling has been present on the membrane surface.

3.3.3 Organic Fouling

Organic fouling typically occurs when the feed water contains organics. The most common organic foulants include alginates, humic acids, fulvic acids and/or fatty acids. Bacteria is one of the most common foulants; microorganisms are often able to thrive and multiply on the membrane surface, producing biofilms and resulting in heavy fouling. Alkaline solutions, such as sodium hypochlorite (NaOCl), are commonly used for removal of organic fouling.

3.3.4 Reversible & Irreversible Fouling

All three types of fouling (particulate or colloidal; inorganic or scaling; and organic fouling) may occur during the lifetime of a membrane module. The type of foulant depends on the feed water characteristics. When cleaned appropriately and with the proper pretreatment, foulants may be removed and membrane performance restored (i.e., reversible fouling).

Irreversible fouling may permanently reduce the performance of the membrane and may only be recovered by replacing the affected membrane module(s). To prevent irreversible fouling from occurring, MANN+HUMMEL WFS highly recommends incorporating the proper pretreatment and cleaning regimes for the hollow fiber UF system.

1. Reversible fouling → foulants may be removed by cleaning; performance may be substantially recovered.
2. Irreversible fouling → foulants cannot be removed by cleaning; performance is compromised and may not be recoverable.

4 Design of PureULTRA II Modules

4.1 PRETREATMENT OF THE FEED WATER

The type and amount of pretreatment largely depends on the feed water source, the feed water composition, and the application, as certain materials may exacerbate the fouling process or even cause immediate damage to the membrane module. Proper pretreatment plays a critical role in the performance and life expectancy of PureULTRA II UF membrane modules.

Typical pretreatment processes include:

- Fat, oil, and grease removal
- Pre-screening
- Coagulation & flocculation
- Flow (load) equalization

Fat, Oil, & Grease Removal

PureULTRA II membrane modules may tolerate a maximum concentration of 2 mg/L emulsified fat, oil, and grease (FOG), but no free FOG. If the FOG concentration exceeds this maximum concentration in the feed water, installing an additional pretreatment step upstream of the UF system is recommended. Generally, FOG is removed by flotation or skimming. The type of flotation may vary based on availability and the FOG concentration in the raw feed water.

Pre-Screening

Most UF plants use basic pre-screening to keep larger particles from entering the membrane module. Depending on the feed water source, application, total plant flow rate, and particle size, several types of pre-filtration are possible. The most common screens for basic pre-screening are auto self-cleaning filters with 100 to 300 µm openings. For seawater applications, MANN+HUMMEL WFS recommends 100 to 150 µm screen size. For most other applications, 150 to 300 µm screens are sufficient. For questions, additional information, or to confirm the type and size of pre-screening equipment, please contact your MANN+HUMMEL WFS representative.

If the pretreatment process includes a final filtering / straining step of particles bigger than 300 µm, a protective in-line UF feed strainer may be omitted.

If a strainer is used, it is highly recommended to avoid using strainers made of any material that may disintegrate (e.g., stainless steel wire mesh) over time as disintegrated material may lead to membrane damage. Rather, the use of bag filters, “wedge wire” strainers (or similar), drum filters, or disc filters is advised.

In the event the customer decides not to install a UF feed strainer, MANN+HUMMEL WFS is not responsible for any membrane and/or consequential damage caused by the entrance of external harmful material.

Coagulation & Flocculation

Coagulation and flocculation are two methods of pretreatment in which chemicals are added to the raw feed water to remove specific particles / foulants that may have a detrimental effect on the modules located downstream.

Coagulation occurs when a chemical (coagulant) is added to water to “destabilize” colloidal suspensions. In a colloidal suspension, particles will settle very slowly or not at all because the particles carry electrical charges on the surface that mutually repel each other. A coagulant (typically a metallic salt) with the opposite charge is added to the water to overcome the repulsive charge, "destabilize" the suspension, and allow the colloidal particles to stick together and form flocs.

Conversely, flocculation uses polymers to clump the small, destabilized particles together into larger flocs, which can be separated from the water easily. Flocculation is a physical process and does not involve neutralization.

Please note that any carryover of polymer-based flocculants / coagulants, especially the cationic type, are not compatible with PureULTRA II UF membrane modules. Polymer based flocculants / coagulants may cause severe and potentially irreversible fouling of the membrane modules.

Coagulation and flocculation are often used together to form the largest possible flocs for easy removal by either filtration or sedimentation. Please consult MANN+HUMMEL WFS if coagulant, aluminum, or ferric-based salts will be dosed into the UF feed flow.

Flow Equalization

With an equalization process the peak flux is virtually eliminated, or at least reduced, and the average flux becomes the main driving force in dimensioning the required membrane surface area. Removal of highly variant peak fluxes drastically reduces both the stress on the membrane and the fouling potential. Also, the overall process flow is much more stable, with less frequent regeneration and chemical cleanings.

Equalization is used if the overall cost of the plant can be reduced; consideration factors are frequency, amount and duration of peak flows, and the availability of space. Flow equalization also enables consistency in raw UF feed and stability of processes.

4.2 MEMBRANE FIBER AND MEMBRANE MODULE SPECIFICATION

PureULTRA II modules (Figure.5) consist of Polyvinylidene Fluoride (PVDF) hollow fiber membranes. The hydrophilic-modified PVDF material is widely used in many applications (e.g., produced water) due to its high mechanical strength with excellent chemical resistance providing long membrane life and reliable operation. Additionally, the membrane modules are optimized for low pressure use, which results in a lower OPEX for the whole membrane filtration system.

The UF fibers developed by MANN+HUMMEL WFS are assembled into a membrane cartridge. The cartridge filled with the hollow fiber membranes is the PureULTRA II module.

The membrane modules are designed to be installed and operated vertically. There are four ports on each membrane module: two on the bottom cap and two on the top cap. The feed water enters during filtration at the bottom connection of the membrane module. The air feed is located at the bottom connection, as well, and is used for the air scouring during the hydraulic cleaning cycle. The permeate port is located on the bottom cap. The vertical port on the top cap is for reject or retentate during cross-flow operation.

PureULTRA II modules with three membrane areas (60/80/107 m^2) provided by MANN+HUMMEL WFS to meet different customer or application requirements. Refer to Appendix 7.1 for detailed fiber and module specifications.

Figure 5. PureULTRA II Module Structure

5 UF System Design

The most important aspect of the UF system design is choosing the appropriate operating flux for a given water source, application, and a specified set of water parameters. If there are temperature fluctuations over the year, then the lowest temperature should be considered when choosing an operating flux. Subsequently, the required membrane area can be determined based on the chosen flux. The design of the entire system accounts for any disruptions and shut-downs due to cleaning, disturbances, as well as any process impacts from both upstream and downstream processes (e.g., RO system operations and CIP downstream).

For specific applications or processes, MANN+HUMMEL WFS may recommend piloting prior to designing a full-scale plant. For questions or additional information about certain applications or processes, please contact your MANN+HUMMEL WFS representative.

A basic P&ID of a system using PureULTRA II membrane modules can be found in Appendix 7.2.

5.1 AUXILLIARY EQUIPMENT

5.1.1 Tanks

To prevent frequent system start-up and shutdown, the volume of the feed tank upstream and permeate tank downstream of the UF system should be sized appropriately. The feed and permeate tanks should be designed with inlet and outlet valves, drain valves, open overflow pipes, and level switches and level transmitters to ensure proper liquid level control in the tanks. The level switch should have the ability to detect high liquid levels to prevent the tanks from overfilling and detect low liquid levels to stop system operation to prevent equipment (pumps and membrane modules) damage. It is recommended to equip the permeate / backwash tank with a level transmitter to ensure enough water is available to execute hydraulic cleanings or chemically enhanced backwashes (CEB).

The permeate and backwash tank can be designed as the same tank for easier operation. If the same tank is used for the permeate and backwash, the tank should be sized according to the amount of water calculated in the above guidelines in addition to the amount of water used in at least one backwash cycle.

It is recommended that the feed and permeate / backwash tanks be constructed from non-corroding materials. The water in the permeate / backwash tank should also be protected from direct sunlight to minimize bacterial and/or algae growth.

Dosing Tanks

Dosing tanks are necessary to store the chemicals required to perform the CEB and cleaning-in-place (CIP). Each chemical is stored in its individual dosing tank. For safety reasons, it is recommended to place dosing tanks in individual bunds to contain possible leaks.

The dosing tanks should have enough storage capacity to hold a minimum of one week's worth of chemicals. Please consult the chemical supplier for suitable tanks, dosing pumps, piping, valves, and instrumentation materials that are compatible with CEB and CIP chemicals.

If sodium hypochlorite (NaOCl) is one of the cleaning chemicals used, it is important to remember that this chemical loses strength over time, especially at higher temperatures. The degradation rate of NaOCl increases with increasing temperature and direct sunlight. Because of this, it is recommended to use a non-translucent tank and to check the chemical strength on a frequent basis. Additionally, due to off-gassing, the tank must also be designed to allow this gas to vent. It is recommended to store sodium hypochlorite under dark and cool (≤ 15°C or ≤ 59°F) conditions.

Cleaning-in-place (CIP) tank

If intensive cleaning is needed, a CIP tank may be required. To account for the amount of CIP water needed for each membrane module, each CIP tank should hold approximately 70 L (18.5 gallons) per module. Please keep in mind that the tanks should also be sized to account for the volume of water in the piping. It is also recommended that the tank have 20% of freeboard.

5.1.2 Pumps & Blowers

Feed pump

The feed pump can be designed based on the gross filtration flux. Pump head can be determined by the amount of pressure upstream of the pump. The flows and pressures for any pre-filtration equipment upstream of the pump, such as auto-filters, must also be accounted for when sizing the pump.
A centrifugal pump with a frequency inverter for flow control and smooth ramp up and down is most commonly used. To prevent cavitation, it is recommended to use large suction piping.

If used for CIP or seawater applications, ensure the pump's materials of construction can tolerate chemicals or deteriorating materials to prevent premature pump failure.

It is possible to use a single feed pump for several lines. However, a redundancy should be built in to prevent a single point failure.

Backwash pump

The backwash pump capacity is based on a backwash flow that is equal to 2x the permeate flow. The backwash pump should be equipped with a frequency inverter for smooth ramp up and down and to maintain a constant backwash flow during the hydraulic and CEB cleaning procedures. Furthermore, the same design considerations for the feed pump apply to the backwash pump.

Air Blower

Air blowers or pressurized air can be used with PureULTRA II modules. The primary purpose of the air is to agitate the membrane fibers during the regeneration process. The air blower should be designed with a blower discharge flow rate of 12 Nm^3/h (7.1 scfm) per module and a maximum air scouring pressure of 1.0 bar (14.5 psi).

Dosing pump

The chemical dosing pump supplies chemicals to the membrane modules during CEB. Each chemical requires its own dosing pump to ensure there is no mixing of the different chemicals. Depending on the application and dosage of chemicals into the system, a solenoid or motor driven dosing pump may be used.

The dosing pump capacity is normally determined by the following parameters:

- Target concentration
- Source concentration
- Backwash flow (directly related to backwash flux and installed membrane area in the UF rack)

5.1.3 Valves

Pneumatic or electric actuated valves are recommended. However, ensure that the opening and closing of the valves is well controlled. Well-controlled valves may help prevent water hammer (sudden pressure surge forced onto the membranes). It is recommended to add air supply and release any restriction on the valve actuators.

It is recommended to use valves with position indicators. These indicators should be connected to a control panel to ensure all valves are in the correct open / close position before transitioning to the next operation step.

Reject Outlet Valve

The reject outlet valve is an open / close device that is closed during filtration and opened only during forward flush, regeneration, EBF, and CIP. Therefore, the sizing of the valve must be designed for the largest possible flow depending on the backwash and forward flush flux.

Permeate Outlet Valve

The permeate outlet valve is an open / close device that is opened during filtration and closed during regeneration, CEB, and CIP. When closed, the permeate outlet valve prevents backwash water from entering the permeate line. The valve should be designed for the largest flow possible depending on the filtration flux.

Feed Inlet Valve

The feed inlet valve should be installed when there is a possibility of feed water flowing to the membrane modules and a high hydraulic pressure can be subsequently applied. This could affect the backwash efficiency of the regeneration process. This is because there is an additional backpressure when the backwash water is sent from the backwash pump to the membrane modules.

Air Blower Inlet Valve
An air blower inlet valve is recommended inside the air pipe to fully isolate the air blower section from the rest of the water-filled piping. This may prevent water from flowing into the air blower. The valve should be installed as close as possible to the junction, where the pipe joins the feed inlet of the UF membranes modules, to minimize flooding of the line.

Drain Outlet Valve
A drain outlet valve can be added wherever necessary to allow the heavier solids to be drained from the bottom of the membrane module in case the solids are unable to be pushed out via the reject line. Draining is carried out by opening the drain outlet valve and the reject outlet valve simultaneously.

Check Valves
Check valves should be installed in pipes where backflow may occur or where multiple lines route. For example, a check valve should be placed in the air pipe. The check valve will block water from entering the air blower when the air blower line / valve is open, but the air blower has not built up enough pressure to push air toward the membrane modules.

Sampling & Drain Valves
Sampling valves and drain valves are recommended. These are typically placed near the system water drains that are used for system maintenance. Sampling valves can be added upstream or downstream of the membrane modules to collect samples for water analysis.

5.1.4 Instrumentation

A set of monitoring equipment is necessary to ensure that the entire system works correctly, safely, and within permissible limits. Digital process monitoring equipment (e.g., pressure gauges and flow meters) is recommended for optimum monitoring and control of the process.

Pressure Measurements
TMP is measured according to the equation given in Chapter 3.2. Pressure sensors should be installed at the feed and on the permeate headers in each UF rack. For smaller UF racks without headers, pressure sensors should be located near the membrane module to reduce the influence of pressure loss caused by piping.

The pressure during backwash should be monitored to ensure that the backwash is carried out correctly and within the allowed pressure limit of the UF modules. The backwash TMP should be similar for each backwash.

The feed pressure should be measured before and after the pretreatment filters to determine the differential pressure. This may determine if cleaning or replacement of the pre-filters is necessary. Maintaining the pre-filters is important to help protect the membrane from harmful particulate matter.

The air blower pressure should be monitored closely to ensure that there is enough pressure to push the air into the modules, but that the pressure does not exceed 1.0 bar (14.5 psi).

Flow Measurement
A flow meter should be installed on the permeate line to monitor the flow during filtration and backwash. If the UF plant consists of multiple UF racks that use a common backwash pump, the backwash flow transmitter may be located at the backwash pump.

Turbidity Measurement
A turbidity meter may be used to monitor the permeate turbidity and to detect potential fiber breakages or system failure. However, periodic sampling and turbidity analyses using a hand-held analyzer is sufficient in monitoring the UF system's performance.

pH Measurement
During the CEB soak period, the operator should take samples and check if the recommended pH (Chapter 6.2) is achieved to ensure effective cleaning. Additionally, the pH must be within the module's allowable pH range (1-12).

5.1.5 Piping

A plumbing system is imperative to ensure the entire UF system works optimally. A series of pipes and fittings is necessary to connect the PureULTRA II modules and auxiliary equipment. To avoid piping dead legs and minimize pressure losses across the UF rack, it is recommended to keep the quantity of fittings (such as elbows) used to a minimum.

The feed and permeate piping should be designed with a maximum flow velocity of 1 m/s (V_p < 1 m/s or V_p < 3.3 ft/s). Backwash piping should be designed with a maximum flow velocity of 2 m/s (V_b < 2 m/s or V_b < 6.6 ft/s) while considering that air provided by air scouring (AS) is present. Air pockets in the piping upstream, inside the UF rack and downstream the UF rack should be avoided. If air pockets have accumulated, install vent valves for frequent venting.

5.1.6 Air Quality Requirement

During UF system operation, compressed air is required for pneumatic valves, air scouring and integrity testing (if applicable). Compressed air supply should meet the following specifications:

- Pneumatic valve operations: ISO 8573-1, class 2/3/2 (oil/water/particles) at 6 barg (87.0 psig) minimum pressure.
- Air scouring: ISO 8573-1, class 1/3/1 (oil/water/particles) at 1.0-2.0 barg (14.5-29.0 psig) pressure.
- Integrity test: ISO 8573-1, class 1/3/1 (oil/water/particles) at 1.0 (+/- 0.1) barg (14.5 +/- 1.5 psig) pressure.

The air source rate range is indicated on the datasheet in Appendix 7.1.

5.2 CLEANING STRATEGY

Depending on the water source, specific application, and water quality, organic and biological fouling and inorganic scaling may occur, requiring different cleaning regimes.

Organic and biological fouling is normally caused by growth of micro-organisms and organics adsorbed on the membrane surface. Organic and biological foulants may be removed and cleaned by executing a CEB or CIP with sodium hypochlorite (NaOCl) and the addition of caustic soda (NaOH) if necessary. pH 12 must never be exceeded during these cleanings.

Inorganic scaling is caused by the precipitation of metal salts on the membrane surface. Inorganic scale may be removed by CEB or CIP with acid. Common acids include citric acid and/or hydrochloric at pH ≥ 1.

Depending on the feed water quality and application, CEB and/or CIP may be used, and different chemicals may be used for optimum cleaning efficiency. The cleaning frequency also depends on site conditions.

Chemically Enhanced Backwash (CEB)
Backwash water flows to the membrane module via the backwash pump. At the same time, chemicals are injected via a dosing pump into the pipeline and are well-mixed by a static mixer before it is sent to the membrane module. Once the chemicals are in the UF modules, the backwash pump is stopped, and the soak timer is started. The purpose is to clean the lumen side of the fibers, as the chemical mixed water will flow from the inside of the fiber outwards to the reject outlet.

After the soak timer has elapsed, the backwash pump rinses out the chemicals. The process is described in detail in Chapter 6.2.2.

Cleaning-In-Place (CIP)
A cleaning solution is prepared with clean water in the CIP tank. A pH meter may be used to check if enough chemicals have been added to the clean water in the CIP tank. Before circulating the CIP solution, it is strongly recommended to replace the pre-screen from the normal, more open screen size to a much tighter screen size of 1 to 5 µm, or to add an additional safety screen of 1 to 5 µm. This will help capture the material coming out of the UF modules and prevent them from re-entering the modules.

Before switching on the CIP feed pump to draw in the CIP solution, ensure that all valves are open to enable circulation across the CIP tank and that all other valves are closed.

Once the pH of the CIP solution is confirmed at the desired pH value, the pre-screen size (bag filter) is replaced, and all valves are in the correct position, the CIP feed pump can be started at a low speed. The CIP solution is then drawn from the CIP tank into the UF system and enters the UF modules via the feed port at the bottom. The CIP solution leaves the UF modules via both permeate and reject ports at the top of the UF modules and returns to the CIP tank.

The total procedure takes several hours and may be repeated with soak and circulation intervals to enhance the effectiveness of the CIP cleaning. It is advised to check the pH in the CIP return water in the beginning and add more chemicals if the pH has deviated from the desired initial value. In the event NaOCl is used for cleaning, the free-chlorine content may be measured rather than pH. The process is described in detail in Chapter 6.2.3.

6 Operation Procedures for PureULTRA II UF Modules

This chapter describes the start-up and operation guidelines for PureULTRA II UF membrane modules. Before start-up is commenced, it is highly recommended to verify that the feed water composition has not changed.

MANN+HUMMEL WFS recommends that operation and maintenance staff be involved in the commissioning process. Additionally, it is recommended that the start-up is carried out in manual mode for all function tests prior to switching to automatic start-up. This will allow for monitoring of any anomalies.

6.1 START-UP CHECKS

Before start-up (i.e., starting of any operations with water), ensure the following is in working condition:

1. The equipment (valves, pumps, air blowers, dosing pumps, etc.) is installed correctly and in working condition.
2. The measuring instruments to be used are calibrated and properly installed.
3. The program controlled by the PLC is functional and runs without errors. This will prevent constant on/off switching of the system.
4. The membrane modules are installed correctly.

Ensure the entire system is clean, especially piping and tanks, to avoid a decontamination of the membrane modules.

6.2 REGULAR OPERATING PROCEDURES

The regular operating procedures would comprise the following:

1. Filtration
2. Hydraulic Cleaning
3. CEB
4. CIP

During filtration, the feed water is treated by applying pressure through the ultrafiltration membrane fibers from the shell side (exterior of the fibers) to the lumen side (interior of the fibers). The rejected particulates are blocked by the fibers, which then accumulate and form a filtration layer on the exterior of the membrane fibers.

The permeate water flows to the permeate/backwash tank where it is stored until the water is required downstream for further treatment or if it is used for backwash. If the product and backwash tanks are separate, be sure that water is always present in the backwash tank.

The flux should be constant throughout operation. It is advised to install the feed pump with a frequency inverter, or a feed flow control valve controlled by the flow output with safety interlocks, to prevent over-pressurizing. Depending on the quality of feed water and flux, a filtration time of 30-60 minutes between hydraulic cleaning cycles may be expected. This 30-60-minute filtration is referred to as a filtration cycle.

During dead-end filtration, the rejected particulate matter will accumulate. This accumulation may result in a gradual increase of transmembrane pressure (TMP) after each filtration and hydraulic cleaning cycle. After reaching a pre-set quantity of filtration-hydraulic cleaning cycles or if the TMP reaches the maximum pressure, the membrane module should be chemically cleaned via CEB or CIP.

Excessive build-up over prolonged periods will affect performance and recoverability of the membrane module. The foulants should be removed regularly through regeneration methods covered in the next section. Fehler! Verweisquelle konnte nicht gefunden werden.6. demonstrates the operating mode during filtration.

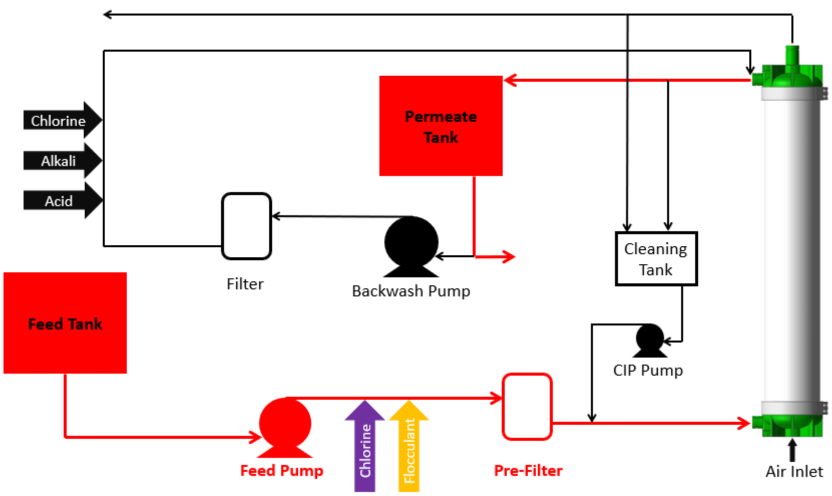


Figure 6. Filtration Mode

6.2.1 Operation of Hydraulic Cleaning

Four steps are normally involved in the hydraulic cleaning cycle.

- Air Scouring
- Drain
- Backwash
- Forward Flush

The sequence of these steps can be altered to improve the hydraulic cleaning efficiency.

Air Scouring (AS)

Air Scouring is essential as the air agitates and dislodges the accumulated particles on the exterior of the membrane fibers (or membrane surface). The air is delivered via the air blower or pressurized airline to the inlet located at the bottom of the membrane module. Ensure that the inlet air pressure is above the feed pressure.

As the air bubbles rise, enough turbulence is created to dislodge the foulants from the membrane surface without damaging the fibers. The timer should be set to approximately 30-60 seconds per air scouring.

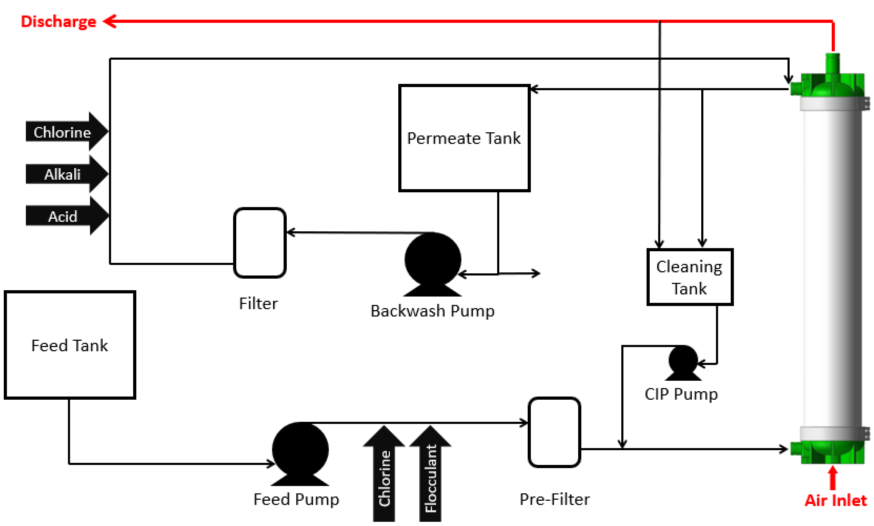


Figure 7. Air Scouring

Drain

A drain step may be added after air scouring, allowing the denser solids loosened by the previous step to be drained via the feedline at the bottom. Depending on the size of the system, the time to drain may take up to 30-60 seconds or longer; the time duration must be set during commissioning.

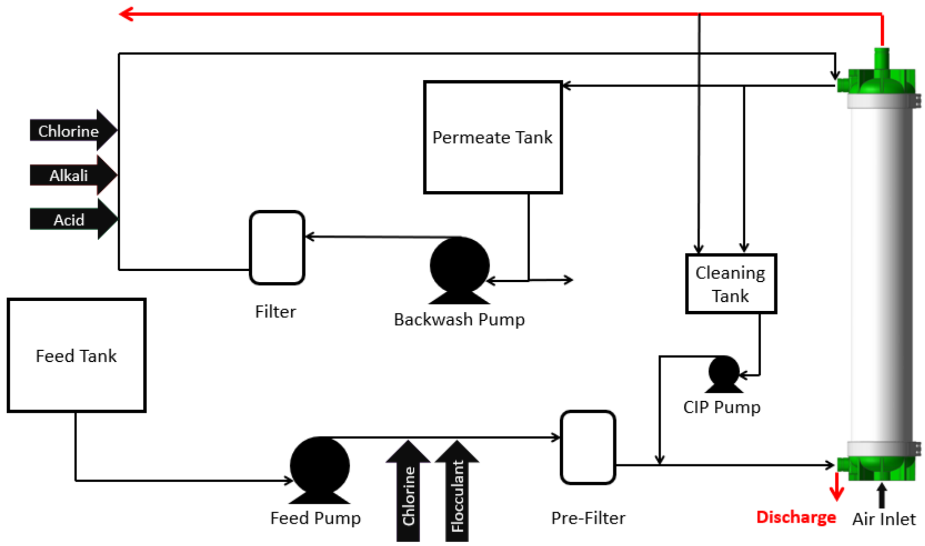


Figure 8. Drain mode

Backwash

Backwash cycle contains two steps, *Top backwash* and *Bottom backwash* to effectively remove the remaining suspended particles from the membrane modules. During backwash, the permeate water is drawn from the product / backwash tank and forced through the module from the filtrate side (lumen of the fibers), passing through the fiber wall toward the module shell side using the backwash pump. Because of this, the flow direction is opposite the filtration flow direction.

During the top backwash step, backwash water is fed from permeate port, passing through the fiber wall from the lumen side and discharged through the reject port. The top backwash step can effectively remove the fouling or suspended particles inside the module, especially the module top parts.

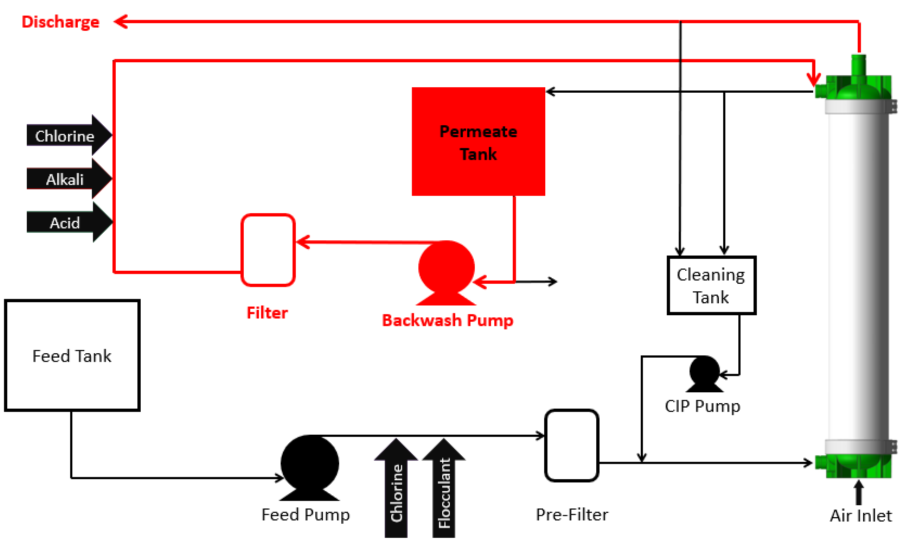


Figure 9. Top Backwash

During the bottom backwash step, backwash water is fed from permeate port, passing through the fiber wall from the lumen side and discharged through the permeate port. The bottom backwash step can effectively remove the fouling or suspended particles inside the module, especially the module bottom parts.

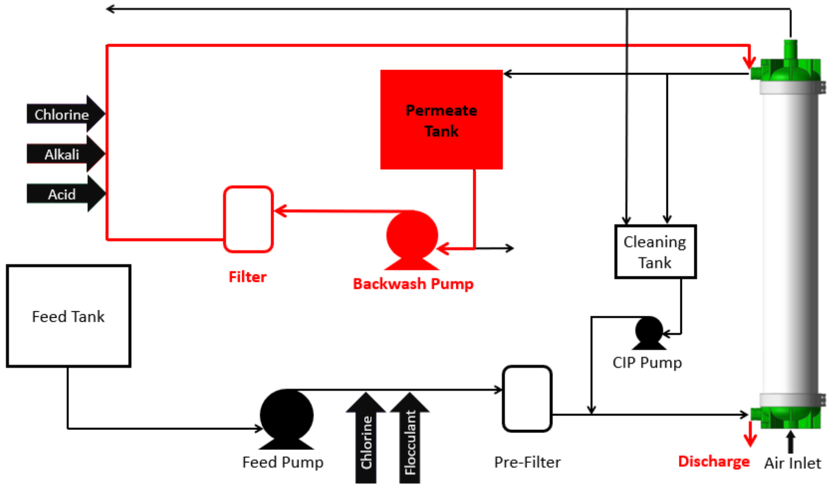


Figure 10. Bottom Backwash

The backwash should be conducted at a flux of 90 to 150 LMH (53.1 to 88.5 gfd). Effective backwash duration is at least 30-60 seconds, discounting the time taken for the pump to ramp up and down. The duration and frequency may be altered depending on the size of installation and the quality of the feed water.

It is highly recommended to ensure a reliable regeneration regime. A constant backwash flow rate is adopted by using an inverter-controlled backwash pump. The pump should be controlled such that the backwash flux is progressively ramped up to the desired backwash flow set-point and ramped down at the end of the backwash without pressure spikes or water hammer.

Forward Flush

A forward flush is implemented to remove the solids or residual chemicals from the system, also to remove the remaining air in the module, as a pre-step for filtration.

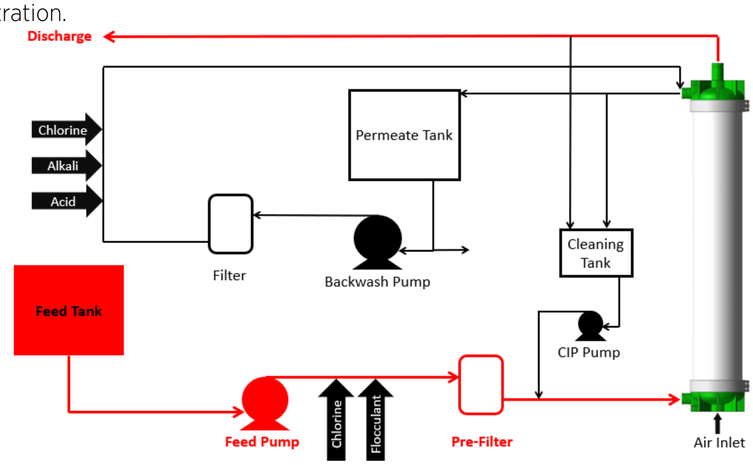


Figure 11. Forward Flush

Performing a forward flush is highly recommended because during forward flushing the product line will be closed. This has the advantage of forcing the water flow lengthwise along the exterior of the membrane fibers, which provides a scrubbing effect on the membrane surface. The forward flush step normally varies between a set time of 30 to 60 seconds.

Chemically Enhanced Backwash (CEB)

A chemically enhanced backwash (CEB) is a maintenance cleaning procedure designed to remove the inorganic particulate matter and microbial growth from the membrane surface quickly. These short, mini cleans may help prolong run times between major membrane cleanings. Depending on the feed water characteristics, CEB cleanings may occur once every few hours or days of operation. Sodium hypochlorite ($NaOCl \leq 1000$ ppm), NaOH (≤ 12) and HCl (≥ 2) are commonly used for CEB cleanings.

A CEB is a hydraulic cleaning cycle with the addition of chemicals. The chemicals are introduced into the backwash water to enhance the cleaning effect of the membrane modules. Five steps are incorporated into the backwash cycle:

1. Air scouring
2. Drain
3. Chemical dosing during backwash (top and/or bottom backwash) (Figure 13/14)
4. Soaking the modules
5. An additional backwash to rinse out the chemicals

Whenever possible, it is recommended to perform at least one backwash cycle prior to a CEB to ensure the larger suspended particles are removed as much as possible. This may increase the effectiveness of the CEB. Below is a description of the CEB:

1. Air scouring is performed to loosen the foulants from the membrane fibers.
2. Drain to remove the particles inside the membrane module.
3. The backwash pump ramps up, and the dosing pump starts to dose the required chemicals into the backwash line. The flux rate during the CEB is typically lower than the backwash flux rate and should not exceed 40 LMH (23.5 gfd).
4. Once the chemicals are in the UF modules, the backwash pump is stopped and a soak timer is started. The soak timer is typically set between 5-20 minutes.
5. When the soak timer has elapsed, the chemicals are rinsed out of the UF modules via backwash. The backwash pump is operated at the set backwash flux without chemical dosing. The time duration should be adjusted during the plant start-up to ensure that all chemicals are completely removed from the membrane modules and system.
6. If the setup permits, initial UF permeate after CEB should be discarded as it may contain residual chemicals that may result in complications to systems down-stream.

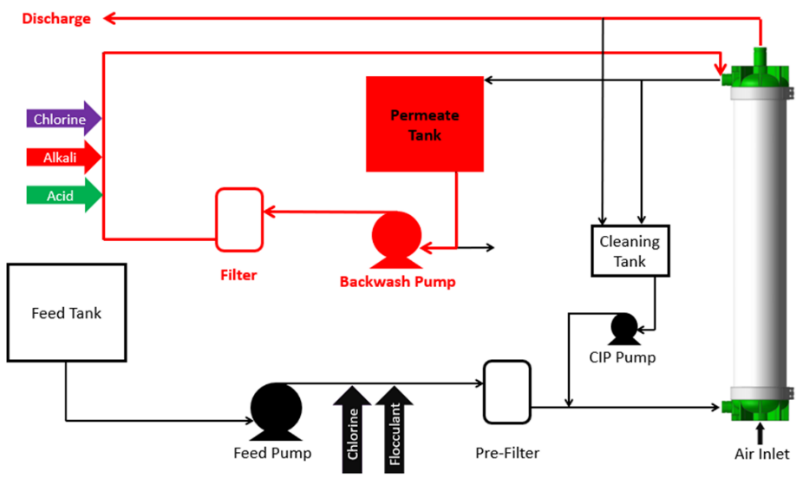


Figure 12. Introduction of chemicals to the system during CEB step (TOP)

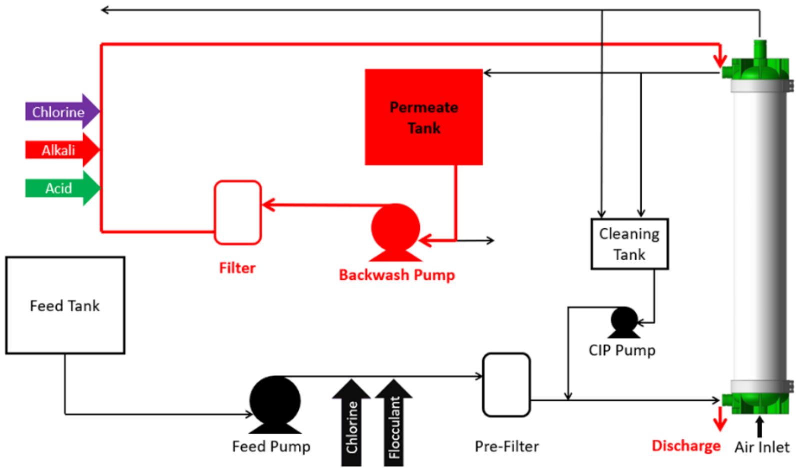


Figure 13. Introduction of chemicals to the system during CEB step (Bottom)

6.2.2 Operation of CIP (Cleaning-in-Place) Stage

When foulants and/or scalants can no longer be efficiently removed by hydraulic cleaning and CEB (due to upsets in the feed water quality or difficult operating conditions, such as ineffective pre-treatment or incorrect chemical dosage), a CIP is recommended.

The main differences between a CEB and CIP is that the CIP requires an additional circulation system and typically takes longer than hydraulic cleaning or CEB.

A CIP cycle is typically carried out once every few months. However, certain feed water conditions may require more frequent CIP cleanings, sometimes on a weekly basis.

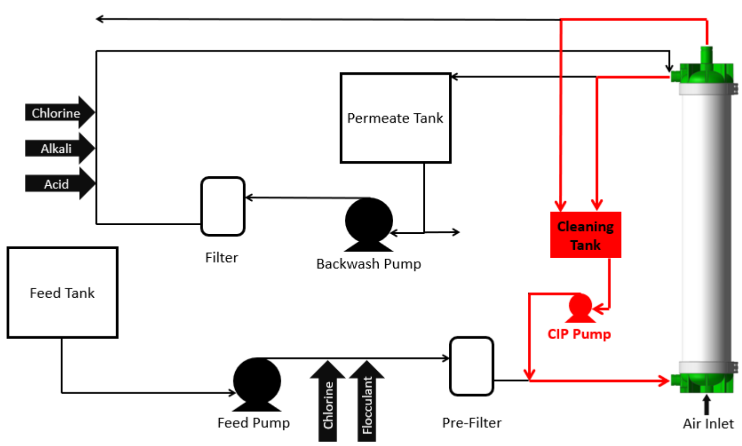


Figure 14. CIP mode

The following points are important and should be taken care of before performing the CIP:

1. The CIP should be performed if periodic hydraulic cleanings and CEB's are unable to recover membrane module performance adequately. The CIP should be considered effective if it recovers at least 75% of the membrane performance.
2. Recommended CIP chemicals are listed in Chapter 5.2.
3. The water used to prepare the CIP cleaning solution must be free of particles and have an alkalinity of less than 70 mg/L (tap water or permeate may be used). This is especially true for caustic / high pH cleaning. Additionally, it is recommended to flush the membrane modules with water after a high pH cleaning and prior to an acid / low pH cleaning.
4. Typical CIPs may take up to 12 hours (but should not exceed 12 hours).

5. The CIP solution can be heated up to 40 °C (but should not exceed 40 °C) to enhance the cleaning efficiency.
6. The CIP solution must be fed to the feed side of the membrane modules to prevent any foulants or scalants from contaminating the permeate side during recirculation.
7. It is highly recommended to isolate the UF rack undergoing CIP from other UF racks and/or other up- and downstream processes.
8. Replace the fine screen at the feed of the UF system by a finer pre-screen of about 5-10 µm.
9. Prepare the CIP solution in a separate CIP tank and check the concentration of the solution by measuring the pH value (or free chlorine if using NaOCl) to ensure enough chemicals are added.
10. Please note that the ratio of the CIP cleaning tank to the entire volume inside the cleaned system (number of modules, piping, CIP tank, etc.) needs to be considered for appropriate calculation of the CIP cleaning solution. The pH and concentration of the CIP solution may need to be adjusted after the CIP solution has started to circulate inside the UF system.

The following steps are carried out manually during CIP and should be closely monitored:

1. The CIP tank must be filled first with water before the addition of any chemicals.
2. The chemicals should be properly mixed. After mixing, check the concentration of the solution. Please check the maximum concentration levels listed in Appendix 7.1.
3. To prevent contamination, the feed tank and product / backwash tank should be isolated from the system by closing the valves on the feed and backwash lines.
4. The chemical solution is either drawn into the UF system (if the individual rack is equipped with a feed pump) or pushed into the UF system (by a CIP pump as part of the CIP system). The process should be monitored to ensure that the recirculated solution passes through the entire system. Be sure to check the concentration of the recirculated chemical solution so that it is the same concentration and pH as when entering the system.
5. While the solution is recirculating, air scouring may be performed intermittently during soaking to enhance the cleaning effect.
6. The cleaning solution is recirculated and soaked for 30-180 minutes (most commonly 60 minutes). The recirculation and soaking time may vary at each site.
7. The water may then be flushed back to the CIP tank after the soak has finished. Take samples of the return water to check if there are enough cleaning chemicals remaining in the CIP water. If the water becomes dirty, replace the chemical solution and repeat the cleaning cycle.
8. Once the cleaning has been deemed effective, drain and dispose the chemicals safely. Then clean the tank and top again with clean water before rinsing the membrane modules.
9. Conduct one or more normal hydraulic cleaning process before shifting the system to normal filtration. Ensure the foulants and/or scalants are discharged and the chemical residuals of permeate water meets the downstream process requirements.

6.3 INTEGRITY TEST

During operation, the hollow fibers may get damaged due to heavy fouling, pressure variation, or water hammer. This may result in impairment of the integrity of membrane module. When fiber breakage occurs, impurities will start to pass through the membrane and into the filtrate. To ensure the system is in proper condition, it is recommended to perform periodic integrity tests to identify possible fiber breakage.

The integrity test requires oil-free pressurized air (> 1.0 bar or > 14.5 psi), an air adjusting valve, and a transparent pipe (> 10 cm or > 4 inches) installed on the concentrate outlet on top of the module.

Auto integrity test systems can test the modules in a system periodically. An integrity test includes the following steps:

1. Stop the system. Close all valves.
2. Introduction of air: Slowly open the air adjust valve (V5) and release valve (V4) to let the air flow into the module from the filtrate water pipe. Close the air valve (V5) when the pressure stabilized to 1.0 bar (or 14.5 psi).
3. Pressure holds or decays: The pressure change will be recorded and analyzed by the monitoring system (PLC). The pressure decay should be less than 5% in 5 minutes if there are not any leaks present. This suggests the membrane is in good condition.

4. Check for bubbles in the concentrate pipe. Mark the module if there are continuous bubbles and repair the module offline.

Integrity tests should be performed every day for drinking water systems.

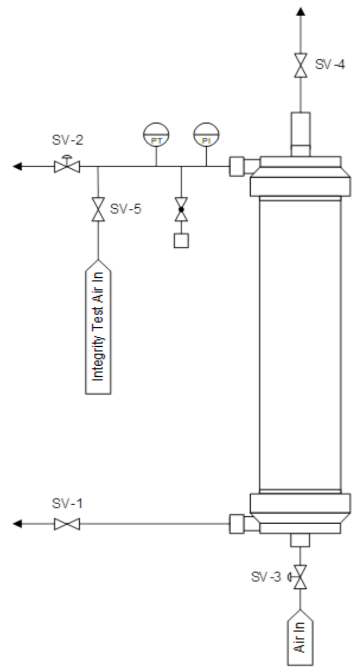


Figure 15. Integrity test flow diagram.

6.4 MODULE REPAIR

Membrane repair requires special training and tools. Contact MANN+HUMMEL WFS to get proper membrane repair training, tools, and plugs.

6.5 SHUTDOWN/PRESERVATION

UF systems are typically designed to run continuously. If shutdown is required, the system must be cleaned to prevent bacterial growth. After backwash, all valves on the UF system should be closed to isolate the system completely from any source of external contamination. Take note that at no point should the fibers be allowed to dry out as this would cause an irrecoverable deterioration of performance due to damage.

If the membrane modules are installed into a rack and not blanked off, the procedure for preservation must also be followed.

If shutdown exceeds seven days, addition of chemical preservatives is necessary.

TABLE 2. SHUTDOWN CONDITIONS

Duration	Recommended Procedures
< 2 days	• Complete at least one regeneration cycle per 24 hours • Close All Valves
> 2 days	• Complete at least one regeneration cycle and perform CEB with 500 ppm NaOCl, followed by usual backwash, without chemicals. • Add preservatives according to Table 1. for different type modules. Renew preservatives every three months

If the module is removed from the skid and stored for a long period of time, the module should be flushed thoroughly using permeate water and stored in an upright position.

The membranes must be stored free of any oxidizing agents during the system shutdowns.

If the module is known to be exposed to freezing conditions, please contact MANN+HUMMEL WFS.

6.6 OPERATING & CLEANING LOGS

Operation and cleaning logs are important for tracking operating conditions and system optimization. In Appendix 7.3, there are three record forms for cleaning monitoring. The first form is used to collect data during filtration and hydraulic cleaning. The second and third are maintenance / cleaning record forms for CEB and CIP data recording.

Data should be recorded the moment the modules are put into operation. The customer should maintain complete documentation of the operating and cleaning conditions and the amount of time the plant has been in operation.

Use of chemicals for feed water pretreatment and CEB / CIP must be monitored closely. This information should also be recorded. While the forms suggest and list certain data points, additional information can certainly be recorded to track the performance of the membrane modules further.

6.7 TROUBLESHOOTING

If an operational issue occurs, a general troubleshooting procedure is recommended to determine the root cause and the recommended solution. In general, please review the recommendations in this manual. Additionally, ensure that all pumps, valves, blowers, and sensors are regularly calibrated for proper function.

The following table lists possible operational issues and the suggested solution.

TABLE 3. TROUBLESHOOTING

	Issue	Recommendation
Low Chemical Cleaning Effect	Sodium Hypochlorite Stock Concentration	It is recommended to check the stock concentration once a month in colder regions or once a week in warmer regions due to its degradation over time (tests available, i.e., from Hach Lange)
	Delivery of Chemical	Make sure that the proper amount of chemicals is pumped into the system (metering of pump, check volume removed from stock tank)
	Biofouling	Use sodium hypochlorite or hydrogen peroxide
	Scaling	Use acids at low pH (pH 1) according to data sheet Check the total alkalinity of the influent; more frequent acid cleanings are required for high alkalinity (hard water) feed waters
	Chemicals	Chemicals used should be approved for membrane compatibility
	CEB not effective	Consider the volume of piping for the dosing time that the chemical is entering the modules. Make sure the correct amount of chemicals reaches the modules Increase dosing time, soaking time, chemical concentration, or frequency between CEB's
	CIP not effective	Check the turbidity of the reject flow after CIP performed. Increase flow and/or time of backwash if turbidity is high

		Increase recirculation time, soaking time, chemical concentration, temperature, or frequency between CIPs Clean in two steps and renew the chemical solution in-between for removal of accumulated particles Use a fine strainer bag during CIP recirculation to prevent accumulation of particles during CIP
Performance	High Pressure	Note that pressure is temperature-dependent (high temperature often means low pressure) Check if pretreatment is working properly Check design for: • Additional backpressure, which may increase feed pressure • Check for high pressure loss due to piping Make sure that no air is accumulated in the fibers
	Effluent Quality	Disinfect piping and all tanks Measure turbidity or Silt Density Index (please check Troubleshooting Measuring Silt Density Index TSG-T-010 for more information)
	Improper Pretreatment	Clean and improve pretreatment If additives are dosed, check the dosage (overdosage should be avoided)
	Influent Quality	Check the influent quality, specifically BOD, COD, TSS, and total alkalinity, to make sure that substances are not entering the modules (which may decrease performance) When influent concentrations are higher than designed, the performance may vary
	Low Hydraulic Cleaning Effect	If the backwash efficiency is lower than expected, increase the backwash flow first, if possible If flow must be decreased due to high pressure, increase the time to obtain the same volume as used before
Malfunctions	Water Hammer Temperature too High pH or Chemical Cleaning Concentration out of Range	In most cases, the module should be replaced Check all operation procedures and safety shutdown scenarios again if reason for malfunction is unknown

	TMP too High	

7 Appendices

7.1 APPENDIX 1. MANN+HUMMEL PUREULTRA II UF MEMBRANE TECHNICAL DATA SHEET (TDS)

MEMBRANE CHARACTERISTICS

Membrane Polymer	Polyvinylidene Fluoride (PVDF)
Nominal Pore Size	0.025 µm
Membrane Type	Hollow Fiber
Hollow Fiber Diameter OD / ID	1.3 mm / 0.7 mm (0.051 inch / 0.028 inch)

MODULE SPECIFICATIONS

Housing Material	UPVC
Membrane Potting	Epoxy / PU
Filtration Flow Path	Out → In
Operating Mode	Dead-end / Cross-Flow
Preservative	Sodium meta-bisulphite/ Glycerin

Model	**Membrane Area**
PHF-60-V	60 m^2 (646 ft^2)
PHF-80-V	80 m^2 (861 ft^2)
PHF-107-V	107 m^2 (1152 ft^2)

OPERATING PARAMETERS

Filtrate Flow Range	2.4 – 12.8 m^3/h (10.6 – 56.5 gpm)
Maximum Feed Pressure (at 20°C / 68°F)	6.4 bar (92.8 psi)
Maximum Transmembrane Pressure	2.3 bar (33.4 psi)
Maximum Backflush Pressure	2.7 bar (39.2 psi)
Typical Air Scour Rate	5 – 14 m^3/h (3.0 – 7.1 SCFM)
Maximum Air Scour Pressure	1.2 bar (17.4 psi)
pH Range for Operation	2.0 – 11.0
Temperature Range	1 – 40°C (33.8 – 104°F)

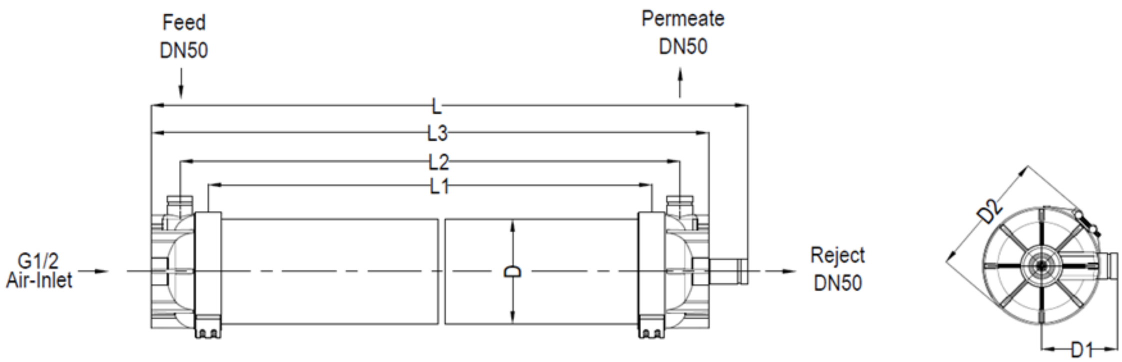
Permeate Quality	**Index / Value**
SDI_{15}	< 3
Filtrate Turbidity [1]	< 0.1 NTU
Removal of more than 0.2 µm diameter particles	99.99%
Removal of total coliform	Below Detectable Limit (BDL) [2]
Removal of fecal coliform	BDL [2]
Removal of bacteria	BDL [3]

[1] Measured online
[2] Detected with 100 mL UF filtrate
[3] Detected with 1 mL UF filtrate

CLEANING PARAMETERS

pH Range	1.0 – 12.0
Maximum Temperature	40°C (104 °F)
Maximum Active Chlorine Concentration	2,000 ppm
Maximum Active Chlorine Exposure	>1,000,000 ppm-hours
Cleaning Chemicals	Sodium Hypochlorite, caustic, hydrochloric acid / sulfuric acid / citric acid

PHYSICAL DIMENSIONS



Model	L	L1	L2	L3	D	D1	D2
PHF-60-V	1507 mm (59.3 in)	1147 mm (45.2 in)	1277 mm (50.3 in)	1415 mm (55.7 in)	250 mm (9.8 in)	180 mm (7.1 in)	300 mm (11.8 in)
PHF-80-V	1860 mm (73.2 in)	1500 mm (59.1 in)	1630 mm (64.2 in)	1768 mm (69.6 in)	250 mm (9.8 in)	180 mm (7.1 in)	300 mm (11.8 in)
PHF-107-V	2360 mm (92.9 in)	2000 mm (78.7 in)	2130 mm (83.9 in)	2268 mm (89.3 in)	250 mm (9.8 in)	180 mm (7.1 in)	300 mm (11.8 in)

	PHF-60-V	PHF-80-V	PHF-107-V
Dry/Wet Weight	43 kg (94 lb)/ 68 kg (149 lb)	50 kg(110 lb) / 83 kg(181 lb)	63 kg(138 lb) / 105 kg(229 lb)
Module Diameter	250 mm (9.8 in)	250 mm (9.8 in)	250 mm (9.8 in)
Module Length	1507 mm (59.3 in)	1860 mm (73.2 in)	2360 mm (93 in)
Feed / Reject Port	2" Victaulic	2" Victaulic	2" Victaulic
Permeate Port	2" Victaulic	2" Victaulic	2" Victaulic

7.2 APPENDIX 2. TYPICAL P&ID FOR MANN+HUMMEL PUREULTRA II UF SYSTEM

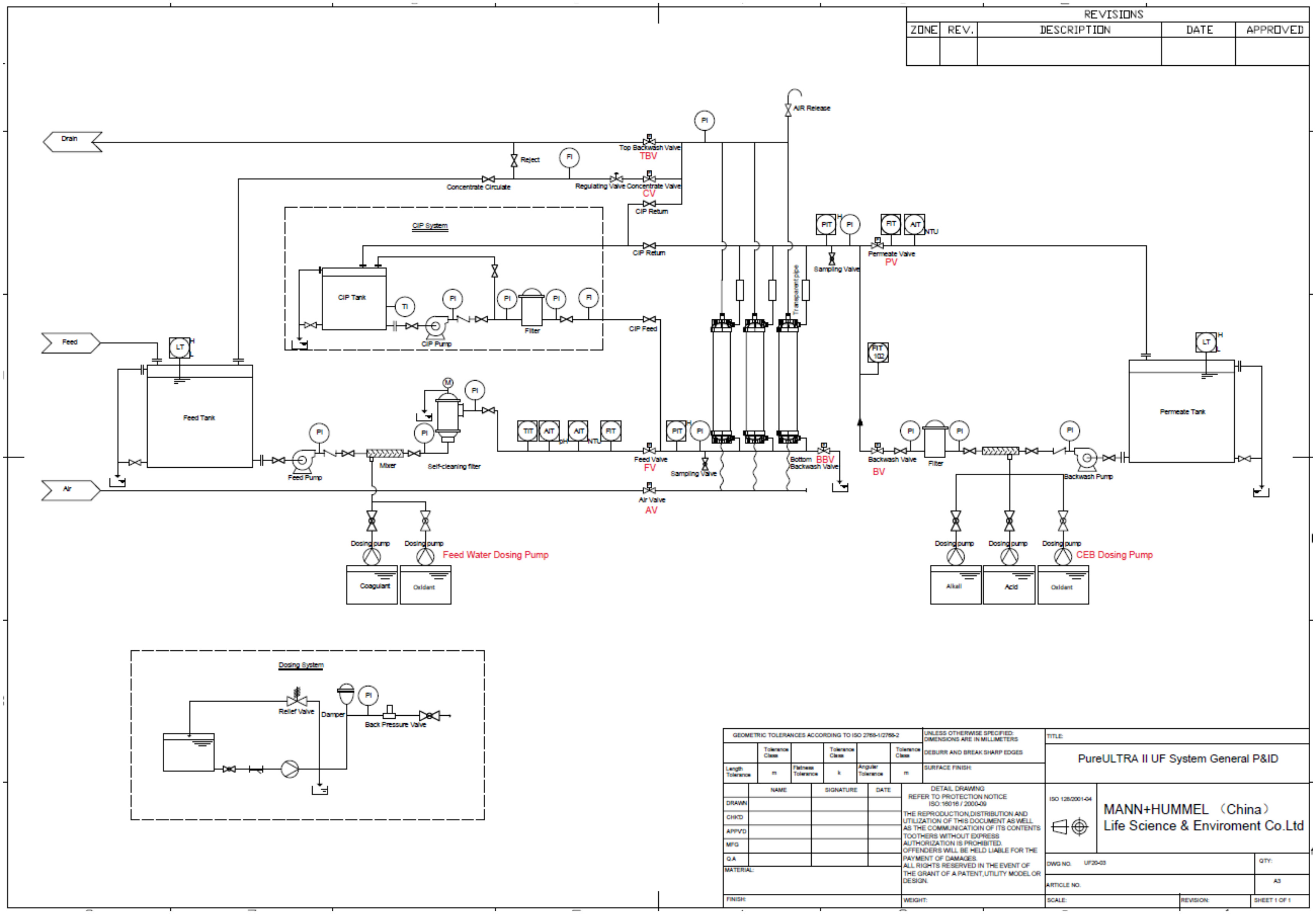


Figure 16. Typical P&ID of UF system using PureULTRA II hollow fiber UF modules

Steps		1	2	3	4	5	6	7
		Forward Flush	Filtration	Air Scouring	Drain	Top Backwash	Bottom Backwash	CIP[5]
Valve & Pump Status	Feed Pump	O	O					
	Feed Water Dosing Pump		Op[1]					
	Backwash Pump					O	O	
	CEB Dosing Pump					Op[3]	Op[4]	
	CIP Pump							O
	Feed Valve (FV)	O	O					
	Permeate Valve (PV)		O					
	Top Backwash Valve (TBV)	O		O	O	O		
	Bottom Backwash Valve (BBV)				O		O	
	Concentrate Valve (CV)		Op[2]					
	Backwash Valve (BV)					O	O	
	Air Valve (AV)			O				

TABLE 4. VALVE ACTIVITIES OF A TYPICAL UF SYSTEM

Note:
O - Open status for pump & valve.
Op - Optional open based on conditions.
1 - Feed Water Dosing Pump open for the conditions that need feedwater adjustment before the membrane.
2 - Concentrate valve open for Cross-Flow filtration mold, if dead-end, this valve should be closed;
3,4 - If chemical enhanced backwash (CEB), open the chemical dosing pump, normal backwash, the dosing pump should be closed.
5 - For CIP mold, all auto-valves close, open CIP manual valves.

7.3 APPENDIX 3. INSTALLATION GUIDANC

Fig.1 Module Assembly Instruction

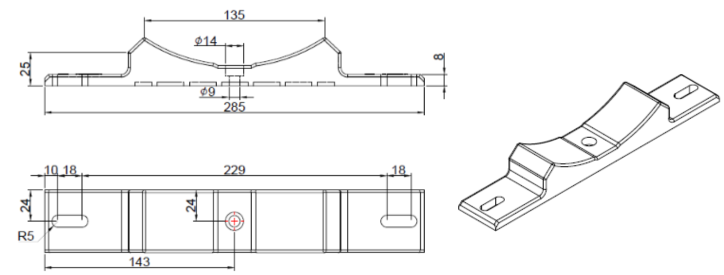


Fig.2 Module Tube Bracket

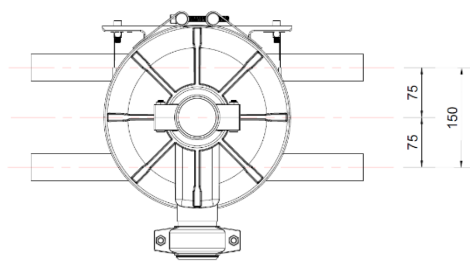


Fig.3 Skid Bottom Support

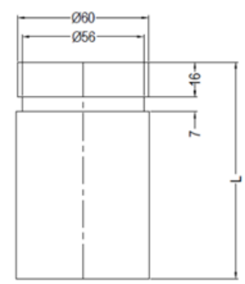


Fig.4 DN50 Coupling Dimension

Installation instructions:

1. Bottom support center-to-center distance 150 mm to support the module on the skid.
2. Fixing belt installation: drill two Ø10 mm holes on the skid frame based on Fig.2. Install the fixing belt with M8 bolt (90mm bolt optional supplied by M+H).
3. Disassemble the coupling plugs on the feed/permeate/reject ports. Drain the preservatives inside the module. Keep the coupling plugs for the next time use.
4. Install the module on the skid based on Fig.3 for bottom support.
5. Connect the module feed/permeate/reject ports to the skid with DN50 coupling connectors and EPDM sealings. Refer to Fig.4 for DN50 coupling connector dimension.
6. Remove the air inlet plug on the bottom cap and connect the air tube quick connector. Keep the air inlet plug for the next time use.
7. Ensure the module tube seated on the bracket and tight the bolts, let the fixing belts fix the module on the skid.

Module Packaging List

Applicable Modules: **PHF-60-V、 PHF-80-V、PHF-107-V**

No.	Parts	PCS
1	**PureULTRA II Module**	1
①	DN50 Coupling, Feed/Permeate/Reject	3
②	DN50 Coupling Plug	3
2	**Accessary package (Optional)**	1
①	Air Tube Quick Connector	1
②	Module Tube Bracket	2
③	Module Fixing Belt	2

Notes:

1. Properly handle the module during transportation and installation. Add or replace the preservatives follow the guidance in the product manual if leakage occurred.
2. Flush and clean the skid pipeline system before module installation.

7.4 APPENDIX 4. UF SYSTEM OPERATING & CLEANING LOG SHEET

OPERATION RECORD FORM

Project Name:	
System:	
Rack No:	

Feed Water Quality
Date collected:

	Nominal	Max		Nominal	Max
TDS (ppm)			Conductivity (µS/cm)		
TSS (ppm)**			Turbidity (NTU)**		
COD (ppm)			SDI15**		
BOD (ppm)			PH**		
Hardness (ppm)			Temperature (°C)**		
Others:			Others:		

			Operation Setting					Filtration Cycle							Backflush Cycle						
SN	Date	Time	Filtration Time	Air Scouring Time	Forward Flush Time	Drain Time	Backflush Time	Product Flow	Filration Flux*	Pressure (Before Pre-Filter) P0	Pressure (Before membrane) P1	Pressure (After membrane) P3	TMP* (P1-P3)	Air Scouring Flow	Forward Flush flow	Backflush Flow	BF Flux*	Pressure (Air Blower) P2	Pressure (BF inlet) P3	Pressure (BF outlet) P4	TMP* (P3-P4)
	dd:mm:yy	hh:mm	min	sec	sec	sec	sec	m^3/h	lmh	psi / bar g	psi / bar g	psi / bar g	ΔP psi / bar g	Nm^3/h	m^3/h	m^3/h	lmh	psi / bar g	psi / bar g	psi / bar g	ΔP psi / bar g
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Footnote:

1.) $System\ Flux = \frac{Product\ Flow\ Rate\ (\frac{m^3}{h})}{Total\ System\ Cartridge\ Surface\ Area\ (m^2)} \times \frac{1000L}{1\ m^3}$

2.) Grey shaded cells are to be calculated.

MAINTENANCE/CLEANING RECORD FORM

CEB

				Operation Setting												Cleaning Chemicals					Final Rinse			
SN	Date	Time	Op. Hr after last CEB	Temp	Solution pH	CEB Flowrate	Air Scouring Time	Backflush Time	Pressure (BF inlet) P3	Pressure (BF outlet) P4	TMP (P3-P4)	Pressure (Air Blower) P2	Dosing Pump rate	Duration (Dosing)	Duration (Soaking)	Chem. Vol	Acid	Caustic	NaOCl	Others	Water Source	Flow	Duration	Reject pH
	dd:mm:yy	hh:mm	Hr	°C	-	m^3/h	sec	sec	psi / bar g	psi / bar g	ΔP psi / bar g	psi / bar g	L/h	min	min	L	(%) / L	(%) / L	(%) / L	(%) / L	-	m^3/h	min	-
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CIP

				Operation Setting												Cleaning Chemicals					Final Rinse			
SN	Date	Time	Op. Hr after last CIP	Temp	Solution pH	Feed Pump (Recirc.)	Air Scouring Time	Feed Recirc. Time	Pressure (CIP in) P1	Pressure (CIP outlet) P4	TMP (P4-P1)	Pressure (Air Blower) P2	Recirc. Duration (Initial)	Duration (Soaking)	Recirc. Duration (Final)	Chem. Vol	Acid	Caustic	NaOCl	Others	Water Source	Flow	Duration	Reject pH
	dd:mm:yy	hh:mm	Hr	°C	-	m^3/h	min	min	psi / bar g	psi / bar g	ΔP psi / bar g	psi / bar g	min	min	min	L	(%) / L	(%) / L	(%) / L	(%) / L	-	m^3/h	min	-
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