# AQUADYN UA860-HP Hollow Fiber UF Modules

## Technical Manual

MANN+HUMMEL

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# 1 Introduction

This manual is intended to provide an overview of AQUADYN® UA860-HP modules and basic information. This manual covers the design as well as the operating and maintenance procedures.

Please read this manual and follow all instructions before handling and operating UA860-HP membrane modules. Mishandling may compromise the module performance or damage the membrane module.

UA860-HP modules use a unique 0.025-micron polyacrylonitrile (PAN) hollow fiber membrane that is hydrophilic, low-fouling, high-flux, and double asymmetric. The double asymmetric property allows the membrane to reject bacteria, solids, and turbidity more effectively due to a filtration layer inside and outside the hollow fiber. Therefore, problems such as pore clogging during backwash do not occur.

The extremely hydrophilic PAN hollow fiber is most suitable for oily water treatment as well as low organics – high solids storm water management applications.

The compact design of the UA860-HP module allows for smaller plant sizes and the high level of possible automation results in easier day-to-day operation.

# 2 Shipping, Handling, & Storage

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

## 2.1 SHIPPING

Every AQUADYN® UA860-HP membrane 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. For more information about the preservation please refer to Table 1.

Upon receipt, and prior to installation, the modules must be inspected for any physical damage. Ensure that the correct product was received. MANN+HUMMEL Water & Fluid Solutions (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.

All UA860-HP membrane modules are packed for international transport directly from MANN+HUMMEL facility. Each membrane module is individually wrapped in plastic and packed with sufficient support inside the single carton box.

## 2.2 HANDLING

Only remove the membrane module from its original packing when ready for commissioning (see Chapter 6.1). The membrane module should always be handled with care 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). If storage temperature outside this range, please contact MANN+HUMMEL WFS for instructions.

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 6.3). For storage exceeding one-year, fresh preservative must be added, as described in Table 1.

TABLE 1. STORAGE CONDITIONS

| **Duration** | **Recommended Procedures** |
|---|---|
| <1 year | No action required |
| >1 year | Drain out the existing preservative and replace the preservative with the following:<br>• Add 4 L (1.1 gal) of preservative consisting of 4.5% Sodium Metabisulphate (SMBS) solution:<br>o 180 g Sodium Metabisulphate (SMBS)<br>o 4 L (1.06 gal) potable water<br>• Pour in the chemicals from the reject port at the top of the membrane module<br>• Subsequently replace the preservatives every 3 months |

# 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.

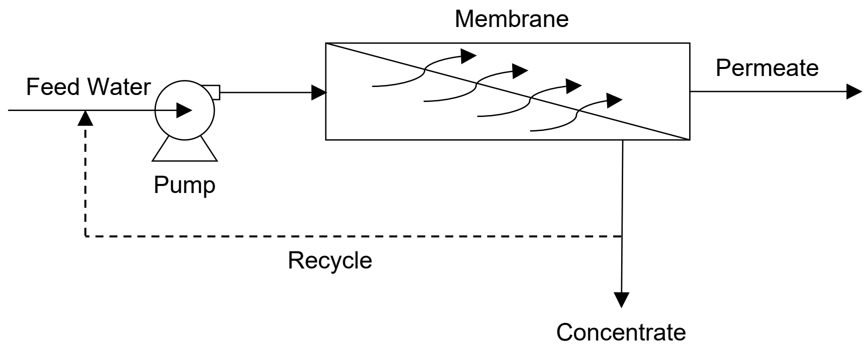



**Figure 1.** Schematic representation of membrane filtration process.

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.

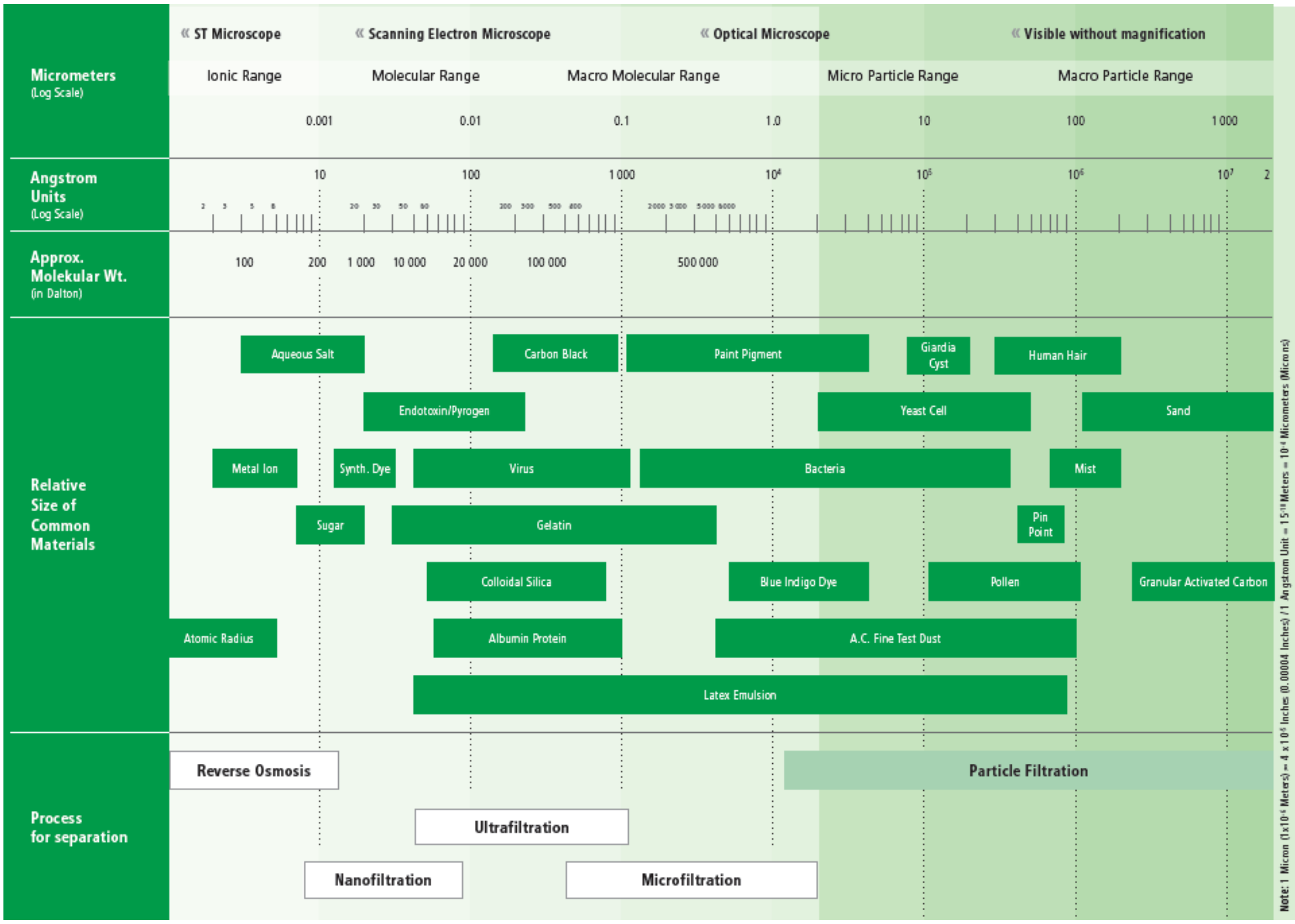



**Figure 2.** Membrane filtration spectrum.

## 3.2 DEFINITIONS & EXPLANATIONS OF COMMON TERMS

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.

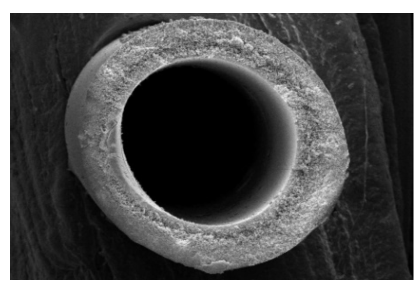


**Figure 3.** An SEM (scanning electron microscope) image featuring the cross section of a hollow fiber membrane.

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.

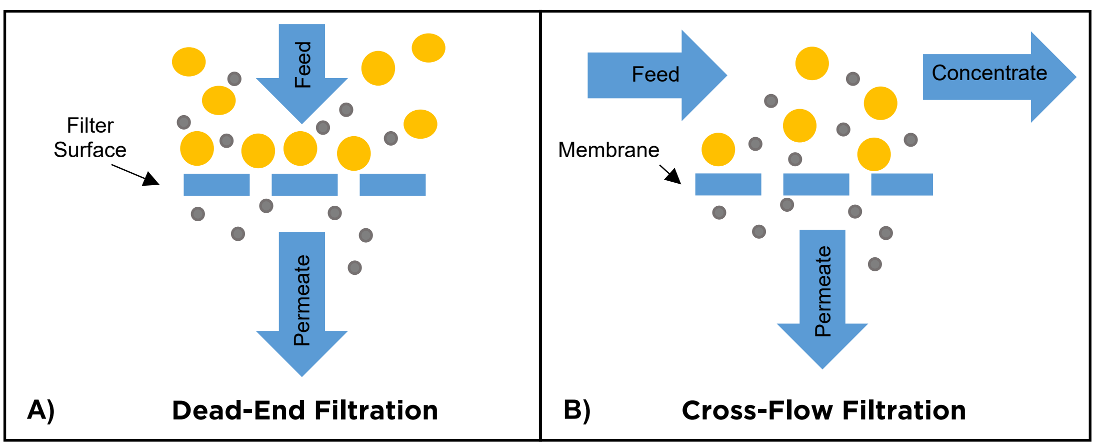



**Figure 4:** Diagrams showing the difference between crossflow and dead-end filtration.

**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.

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

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

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:

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

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:

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

**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):

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

**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.

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

**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 20˚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 (in °C):

$$\text{Normalized Permeability} = \frac{\text{Gross Flux}}{\text{TMP}} \cdot\ 1.024^{(20-\text{T})}\left[\frac{\text{L}}{\text{m}^2 \cdot \text{h} \cdot \text{bar}}\right]$$

**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 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.

**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.

**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.

**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 (NaClO), are commonly used for removal of organic fouling.

**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 AQUADYN® UA860-HP Modules

## 4.1 PRETREATMENT OF THE RAW 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 AQUADYN® UA860-HP UF membrane modules.

Typical pretreatment processes include:

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

**Fat, Oil, & Grease Removal**
UA860-HP membrane modules may tolerate a maximum concentration of 15 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 80 to 400 µm openings. For seawater applications, MANN+HUMMEL WFS recommends 80 to 100 µm screen size. For most other applications, 200 to 400 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 400 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.

**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 UA860-HP 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 & MEMBRANE MODULE SPECIFICATION

AQUADYN® UA860-HP modules (Figure 5) consist of polyacrylonitrile (PAN) hollow fiber membranes. The hydrophilic-modified PAN material is widely used in many applications (e.g. produced water) due to its narrow pore size distribution and its high selectivity and flux. Additionally, the membrane modules are optimized for low pressure use, which results in a lower OPEX for the whole membrane filtration system.

The membrane modules are designed to be installed and operated vertically. There are four connections on each membrane module: two on the bottom cap and two on the top cap. The feed water enters at the top of the module during filtration. The air feed is located at the top of the module, as well, and is used for air scouring during the hydraulic cleaning cycle. Two permeate ports are located on the side and in the middle of the bottom cap, providing treated water during filtration. The two permeate connections on the bottom cap offer flexibility in the design and installation of the modules.

More detailed information about UA860-HP module specifications can be found on the data sheet on the MANN+HUMMEL WFS website.

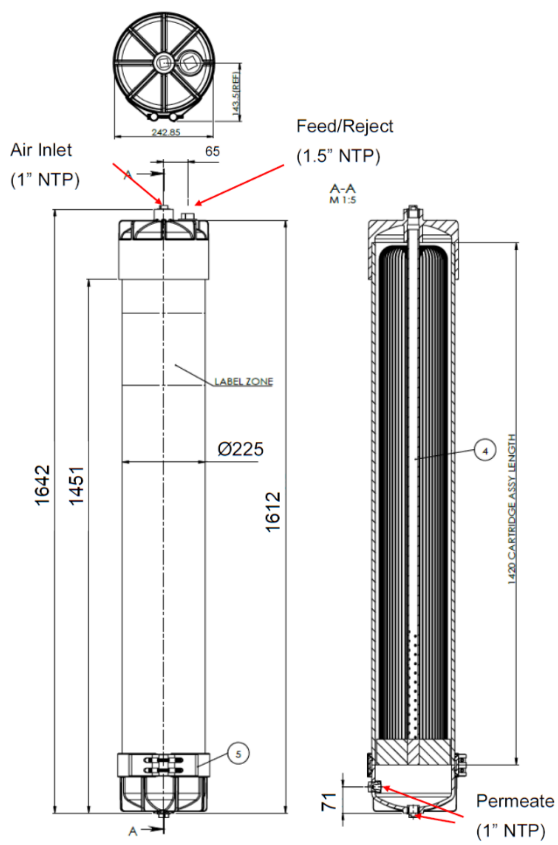



Figure 5. UA860HP

# 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 AQUADYN® UA860-HP membrane modules can be found in Appendix 7.1.

## 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 (NaClO) 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 NaClO 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 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 gross filtrate / permeate flux of the system. Typically, backwash flow is 2X filtrate / 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 AQUADYN® UA860-HP 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 8.3 $Nm^3/h$ (4.9 scfm) per module and a maximum air scouring pressure of 0.8 bar (11.6 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.

**Backwash Outlet Valve**
The backwash outlet valve is an open / close device that is closed during filtration and opened only during regeneration, CEB, and CIP. The sizing of the valve should be designed for the largest possible flow depending on the backwash 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.

**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 0.8 bar (11.6 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 5.2) is achieved to ensure effective cleaning. Additionally, the pH must be within the module's allowable pH range.

### 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 AQUADYN® UA860-HP 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.

## 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 (NaClO) and the addition of caustic soda (NaOH) if necessary. pH 10 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 2, never be exceeded the lower limit of 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 6.3.1.

**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 UF 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 UF 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 air supply connection (normally used for air supply for air scouring) at the top of the UF module(s) and the CIP solution leaves the UF modules via the feed connection (also at the top of the UF module(s)) 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 NaClO is used for cleaning, the free-chlorine content may be measured rather than pH. The process is described in detail in Chapter 6.3.2.

### 5.3 RACK INSTALLATION

The modules can be arranged as a fixed unit. This unit is called rack (or skid) as shown in Figures 6.

Preparation before rack installation:

- Clean the entire system, especially piping and hoses to avoid contamination of the membrane modules.
- Check the functionality of the membrane modules after unpacking.
- Membrane modules should be installed shortly before start-up is planned to keep the modules from sitting without preservative for too long.
- Write down the module serial number and the rack position.

Rack installation:

- The UF modules can be installed on either side of the manifold and may be installed all in line or in staggered position.
- Install the modules onto the rack on a level surface. Adjustable mountings are recommended for profile adjustments.
- The frame of this rack should be designed and built to support the membrane modules fully.
- Protect the modules from instability (potential tipping and rocking). The holding straps may be installed at the top and bottom to provide lateral stability and grip the membrane modules.
- Rack vibrations should be avoided.
- Modules should be installed at a serviceable height at the bottom of the rack to allow for sufficient space for maintenance and pipe / hose connections.
- Do not use the modules or the module connectors for mechanical support during assembly.
- Design and build the headers to keep the pressure loss inside the headers to a minimum.

**Figure 6.** Rack with AQUADYN® UA860-HP UF modules

# 6 Operation Procedures for AQUADYN® UA860-HP UF Modules

This chapter describes the start-up and operation guidelines for AQUADYN® UA860-HP 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 and/or CIP

**Note: It is advised to execute an initial backwash at first start-up (make sure the backwash tank is filled with clean water).*

### 6.2.1 Operation of Filtration Stage

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, accumulating, and forming 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 20-60 minutes between hydraulic cleaning cycles may be expected. This 20-60-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. Figure 7 demonstrates the operating mode during filtration.

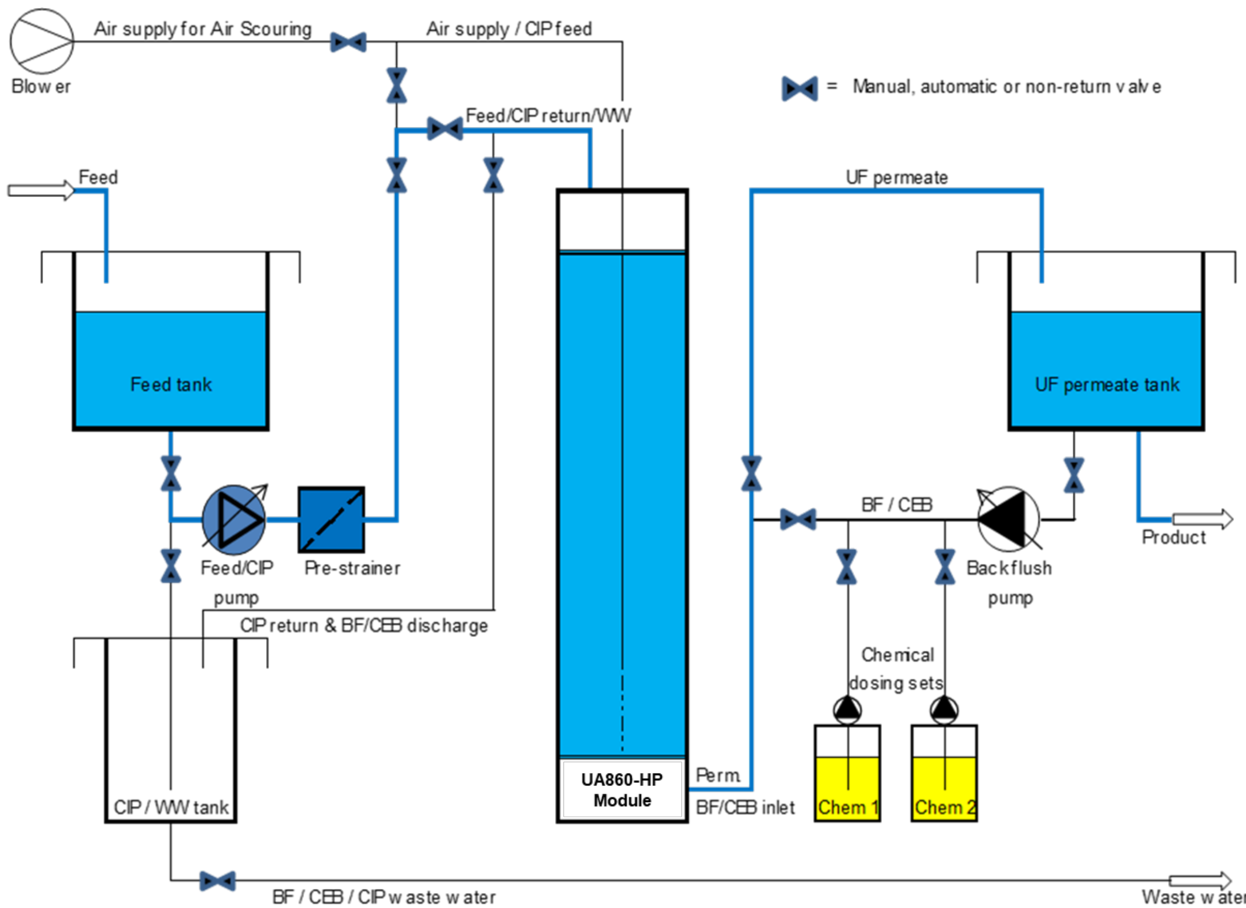



**Figure 7.** Filtration mode

### 6.2.2 Operation of Hydraulic Cleaning

Two steps are normally involved in the hydraulic cleaning cycle.

- Air Scouring
- Backwash

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. The air connection is at the top side of the module, but the air is released into the membrane module at the bottom via the perforated center pipe (see Figure 8). Ensure that the air pressure at the inlet is above the feed pressure and that the backwash outlet valve is open.

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.

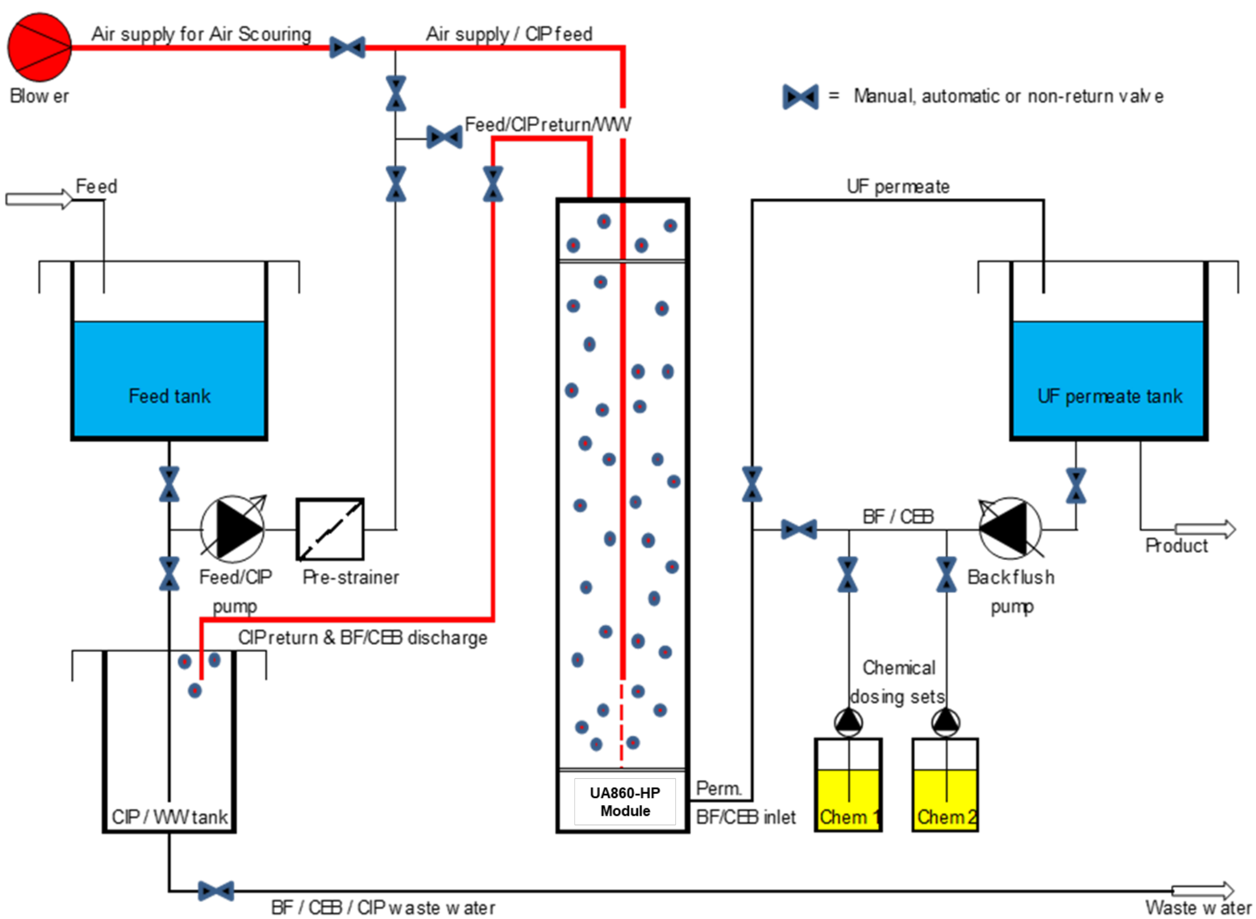



**Figure 8.** Air scouring step during regeneration cycle

**Backwash**

Backwash is used to 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) toward the feed side (shell side) using the backwash pump. Because of this, the flow direction is opposite the filtration flow direction.

The backwash water, with the removed suspended particles, is then forced out through the feed port located at the top of the membrane module into the feed header and then directed to the drain. The backwash should be conducted at a flux of 80 to 160 LMH (47.0 to 94.0 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.

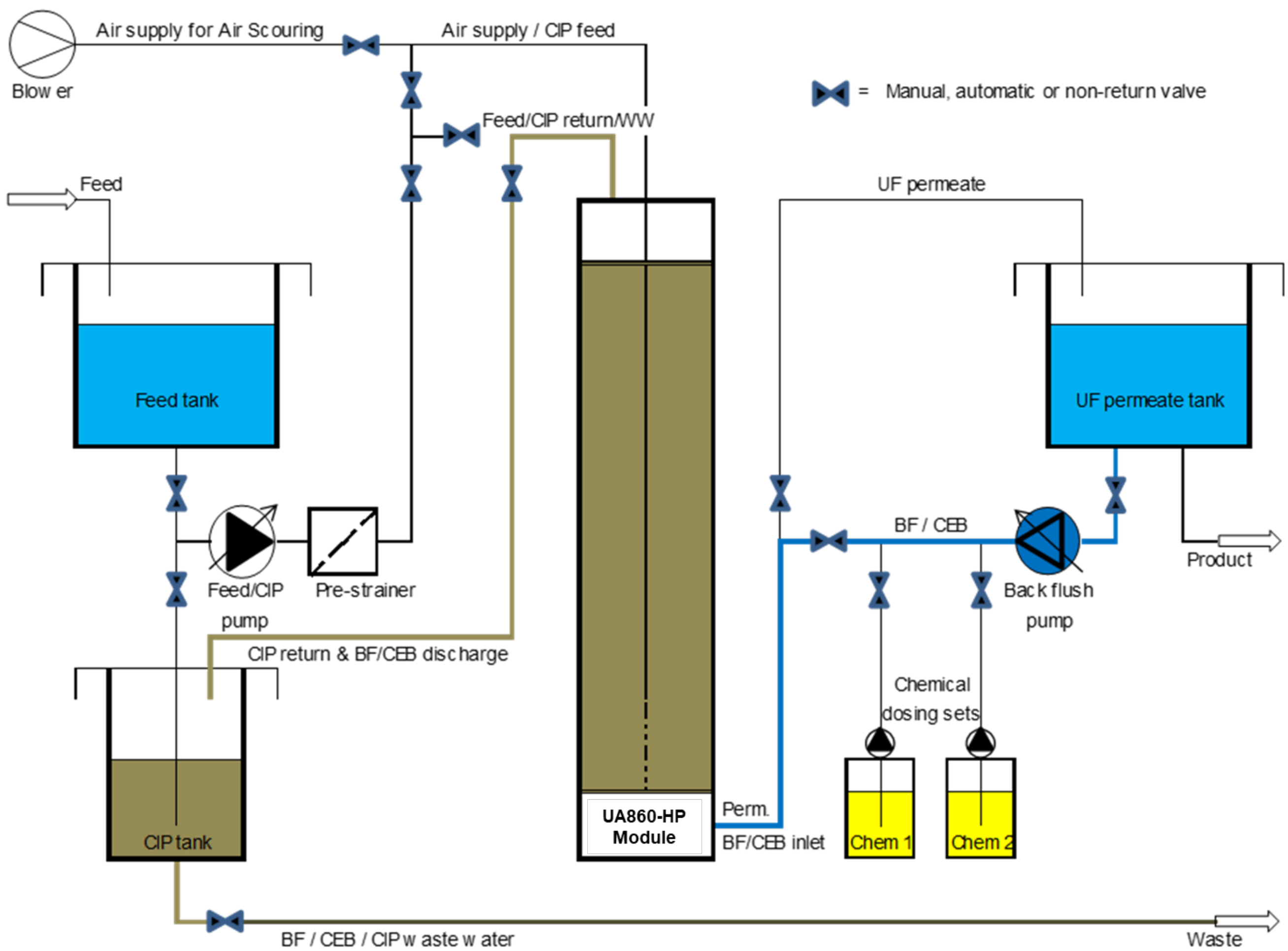



**Figure 9.** Backwash step during hydraulic cleaning cycle

### Chemically Enhanced Backwash (CEB)

A chemically enhanced backwash (CEB) is a maintenance cleaning procedure designed to remove 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 (NaClO) is 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. Three steps are incorporated into the backwash cycle:

1. Chemical dosing during backwash (Figures 10 & 11)
2. Soaking the modules
3. 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 and backwash (per usual hydraulic cleaning settings) is performed to loosen the foulants from the membrane fibers.
2. At the end of the backwash in Step 1, the backwash pump ramps down to about 50 LMH (29.4 gfd) and the dosing pump starts to dose the required chemicals into the backwash line.
3. 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.
4. 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.

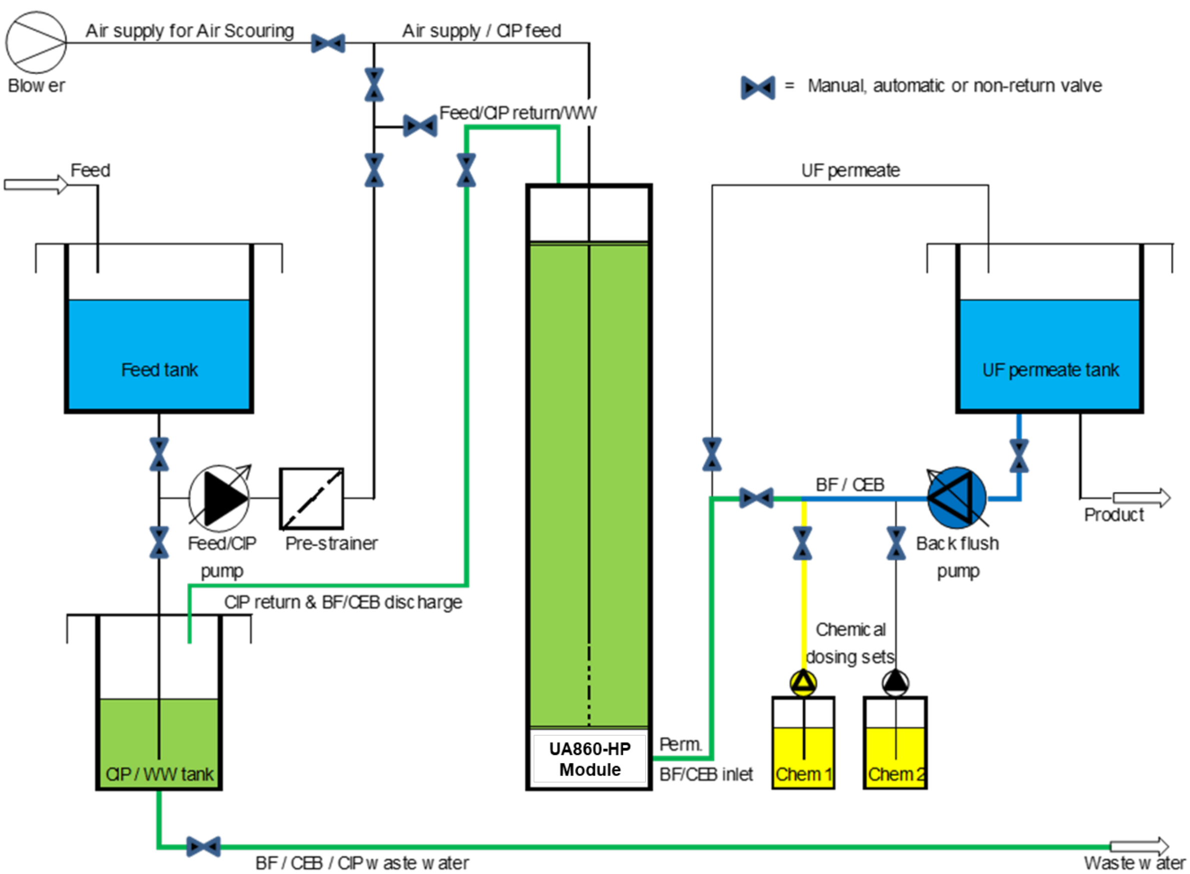



**Figure 10.** Introduction of chemicals (chem 1) to the system during CEB

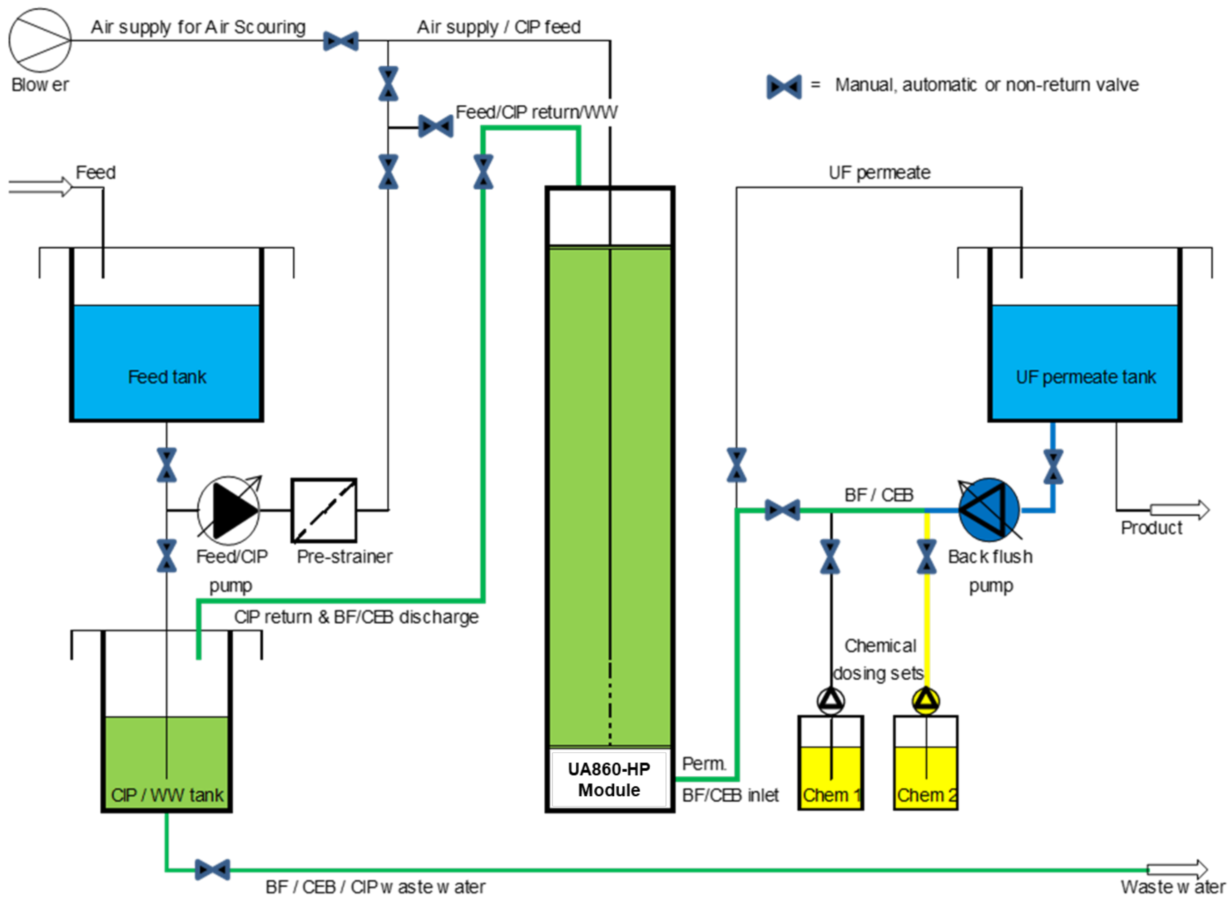



**Figure 11.** Introduction of chemicals (Chem 2) to the systems during CEB

### 6.2.3 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 a CIP tank and typically takes longer than hydraulic cleaning or CEB. The CIP is normally done only on the feed side and does not involve the permeate side of the membrane module. This means that CIP specifically targets cleaning the exterior of the fibers, whereas CEB cleans the fibers from the inside-out. Because of this, the two cleaning procedures complement each other well.

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.

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 must be fed to the feed side of the membrane modules to prevent any foulants or scalants from contaminating the permeate side during recirculation.
6. It is highly recommended to isolate the UF rack undergoing CIP from other UF racks and/or other up- and downstream processes.
7. Replace the fine screen at the feed of the UF system by a finer pre-screen of about 5-10 µm.
8. 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 NaClO) to ensure enough chemicals are added.
9. 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 datasheet.
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. Do a backwash of the membrane modules at 80-100 LMH (47.0-58.8 gfd) for 30-1800 seconds depending on the quality of the reject.

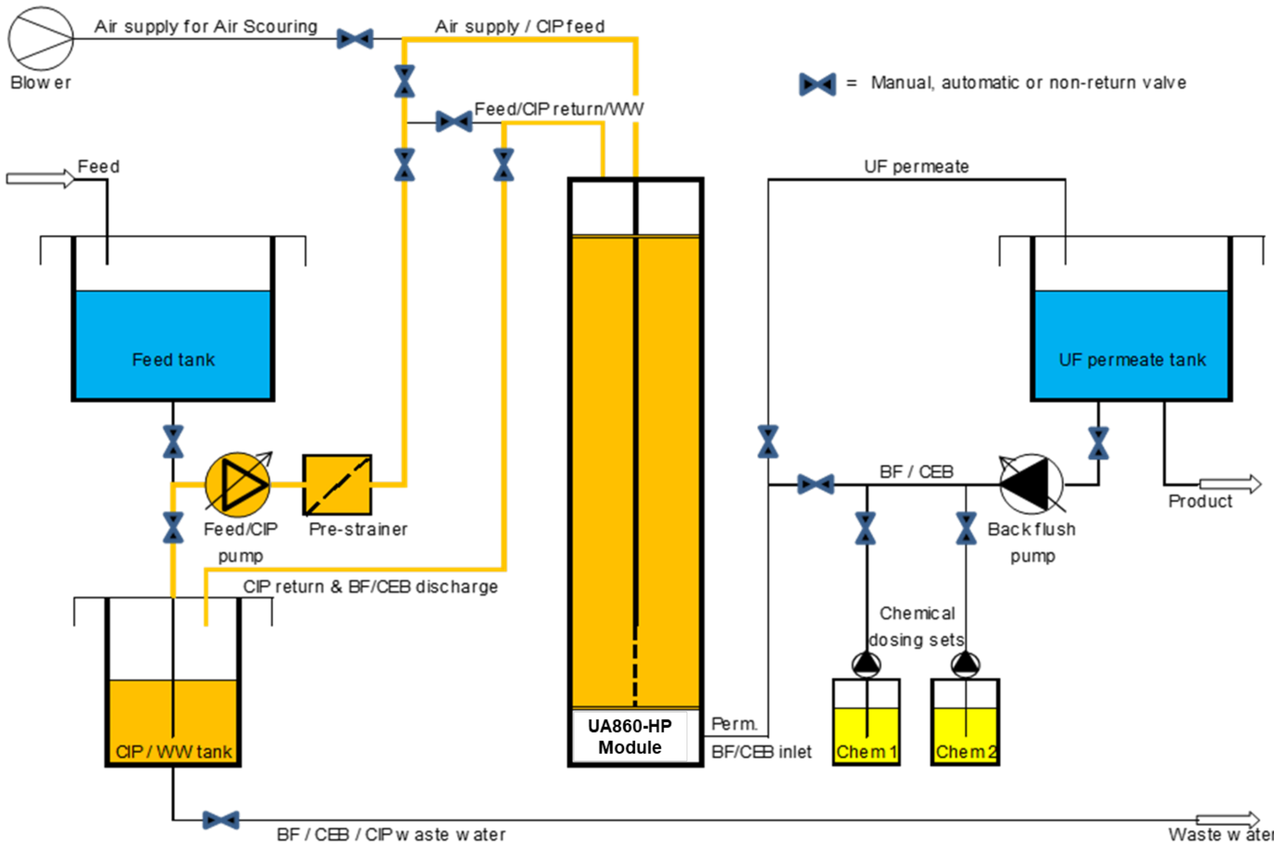



**Figure 12.** CIP Mode

## 6.3 SHUTDOWN

UF systems are typically designed to run continuously. If shutdown is required and the shutdown lasts for more than one week, a chemically enhanced backwash (CEB) is necessary.

For proper shutdown, it is recommended to follow these steps:

1. First execute a hydraulic cleaning cycle.
2. Perform a CEB with 100 ppm NaClO as described in Chapter 6.2.2.
3. At shutdown, the water in the module is replaced with permeate or drinking water by backwash to prevent bacterial growth.
4. After backwash, all valves on the UF rack are closed to isolate the UF rack.
5. Take note that at no point should the fibers be allowed to dry. If the fibers dry out, their performance will not be recoverable.
6. This cleaning procedure should be repeated each week the modules are not in operation.
7. The module should be stored in an upright position and free of any oxidizing agents during system shutdowns.

For questions or additional information about shutdown procedures, please contact MANN+HUMMEL WFS Technical Service.

## 6.4 OPERATING & CLEANING LOGS

Operation and cleaning logs are important for tracking operating conditions and system optimization. In Appendix 7.2, 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.

## 6.5 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 (Table 2) lists possible operational issues and the suggested solution.

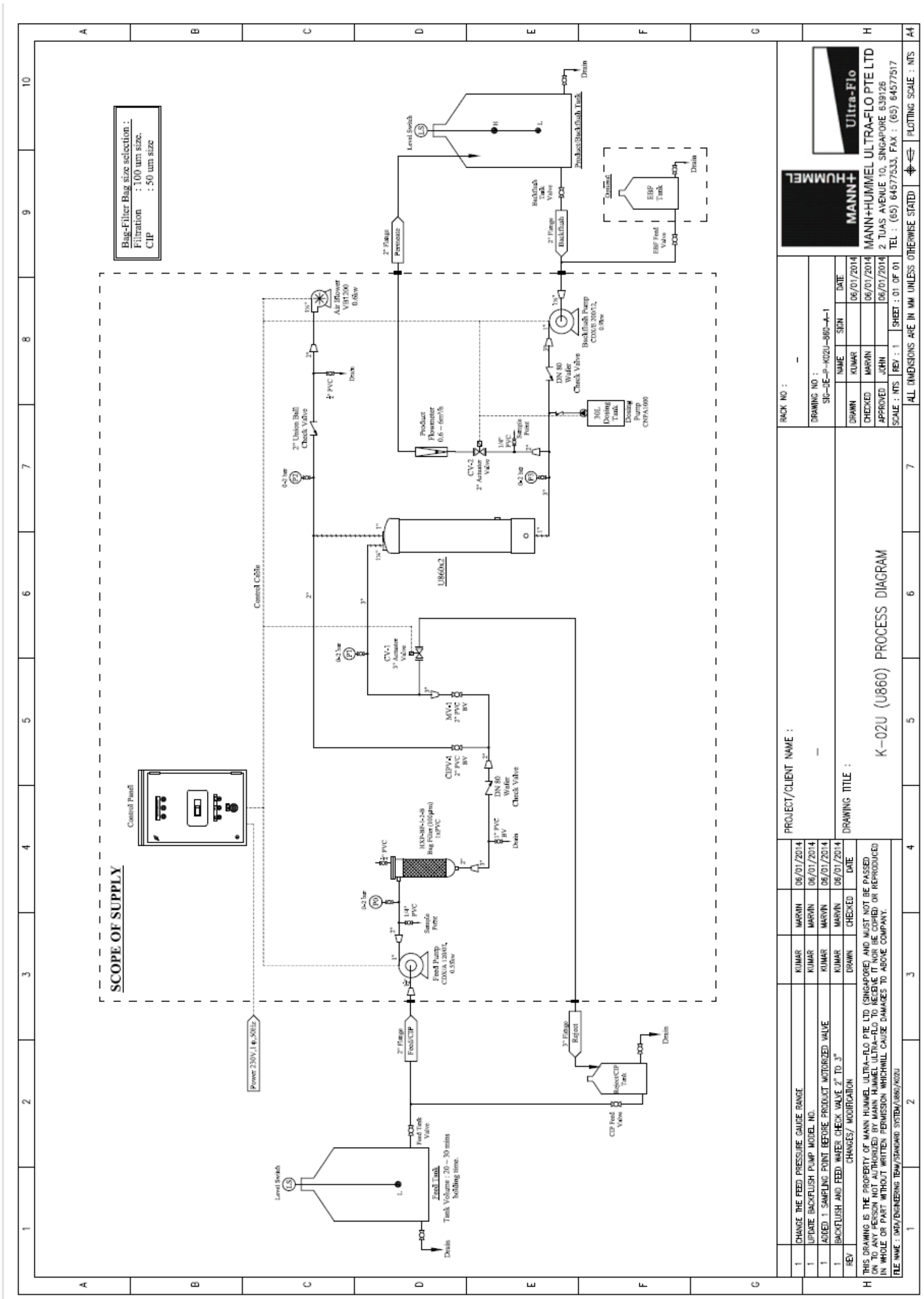
**TABLE 2. TROUBLESHOOTING**

| | Issue | Recommendation |
|---|---|---|
| **Low Chemical Cleaning Effect** | Bleach Stock Concentration | It is recommended to check the bleach 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 bleach or hydrogen peroxide |
| | Scaling | Use acids at low pH (pH 2) according to data sheet<br><br>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<br><br>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<br><br>Increase recirculation time, soaking time, chemical concentration, temperature, or frequency between CIPs<br><br>Clean in two steps and renew the chemical solution in-between for removal of accumulated particles<br><br>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<br><br>Check design for:<br>• Additional backpressure, which may increase feed pressure<br>• Check for high pressure loss due to piping<br><br>Make sure that no air is accumulated in the fibers |
| | Effluent Quality | Disinfect piping and all tanks<br><br>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<br><br>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)<br><br>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<br><br>If flow must be decreased due to high pressure, increase the time to obtain the same volume as used before |
| **Malfunctions** | Water Hammer<br><br>Temperature too High<br><br>pH or Chemical Cleaning Concentration out of Range<br><br>TMP too High | In most cases, the module should be replaced<br><br>Check all operation procedures and safety shutdown scenarios again if reason for malfunction is unknown |

# 7 Appendices

### 7.1 APPENDIX – BASIC P&ID OF A SYSTEM USING AQUADYN® UA860-HP UF MODULES



## 7.2 APPENDIX - OPERATION & CLEANING RECORD LOGS

**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 |
| 1 | | | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | | | | | |

**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.

**CLEANING RECORD FORM**

| | |
|---|---|
| Project Name: | |
| System: | |
| Rack No: | |

**CIP**

| | Operation Information | | | | CIP Tank | | | | | | | | Operation Setting | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date | Time | Op. Hr after last CIP | TMP before CIP | Water Temperature | Volume Water CIP Tank | Volume Chemical CIP Tank | NaOCl | Acid | Caustic | pH CIP Tank | Conc. Chemicals after in Tank after CIP | CIP Flowrate | Circulation Time | Pressure (before Membrane P1) | Pressure (After membrane P2) | Air Scouring Time | Soaking Time | TMP after CIP |
| | dd:mm:yy | hh:mm | hh | ΔP bar | °C | $m^3$ | $m^3$ | % / l | % / l | % / l | | % / l | $m^3/h$ | min | bar | bar | min | min | ΔP bar |
| 1 | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | | |
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