AXEON
WATER

RO AND NF MEMBRANE ELEMENTS

Product Use and Maintenance Manual

INDUSTRIES


AGRICULTURE


CHEMICAL & PETROCHEMICAL


COMMERCIAL

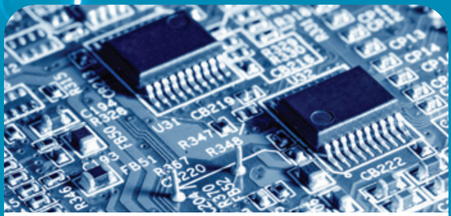

DESALINATION


FOOD & BEVERAGE


HEALTHCARE & BIOPROCESSING


HVAC / PLUMBING


LIFE SCIENCES


MICROELECTRONICS


MINING & METALS


MUNICIPAL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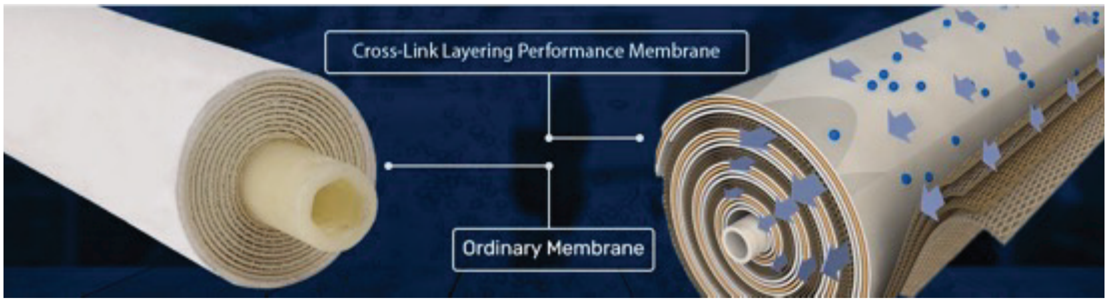
POWER GENERATION


PULP & PAPER


RESIDENTIAL

MEMBRANE TECHNOLOGY



AXEON Water Technologies is a membrane technology company and has been a driving force behind reverse osmosis technology since the company was founded in 1989. Built on the premise of innovation and quality, AXEON has manufactured membrane elements for over three decades, which many original equipment manufacturers from around the globe have come to rely on.

From years of experience, AXEON understands that typical reverse osmosis membranes are known for being delicate and susceptible to physical and material damage. This can originate from premature organic or inorganic fouling, which can lead to reduced production flow rates and poor salt rejection levels—thus leading to costly element replacements.

AXEON is proud to announce an innovation in membrane flat sheet material—a non-woven media that allows for longer membrane life and improved performance. This exclusive and specialized treatment process creates a lattice-type structure on the surface of the media, which is called cross-link layering. The membrane flat sheet surface is then given an electrical charge and smoothness to its structure, thus increasing its hydrophilicity. This in turn decreases the adhesion of contaminants and pollutants on the membrane surface and results in less fouling and extension of the service life for the membrane elements.

By incorporating cross-link layering technology into our polyamide membranes, we enable you to achieve pure water faster, with a lower chance of fouling and higher energy-efficiency.

This membrane technology is applied to a variety of membrane flat sheets that are utilized inside of AXEON membranes. From low-energy to extra low-energy brackish water series membranes, AXEON's lineup of standard size membranes starting with 1.8", 2.5", 4.0" and 8.0" diameters make it easy to realize the benefits of improved performance and quality. For your next product line or project, make sure to have "AXEON Inside" for true performance, availability, and competitiveness.

TABLE OF CONTENTS

1. MEMBRANE ELEMENTS AND SYSTEM USE

1. MEMBRANE ELEMENTS AND SYSTEM USE

Membrane Elements Installation and Disassembly

INSTALLATION PREPARATION

1. To record the relative position of each pressure vessel and membrane element, a schematic diagram for identifying the installation position of the pressure vessel and the membrane element should be prepared. When loading and unloading the elements, please fill in the serial number of the membrane element (showed on the membrane element label) on the schematic diagram as the element number; the schematic diagram indicating the location of the pressure vessel and the membrane element will help to track the running situation track of each individual element in the system.

2. The following equipments are recommended: safety shoes, rubber gloves, silicone lubricant, glycerin, safety glasses, alien wrench, pipe tong, shears, clean rags, a swab large enough to fill the inside diameter of the pressure vessel, etc.

3. Check the upstream water inlet pipeline carefully, and remove all dust, grease, metal debris, etc. that may exist in the pipeline; if necessary, chemically clean the inlet pipeline and pressure vessel to ensure that all foreign objects are effectively removed.

4. Check the inlet water quality carefully; before the membrane element is installed, flush the membrane system with the produced water of an effective pretreatment system for about 30 minutes, and check whether the inlet water quality of the membrane system meets the regulations and check whether there is any leakage in the pipeline.

5. Remove all end cap assemblies and thrust rings from all pressure vessels, spray clean water through the open pressure vessels to remove any dust or debris present in the vessels. Soak the swab in a glycerin/water solution and move it back and forth through the pressure vessel until the vessel is clean and lubricated.

6. Before installing the elements, ensure that all parts and chemicals for the installation and commissioning of the system are complete, and the pretreatment system operates normally and effectively; otherwise, do not open the membrane elements packaging bag until all the above items are confirmed.

ELEMENT LOADING

1. Open the packaging carton and carefully take out the membrane element from the packaging bag; check whether the position and direction of the brine seal ring on the element is correct (the opening direction of the brine seal must face the water inlet direction, as shown in Figure 1.1); take out all the membrane elements to be installed and place them vertically in order.

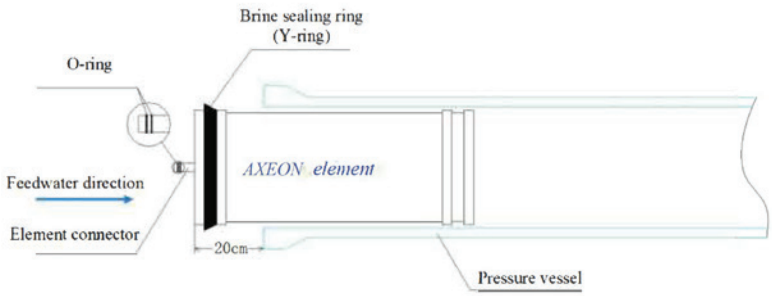


Figure 1.1

ELEMENT LOADING (CONT.)

2. Lubricate the brine seals and permeate tube with a very thin layer of glycerin. Then push the membrane elements in parallel into the feedwater end of the pressure vessel (attention to place the end which without brine seals first). Until the end of element with brine seals is approximately 20 cm to the feed water end of the pressure vessel (as shown in Figure 1.1). Above always load membrane elements into the feedwater end of the pressure vessel.

3. Install the interconnector into the permeate tube of the element if applicable (as shown in Figure 1.1), lubricate the O-ring seals on the interconnector and the inside of the product water tube with a very thin layer of NSF silicone lubricant. Check whether the O-ring is damaged, and be careful not to twist the O-ring for installation.

4. As shown in Figure 1.2, hold the "to be pushed" membrane element outside the pressure vessel, and insert the "to be connected" membrane element center tube connector that has entered into the pressure vessel into the "to be pushed" membrane element center tube (Be careful the membrane element weight is not supported by the interconnector), and then push the "to be pushed" membrane element into the pressure vessel until its end is approximately 20 cm to the feed water end of the pressure vessel (Be careful not to damage the membrane element by collision with the edge of pressure vessel).

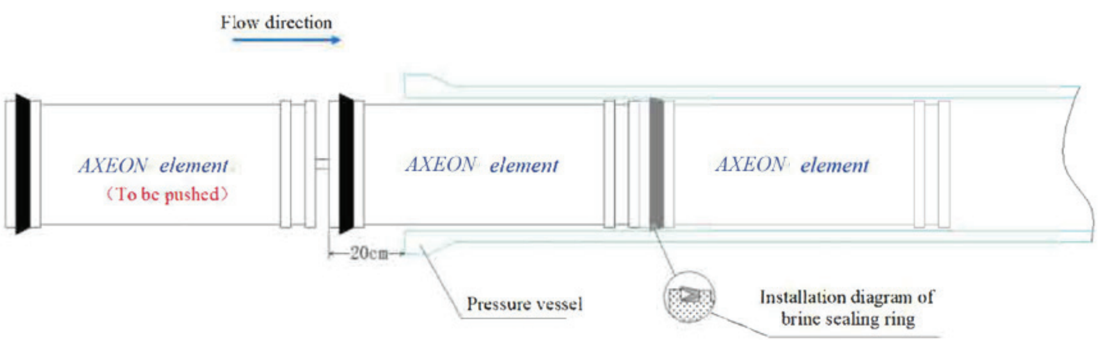


Figure 1.2

5. Repeat steps "3" and "4" until the pressure vessel is filled with membrane elements.

6. As shown in Figure 1.3, correctly combine the membrane element adapter, thrust ring and concentrated water end plate for 8" membranes. Align the concentrated water end plate assembly with the "first" membrane element center tube and push it into the pressure vessel in parallel. Align it with the external connecting pipe and fix it with screws or end plate snap ring if applicable.

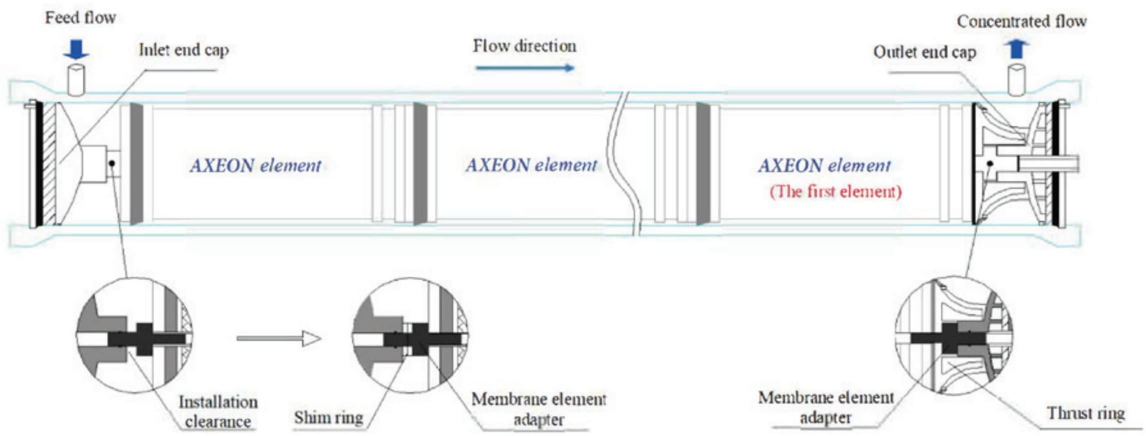


Figure 1.3

ELEMENT LOADING (CONT.)

7. Push the membrane element from the inlet site to the concentrated water, until the “first” membrane element is tightly connected with the concentrated water end plate assembly. Then install the end plate on the inlet side.

8. When installing the water inlet end plate, gaskets should be used to adjust and eliminate the possible gap between the membrane element adapter and the water inlet end plate (as shown in Figure 1.3) to prevent the membrane element from being exposed to pressure when the system is started and stopped. The sudden change of the water inlet pressure of the pressure vessel causes the axial displacement of the membrane element in the pressure vessel, which causes the brine seal ring to wear and age and affect the sealing performance.

9. Repeat these steps until all elements are loaded into the pressure vessels.

MEMBRANE ELEMENT DISASSEMBLY

1. Disconnect the hard plumbing at each end of the pressure vessel and remove connection components.

2. Remove the heads assemblies from each end of the pressure vessel.

3. Use a PVC pipe or other disassembly tool to push the membrane element from the water inlet end to the concentrated water end until the membrane element exposes from the concentrated water end. Note that only one element is pushed out at a time. When the element is pushed out of the pressure vessel, it should be caught in time. Hold the element to avoid damage to the membrane element or personal injury (at the same time be careful not to let the connector support the weight of the membrane element).

4. Soak the removed membrane element with “M-100 standard protection solution”, put it in a clean plastic bag, and seal it for storage. (“M-100 standard protection solution” must be prepared with RO water).

System Operation

INITIAL START-UP

1. The initial system start-up is **typically performed just after the element loading**.

2. For start-up, **the following should also be part of the equipments at the site**: Safety glasses, Thermometer, pH meter, Conductivity meter, ORP meter, Bottles for water samples, SDI measuring equipment, Scale to weigh one element, Analysis equipment for water samples Total hardness, Calcium, Total Alkalinity, Chloride, Free chlorine, Sulfate, Silica, Iron and other equipment as needed.

3. Before starting up the AXEON reverse osmosis system, **make sure that the whole pretreatment section is working in accordance with the specifications**. do the pretreatment effluent water quality inspection, ensure that the following indicators of the membrane system feedwater are stable or qualified: stable feed water flow, pollution index (SDI15), turbidity (NTU), residual chlorine and other oxidants, reducing agent concentration (if used to remove residual chlorine), conductivity, pH, temperature, bacterial count, etc.

4. **AXEON Reverse Osmosis System Pre-Start-Up Checklist**

    a. All equipment from the supply source to the membrane including piping, vessels, instruments and dosing systems meet the anti-corrosion requirements, and compatible with the pH range of daily operations and chemical cleaning;

    b. All pretreatment devices have been backwashed or rinsed and are in a clean state.

    c. The cartridge filter is installed or replaced with a new filter element. And no surfactants, lubricants, fabrics, etc.

    d. Confirm that the feedwater pipeline has been effectively flushed, and all dust, grease, lubricating oil, metal residues, etc. have been removed.

    e. The dosing device is in a normal and operable state.

    f. Provisions exist for preventing the RO system from operating when the dosage pumps are shut down, Provisions exist for preventing the dosage pumps from operating when the RO system is shut down

    g. If chlorine is used for pretreatment, provisions exist to ensure complete chlorine removal prior to the membranes

    h. Planned instrumentation is installed and operative. And allows proper operation and monitoring of the pretreatment and RO system

    i. Pressure relief protection is installed and correctly set.

    j. Provisions exist for preventing the permeate pressure from exceeding the feed/concentrate pressure more than 0.03MPa or 4.4 psi at any time.

    k. All interlocks, time delay relays and alarms are properly set.

    l. Ensure that each pressure vessel can be sampled individually.

    m. Ensure that the membrane systems and each stage of the feed water, permeate water, concentrated water can be sampled if applicable.

INITIAL START-UP (CONT.)

n. Pressure vessel and the cleaning pipeline are connected correctly.

o. Pressure vessels are secured fixed on the bracket.

p. All pressure vessels are filled with membrane element, or membrane element are safely and effectively fixed in the pressure vessel and cannot be moved. The pressure vessel is properly and safely installed with end caps.

q. All the pressure vessels are connected safely and correctly, especially check the clamp joints and the pressure vessel end seals.

r. Permeate flow control valve is in open position.

s. The permeate flow by reverse osmosis and nanofiltration membrane devices can be directly discharged.

t. Concentrate flow control valve is in open position.

u. Fully close throttle valve CW and then open one full turn CCW.

5. Start sequence of membrane systems

a. Redirect permeate water to the drain for this procedure. Fully open the concentrate valve (counter clockwise). Fully close the recycle valve (clockwise) if applicable.

b. Let the system purge until no bubbles appear in concentrate flow meter. It may be necessary to flush the system more than one cycle. When the RO system has been purged of air, turn it on and slowly adjust the concentrate valve (and recycle valve if you are recycling water) to the designed flow and pressure. Close the small red lever on the top of the solenoid valve. Inspect for leaks.

c. Allow the system to run uninterrupted for at least 1 hour to flush the preservative solution from the system.

d. Check whether the dosage of all chemical agents is consistent with the design value and determine the pH value of the feed water.

e. After the system runs continuously, check the permeate conductivity from each pressure vessel to determine whether there is leakage or other failures of the membrane element and the pressure vessel O-rings.

f. When the permeate water quality is qualified, open the permeate water delivery valve, close the permeate water discharge valve, and introduce the permeate water into the permeate water tank. (Applicable only if the unit has a three-way valve.)

i. Record all the data of the initial operation of the systems as a reference standard for evaluating the long-term performance stability of the systems in the future. The systems test items are as follows (system parameter monitoring item list):

NO.	Measurement item	Unit	Minimum detection frequency
1	System(stage)permeate flow rate	m^3/h	2 times/day
2	System concentrate flow rate	m^3/h	2 times/day
3	Operating pressure	MPa (psi)	2 times/day
4	1 st stage concentrate pressure	MPa (psi)	2 times/day
5	System concentrate pressure	MPa (psi)	2 times/day
6	Inlet TDS	μS/cm	2 times/day
7	Output TDS	μS/cm	2 times/day
8	Concentrate flow TDS	μS/cm	2 times/day
9	SDI_{15}	/	2 times/day
10	Turbidity	NTU	2 times/day
11	Temperature	℃	2 times/day
12	pH	/	2 times/day
13	ORP	mv	1 time/every 4 hours
14	Residual Chlorine	mg/L	2 times/day

Membrane Systems Shut-Down

PRECAUTIONS FOR MEMBRANE SYSTEMS SHUT-DOWN

1. Stop the high-pressure pump.

2. Let the membrane systems run flushing at a low pressure setting of 0.3 MPa or 44 psi to improve the flushing effect of membrane element under high-flow concentrated water discharge.

3. The systems must be flushed preferentially with permeate water or alternatively with high quality feed water, fully replace the concentrated water in the pressure vessel and membrane element until concentrate conductivity matches feed water conductivity.

4. Low-pressure flushing water shall contain no chemicals used for the pretreatment, especially no scale inhibitors.

5. When shutting down, ensure that the pressure vessel is completely filled with high-quality water (better using the membrane systems permeate water). and install check valves on the concentrated water and permeate water pipelines.

6. No operation can make the back pressure on the permeate water side exceed 0.03 MPa or 4.4 psi.

7. For extended shut-down of the systems, please refer to the Membrane Systems Shut down Protection in this document.

STORAGE OF MEMBRANE ELEMENT

1. Majority of AXEON membrane elements are dry type, a small part of wet type membrane elements are sampling qualified products in the manufacturing process.

2. AXEON wet membrane element should be stored in M-100 standard protective liquid, It is sealed with a packaging bag when it is sold out of the factory. It must be used within 90 days. If it cannot be used, it should be replaced with the same protective liquid.

3. The membrane element should always remain wet after being used. Avoid membranes drying or flux damage can occur.

4. The storage of wet membrane element must be immersed in "M-100 standard protective liquid" prepared with RO water; in winter, it needs to be added to "M-100 standard protective liquid" 20% glycol to prevent freezing; protective liquid should be replaced every 90 days.

5. Whether dry or wet membrane elements are used or reused, they should be stored in a vacuum sealed packaging state; the packaged membrane element should be packed in the packaging box, and the storage location should be cold and dry and away from direct sunlight.

6. The storage temperature of dry membrane element: ≤45 °C or 113 °F, long-term storage after sealing.

7. The storage temperature of wet membrane element : 0-45 °C or 32-113 °F.

PROTECTION OF MEMBRANE SYSTEMS SHUT-DOWN

1. Short-term shut-down: If the membrane systems needs to stop running but less than 48 hours, the following protective measures can be taken:

   a. Flush the systems with membrane permeate water.

   b. Fill the pressure vessel with the membrane systems permeate water, exhaust the air, and close all valves to prevent the membrane element from drying out, air entering, and microbial growth.

   c. The membrane systems should be flushed according to the above method every 24 hours. If the ambient temperature is higher than 77-80 °F (27°C), the flushing frequency should be adjusted to once every 12 hours.

2. Long-term shut-down: If the membrane systems needs to stop running more than 48 hours, the following protective measures can be taken:

    a. Use chemical cleaning methods to sterilize the membrane systems.

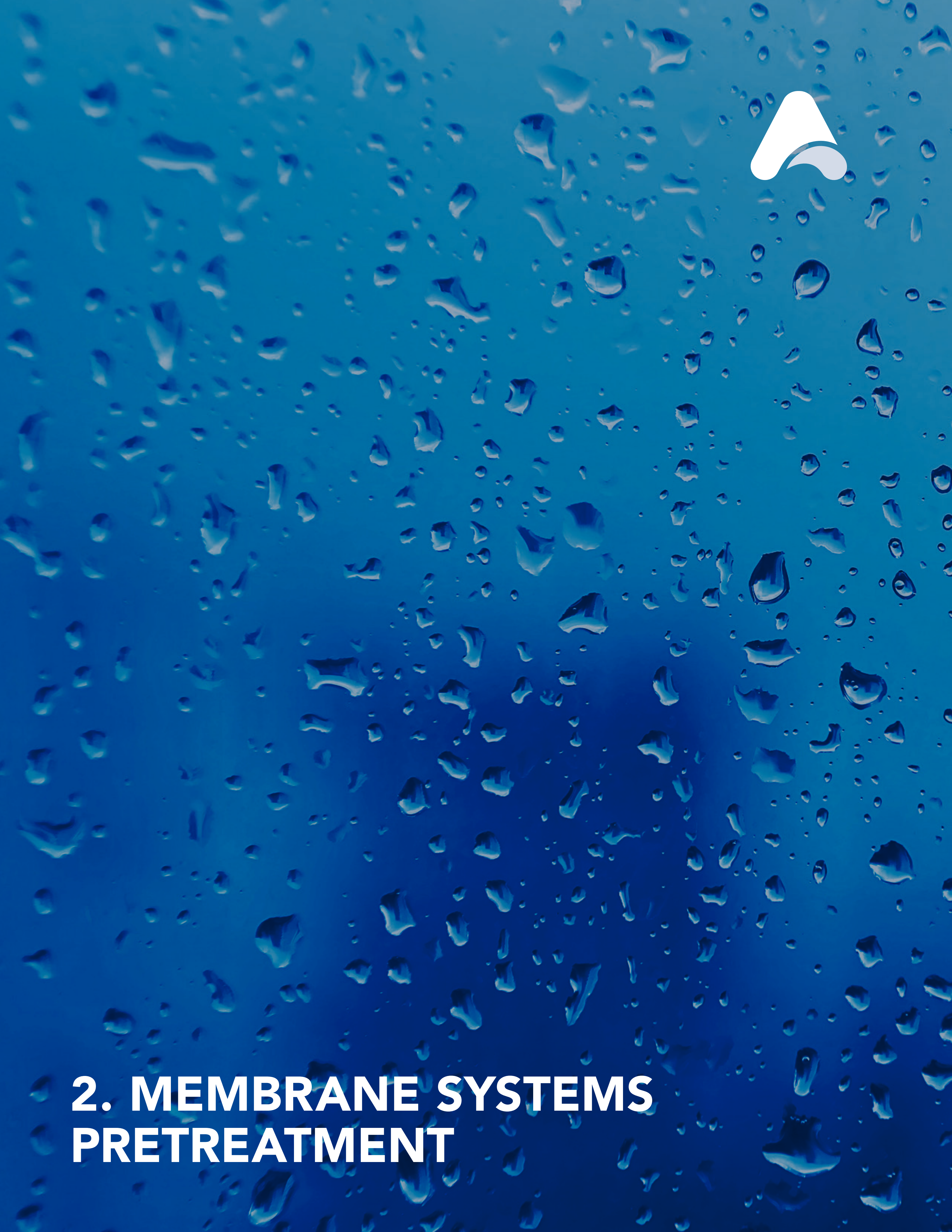
    b. Fill the pressure vessel with "M-100 standard protective liquid" prepared with the membrane systems permeate water, vent the air, and close all valves to prevent the membrane element from drying out, air entering and microbial growth.

    c. Check the pH value of the protection liquid regularly, and replace the protection liquid when the pH value is less than 3.

    d. Rinse and replace the protective liquid according to the above method every 30 days. If the ambient temperature is higher than 77-80 °F (27 °C), the time should be shortened to 15 days.

    e. During the system shut-down, the storage temperature of the membrane systems should be controlled at 41-113 °F (5-45 °C).

    f. When membrane systems are reused , flushing the membrane systems under low-pressure and high-flow permeate water for more than 1 hour, and then high-pressure flushing (5-10) minutes until the permeate water is qualified; whether low-pressure or high-pressure flushing, the water discharge valve should be fully opened to prevent back pressure and unqualified permeate water from entering the permeate water tank.



2. MEMBRANE SYSTEMS PRETREATMENT

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Importance of Pretreatment

Reverse osmosis or nanofiltration technology is one of the various water treatment methods. A complete and effective reverse osmosis or nanofiltration membrane systems includes the following three necessary components: raw water pretreatment device, reverse osmosis or nanofiltration membrane device, and post-treatment device. The main function of reverse osmosis or nanofiltration membrane is to separate or remove water generally contains a certain concentration of suspended solids and soluble substances (including easily soluble salts (such as chloride) and insoluble salts (such as carbonate, sulfate and silicate).

If the pretreatment device cannot remove the suspended matter and excessive insoluble salt in the raw water, and make it enter the reverse osmosis or nanofiltration membrane device, the insoluble salt exceeds its saturation limit and precipitates, and the suspended matter will gradually accumulate on the membrane element Internally, the membrane elements are contaminated, blocked, and scaled, the operating efficiency of the membrane systems is reduced, and the quality of the permeate water is reduced. It can be seen that the operation of the membrane systems fails, in most cases due to the imperfect function of the pretreatment system.

In order to prolong the service life of membrane element and membrane systems, necessary pretreatment devices must be used to effectively remove suspended solids, colloids, microorganisms and other impurities in the raw water, control the precipitation of insoluble salts, ensure the feed water quality of reverse osmosis or nanofiltration membrane device, so that the membrane element can operate under healthy conditions.

In addition, selecting appropriate and necessary pretreatment devices can significantly improve the energy efficiency of membrane element and membrane systems, reduce the cleaning frequency of reverse osmosis or nanofiltration membrane devices, and reduce system operating costs. Therefore, pretreatment is an important and necessary guarantee for the stable operation of the membrane systems.

Must-Know Concepts

RAW WATER

The raw water entering the membrane systems generally includes: RO/NF membrane systems permeate water, surface water, groundwater, reclaimed water, seawater, or other liquid materials, etc.

1. **RO/NF membrane systems permeate water:** For primary reverse osmosis or nanofiltration permeate water, simpler pretreatment (such as PP filter element) can be used, and the water quality can meet the requirements of membrane inlet.

2. **Surface water:** The general term of dynamic water and static water on the land surface, also called "land water", including various liquid and solid water bodies, mainly rivers, lakes, swamps, glaciers, ice caps, etc. Surface water quality is complex, algae and other microorganisms are abundant, and water quality changes greatly due to seasonal changes. According to the actual water quality, the corresponding pretreatment processes such as flocculation and sedimentation, MF, UF, multi-media, and sterilization can be used to make the water quality meet the requirements of membrane inlet.

RAW WATER (CONT.)

3. **Groundwater:** Refers to various forms of gravity water buried below the surface. Groundwater is generally relatively clean, with low suspended solids content and low turbidity. It only needs simple pretreatment (multimedia, scale inhibitor, softening) to meet the requirements of membrane inlet. Bacteria will exist in some groundwater. For this, we need to choose a suitable pretreatment process according to the actual situation.

4. **Reclaimed Water:** Refers to water that can be beneficially used after sewage or rainwater is properly treated to reach a certain water quality index and meet certain use requirements. For the reclaimed water that meets the standard, please refer to the surface water pretreatment plan. The current mature solution is the double membrane treatment.

5. **Sea Water:** The salt content is generally (25000-35000) mg/L, which can be understood as surface water with high salt content. Affected by the high salt content of seawater, the seawater desalination system must have extremely high osmotic pressure. To ensure the stable operation of the membrane system, generally the recovery rate of the seawater desalination system is less than 50%.

6. **Other Feed Liquids:** Through combinations of different reverse osmosis membrane system and nanofiltration membrane system, can separate different solutes in some feed liquid. This process is affected by different feed liquids and processes, so should test and confirm the suitable pre-treatment process by yourself.

SCALING

As the permeate flow and concentrated raw water are continuously drained away during the RO system operation, the undissolved salt exceeds its saturation limit and causes deposition. This phenomenon is called scaling. This phenomenon first appears at the end of the RO system and gradually appears at the inlet side because it is caused by the concentration of the raw water. The scaling will have occurred in a very short time under the improper operation (the system recovery rate is too high). Common fouling and insoluble salts are: CaCO3, $CaSO_4$, $BaSO_4$, $SrSO_4$, CaF_2, $Ca_3(PO_4)_2$, (SiO_3^{2-}) etc.

FOULING

The impurities such as insoluble solids, colloids, organic matter, microorganisms in the raw water are gradually deposited and adsorb on the surface of membranes, causing the performance of the membrane system to decrease. This phenomenon mainly appears at the inlet side. Common foulings are: colloid and particulate matter (silt, clay, activated carbon powder, microbial remains, metal oxides, etc.), humus, fulvic acid, tannic acid, flocculants, etc.

Microorganisms will also greatly affect the performance of membrane elements, some microbial metabolites (polysaccharides, mucus, etc.) will adhere to the surface of the membrane, forming colonies, causing the membrane to be destroyed. After such impurities are cleaned, the dissolved solids enter the pure water side through the destroyed membrane; the rejection rate of the system may drop sharply.

MEMBRANE DEGRADATION

Membrane degradation is the degradation of membrane element performance caused by chemical properties changes in the separation layer of the membrane element. Mainly resulted in the decrease of permeate flow and rejection rate. The main substances that affect membrane degradation are oxidants (residual chlorine, potassium permanganate, ozone and other oxidants), too high or too low pH value of cleaning agent, excess temperature, etc.

Conventional Pre-Treatment Methods

MULTI-MEDIA FILTER

Multi-media filter is a process of using one or several filter media to pass water with higher turbidity through a certain thickness of granular or non-granular materials under a certain pressure, thereby effectively removing suspended impurities and clarifying the water. It is mainly to remove suspended or colloidal impurities in water, especially to effectively remove tiny particles and bacteria that cannot be removed by precipitation technology. BOD_5 and COD can also remove these suspended or colloidal impurities. Commonly used filter materials include quartz sand, anthracite, manganese sand, activated carbon, magnetite, garnet, porous ceramics, plastic balls, fiber balls, etc. The design and operation of the multi-media filter can refer to some related literature.

FLOCCULANTS AND COAGULANTS

Flocculants are a group with positive (negative) electricity and particles with positive (negative) electricity which are difficult to separate in the water close to each other, lower the electric potential, make it in an unstable state, gather the particles through the polymerism, and separated by physical or chemical methods. Flocculants are mainly used in water supply and sewage treatment fields.

There are many varieties of flocculants, from low-molecular-weight to high-molecular-weight, from single type to compound type. The general trend is cheap, practical, non-toxic and efficient. Inorganic flocculants are cheap, but they have an adverse effect on human health and the ecological environment; Although the organic polymer flocculants of little dosage, small scum output, strong flocculation ability easing separate floes, and good effect of oil and suspended solids removal, but the residual monomers of this type of polymer will cause malformation, cancer, mutation, which limits their application; microbial flocculants have no secondary pollution, easy to use, and have application prospects seductive, so it may replace or partially replace traditional inorganic polymers and synthetic organic polymer flocculants in the future.

MF, UF

Microfiltration (MF) and ultrafiltration (UF) can effectively remove insoluble solid suspended solids in water. Under a certain pressure, the small molecular solutes and solvents passe through a special membrane with a certain pore size, the macromolecular solutes are impermeable and on one side of the membrane, thereby the macromolecular is partially purified. Ultrafiltration technology is a kind of membrane separation technology. It is a process that under the outside pressure, the colloids, particles and high molecular weight substances are retained, water and small solute particles pass through the membrane The MF/UF needs to be cleaned/backwashed regularly to restore performance after using. Please consult the microfiltration/ultrafiltration manufacturers for details.

PRECISION FILTER

Precision filter (also known as security filter), the cylinder shell is generally made of stainless steel, the inside uses PP melt-blown, wire burning, folding, titanium filter, activated carbon filter and other tubular filter elements as filter elements, select the filter elements according to different filter media and the design process to meet the effluent quality requirements.

Precision filters are usually used as the last process of pretreatment to protect high-pressure pumps and membrane elements from impact damage and fouling caused by welding slag, particles, impurities, etc. It is usually recommended to select a precision at 5μm. The filter element of the precision filter needs to be replaced regularly according to the pressure difference or the usage time (the service life is no longer than three months). Do not reuse the filter to avoid it becoming contaminated by microorganisms and bacteria. Please contact AXEON for details.

SDI (Colloid, Particle)

The Silt Density Index (SDI) is one of the important parameters of water quality indicators. It shows the content of particles, colloids and other objects that block the purification equipment in the water. It can select the corresponding water purification technology or equipment through the SDI value. The SDI value can be determined according to the method specified in ASTM4189-95, which is a recognized standard test method in the industry.

SDI value is one of the important indicators for measuring the inlet water of the membrane system in the water treatment process. It is the main solution to inspect whether the outlet water of pretreatment system meets the standard of inlet water of membrane system. It is very important for membrane system operation.

The SDI value is measuring the flow attenuation through a 47 diameter, 45μm pore membrane. The colloid is easier to block the membrane than the particulate (such as sand, incrustation, etc.) under 0.45μm pore. The attenuation of the flow rate is converted to a value between 1 and 100, which is the SDI value. The lower of the SDI value, the smaller blocking of the water cause to membranes. In consideration of economy and efficiency, most membrane manufacturers recommend that the influent SDI value is not higher than 5.

(ASTM4189-95) SDI MEASUREMENT

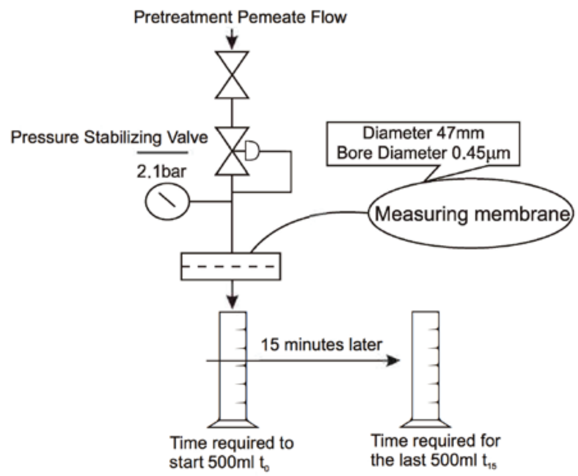
SDI measurement is based on the measurement of the blocking coefficient (PI, %). The measurement is continuously add the water(under the certain pressure 0.2MPa or 30 psi) to the Φ47mm 0.45μm microporous filter membrane, record the time T_i (Seconds) for filtering 500ML water, and the time T_f (Seconds) for filtering 500ML after 15 minutes, then calculate the SDI value as below:

$$SDI= [(1-T_i/T_f)*100] / 15$$

"15" means 15 minutes. When the pollutants in the water are high, can take 100ML, 200ML, 300ML water for filtering. The interval time can be changed to 10 minutes, 5 minutes, etc. The "15" in the calculation formula is adjusted to 10 or 5 accordingly.

MEASUREMENT STEPS

1. Connect the SDI analyzer to the sampling point (do not install the membrane)
2. Open the valve on the analyzer and flush the system thoroughly for several minutes
3. Close the valve on the analyzer, and then use blunt tweezers to put the 0.45μm filter membrane into the filter holder
4. Confirm that the O-ring is in good condition, place the O-ring on the filter membrane accurately, then cover the upper half of the filter membrane fixture and fix it with bolts;
5. Slightly open the valve and slowly loosen 1-2 butterfly bolts to eliminate the air at the filter membrane when the water flows;
6. Make sure the air is completely discharged. Keeping the water flow continuous, retighten the pentalink.
7. Open the valve completely and adjust the pressure regulator, until the pressure remains at 0.2 MPa or 30psi (if the pressure can not up to 0.2MPa or 30pis, then test under current pressure, the pressure can not lower than 0.1 MPa or 15psi).
8. Use a suitable container to collect the sample water, and start recording with a stopwatch when the water enters the container. The time for collecting 500ML sample water is T_i (Seconds)
9. When the sample water flows 15 minutes(including the time for collecting the initial 500ML water), use the container to collect 500ML sample water again and record the time as T_f.
10. Close the ball valve, loosen the pentalink of the microporous membrane filter container, and take out the filter membrane for storage.
11. Dry the microporous filter and the microporous membrane support orifice plate.



SDI Basic principle diagram

CALCULATION METHOD

1. If the feedwater pressure is 0.2MPa or 30psi while measuring, substitute the data obtained during the measurement process into the following formula to calculate SDI value:

$$SDI = [(1 - T_i/T_f)*100] / 15$$

Where : T_i : Time required to the first collection of 500ml sample(unit: second)
T_f : Time required to the second collection of 500ml sample(unit: second)

2. When the pressure value can not reach 0.2MPa or 30psi during measurement process, the existing pressure value can be used instead, but the measured SDI value must be converted to the one at 0.2MPa or 30psi condition. The method is as follows:

%Pp= $(1-T_i/T_f)*100$ (%Pp is the blocking index at a non-standard pressure of 0.2MPa or 30psi)

$$SDI = \%Pp30 / 15$$

Scale Prevention

For the saltness in concentrated water less than 1%, the possibility of $CaCO_3$ scaling can be judged by the value of LSI_c.

$$LSI_c = pH_c - pH_s$$

Where: pH_c is the pH value of concentrated water, pHS is the pH value when $CaCO_3$ is saturated, When $LSI_c \geq 0$. $CaCO_3$ will be scaled.

Most untreated raw water has a positive LSI_c value. In order to prevent $CaCO_3$ scaling, measures such as adding scale inhibitor or resin softening must be used in the feedwater of membrane system.

Scale Prevention (Cont.)

Otherwise, the raw water LSI_c must be a negative value as guaranteed. The conditions for controlling $CaCO_3$ scaling are:

- $LSI_c < 0$ No need to add scale inhibitor;
- $LSI_c \leq 1.8 \sim 2.0$ Add scale inhibitor alone or chemically soften completely;
- $LSI_c > 1.8 \sim 2.0$ Add acid to LSI_c till to 1.8-2.0, then add scale inhibitor or use chemical softening completely

SOFTENING (ION EXCHANGE METHOD)

Ion exchange refers to the exchange of ions in a solid ion exchanger with ones in a dilute solution to achieve the purpose of extracting or removing some ions in the solution. Ion exchange resin is the main part of softening system. In the membrane system, ion exchange resin is generally used to remove the hardness and alkalinity in the water and avoid scaling of membrane system. The strong acid cation resin can be replaced with Na+ ions or removed scale cations with Ca^{2+}, Ba^{2+} and Sr^{2+} in the water. The saturated resin can be regenerated by NaCl. Appropriate operating conditions and timely resin regeneration can effectively eliminate the risk of carbonate scale and sulfate scale in the system, and can also reduce TDS in the water. But it should be noted that ion exchange may cause pH value changes in the water.

SCALE INHIBITOR ADDITION

Scaling can decrease the permeate flow rate and increase salt passage of RO/NF, which may affect the normal operation of the RO/NF membrane system and shorten membrane elements service life. Scale inhibitor is a kind of agentia that can disperse insoluble inorganic salts in the water and prevent or interfere with the precipitation and scaling of it. They can be used to control carbonate scale, sulfate scale and calcium fluoride scale.

The dosage of scale inhibitor: the dosage of general water quality is 3-5ppm (standard solution), the reclaimed water quality is recommended to be 8-10ppm. The specific dosage should also be determined according to the static or dynamic scale inhibition experiment of feedwater quality and the calculation software of scale inhibitor manufacturer to ensure the application effect of scale inhibitor. It is noted that overdosing should be avoided, because excessive scale inhibitors are also contaminants to the membrane. At the same time, make certain that no significant amounts of cationic polymers are present when adding an anionic scale inhibitor, otherwise the cationic polyelectrolyte may have a coordinated precipitation reaction with the negatively charged scale inhibitor and pollute the membrane surface.

SYSTEM OPERATION PARAMETER ADJUSTMENT

When the effect of some small-scale systems or anti-scaling measures is not good, the insoluble salt rejection in the concentrated water of the system can be controlled by reducing the system's recovery rate, so that the insoluble salt is lower than its solubility product, and scaling will not occur. In addition, the reduction for pH of raw water can achieve the effect of preventing scaling.

Microorganisms Fouling Control

Microorganisms is a collective term for all tiny organisms that are difficult for individuals to observe with naked eyes, including bacteria, viruses, fungi and a few algae, etc. They are widely exist in various raw waters. After the raw water flow into the membrane system and continuously concentrated, the dissolved nutrients in the raw water gradually accumulated on the membrane surface, creating an ideal environment for the formation of a biofilm. Microbial metabolites, debris, polysaccharides, etc. form colloidal biofilms or mucus, causing fouling and damage to membrane elements. Severe microbial contamination is difficult to restore system performance by cleaning, and the remaining microorganisms will multiply quickly after cleaning, causing system fouling again.

DISINFECTION

Microbial contamination will seriously affect membranes' performance, which is mainly for gradual decrease of water flux and gradual increase of the operating pressure difference, and the slow decrease of salt rejection. In order to prevent microbial contamination, the raw water is usually sterilized. The fungicide can effectively control the growth of microorganisms in the membrane system by affecting the growth and division of microorganisms, spore germination, cell expansion, damaging cell walls and disintegrating cytoplasm.

According to the sterilization mechanism, bactericides can be divided into two categories: oxidizing and non-oxidizing. The oxidizing bactericides destroys the enzyme system of bacteria with the oxidation function of agentia to achieve the purpose of sterilization. The common oxidizing bactericides included sodium hypochlorite, ozone, hydrogen peroxide, etc. Since oxidizing bactericides have strong oxidizing properties, the reductant such as sodium bisulfite must be added when membranes system is working. Real-time detection is required to ensure the feedwater does not contain residual chlorine. Nonoxidizing bactericides mainly rely on the penetration into the bacteria or after being hydrolyzed in the water and form complex precipitation with some bacteria components to achieve sterilization effect. The commonly used non-oxidizing bactericides include DBNPA, isothiazolinone, etc.

OXIDANT REMOVAL

Although oxidizing bactericides can effectively and quickly inactivate microorganisms, oxidants can also destroy the separation layer of membrane elements and shorten service life. Therefore, the oxidation-reduction potential of feedwater should be closely monitored to ensure the oxidant in the raw water is removed. Special attention on tap water (existence of chlorine), reclaimed water (certain sterilization step),UF (backwash sterilization, etc.), circulating water (certain oxidizing agentia), polluted groundwater, surface water, etc. The oxidizing substances in feedwater are generally removed by reductant. In some small systems, activated carbon devices can be used to remove the oxidants in the water.

SODIUM BISULFITE

Sodium bisulfite is the common reductant and bactericides which exists in the membrane protective Solution. Sodium bisulfite can quickly react with oxidants, so as to achieve the function of removing oxidizing substances in raw water. Generally speaking, we can use 3mg/L sodium bisulfite to restore 1 mg/L free chlorine.

Prevention of Organic Pollution

Organics with complex chemical properties and chemical composition commonly exists in various water and can be found with different types and concentrations, which will directly or indirectly affect the physical, chemical, biological properties of water. After organics enters the membrane system, it will gradually adhere to the membrane surface as raw water is concentrated, causing the membrane system permeate flow to attenuate. Under certain special circumstances, it will cause irreversible membrane flux loss.

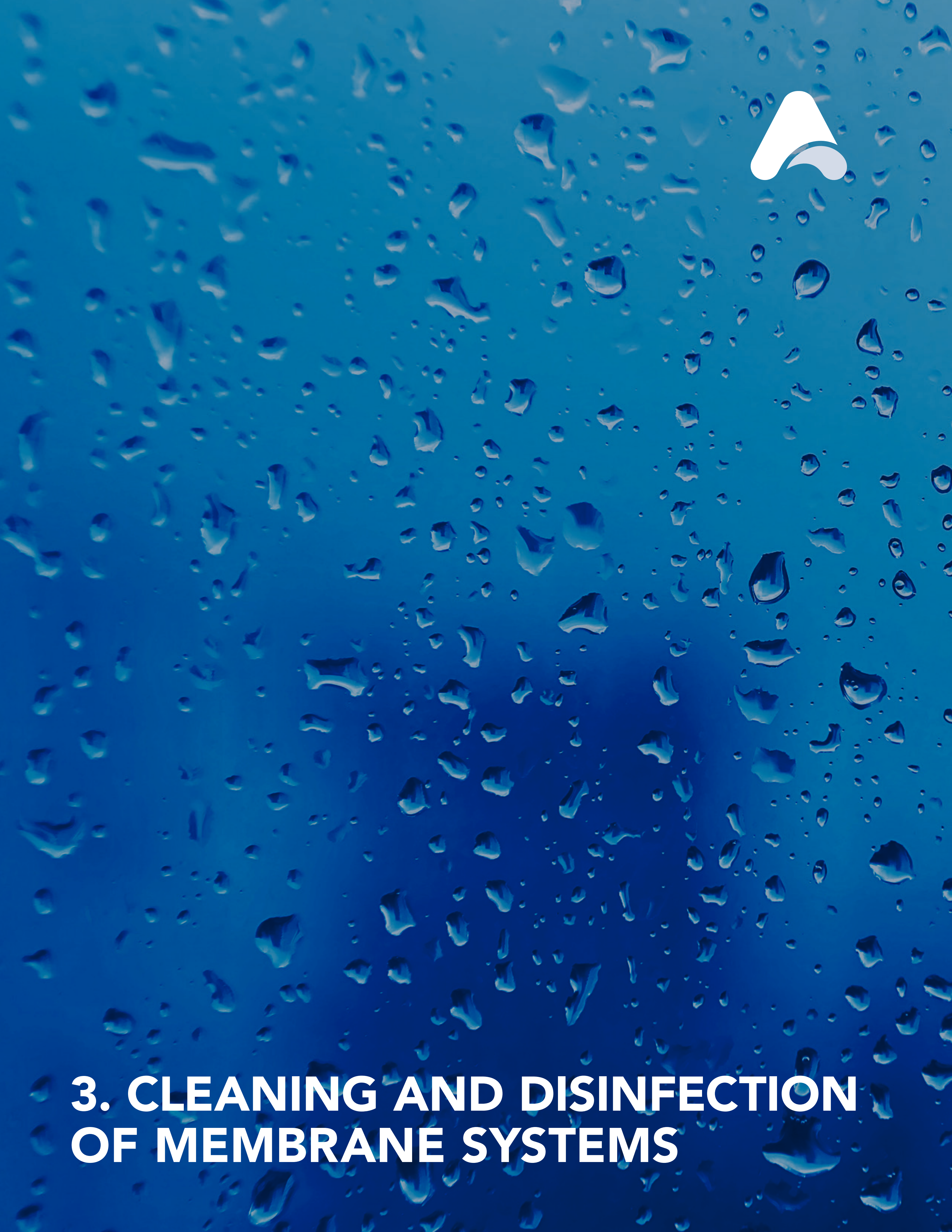
Therefore, to adopt flocculation, ultrafiltration, adsorption and other methods, to remove organic matter from the membrane system. Organic pollution is similar to colloid pollution. Alkaline cleaning and other cleaning methods can be used when cleaning the system. In the application of some membrane systems such as waste water and material separation, small or pilot tests should be carried out according to each material liquid to determine the restorative ability of membrane element after cleaning caused by organic contamination and the feasibility of material separation.

Prevention of Iron, Manganese and Other Oxide Pollution

When high iron or manganese ions are present in the raw water (over 0.05mg/L), iron (manganese) pollution may be present in the membrane system due to the effect of chemical properties, the frequency of iron pollution is obviously higher than that of manganese pollution. The main methods to prevent iron pollution are to control the contact between raw water and air or oxidant, to reduce the pH value of raw water. Generally speaking, we can remove iron and manganese ions in water through ion exchange, flocculation, advance oxidation then filtration, synchronous oxidation method and so on. Please refer to the relevant details literature.

Summary of Pretreatment Options

Pretreatment		Table						
		Difficult dissolved salts	Iron and Manganese	Microorganism	Organic Matter	Oxidant	High SDI	Silicate
Options	Flocculation				Possible		Effective	
	Scale inhibitors	Effective						
	Ion exchange	Effective						
	System Control							Effective
	MF/UF			Possible	Effective		Effective	Effective
	Activated carbon				Effective	Effective		
	Restore					Effective		
	Oxide Sterilization			Effective				
	Oxidation Filtration		Effective					



3. CLEANING AND DISINFECTION OF MEMBRANE SYSTEMS

3. CLEANING AND DISINFECTION OF MEMBRANE SYSTEMS

Membrane System Cleaning

CLEANING TIPS

Membrane system cleaning method: Physical and Chemicals Cleaning. Physical cleaning is a process of “flushing”. It refers to the use of “low pressure and large flow” inlet water in the concentration channel of the membrane element to wash away the pollutants and deposits attached to the membrane surface. Typical flushing pressure is below 60psi (0.4MPa). Flush the 8 inch membrane elements with feed water at 7.2 - 12 m^3/h at 31-53 GPM, 4 inch membrane elements with feed water at 1.8 - 2.5m^3/h at 8-11 GPM. Physical flushing shall be doing frequently.

After the membrane system has been running some time, the reverse osmosis and nanofiltration membrane elements will be contaminated by mineral scale, biological matter, colloidal particles and insoluble organic constituents. Deposits build up on the membrane surfaces during operation, which neither will cause drop for normalized permeate flow, and normalized salt rejection, separately, or both elements should be chemical cleaned when the below mentioned parameters are occur, physical washing can no longer restore the performance of reverse osmosis and nanofiltration membrane elements.

1. The normalized permeate flow drops 10% -15% or above.
2. The normalized pressure differential (between feed pressure and concentrate pressure) increases 15% or above.
3. The normalized salt passage increases 10-15% or above.

Physical cleaning is recommended before chemical cleaning.

CONFIRMATION OF SCALE TYPE

Before chemical cleaning, it is important to determine the type of scale on the membrane surface. The best way to determine the scale type is to perform a chemical analysis of the residues collected on the SDI test diaphragm to determine the main types of contaminants and then conduct targeted chemical cleaning.

In the absence of chemical analysis, according to the determination of SDI, the color and density of the residue on the membrane flat sheet can be measured, and then the scale can be classified. Such as, if it is brown, fouling by iron scale may be present. If it is white, fouling probably by silicon, sandy clay, calcium scale, etc. The appearance of lens is characteristic of inorganic colloid and calcium scale. Biological fouling or organic material is often slimy, except the odor analysis.

CHOICE OF CLEANING AGENTS

Chemical cleaning agents and methods selection should be determined by the condition of raw water.

1. If the raw water has higher hardness, the membrane elements are more prone to scale fouling, generally cleaned with acidic chemicals; raw water with organic content is likely to cause organic contamination of the membrane elements, generally alkaline chemicals will be used for cleaning.

2. When the system is dominated by salt scale, it is recommended to first pickle and then alkali cleaning; when the system is mainly polluted by organic matter, it is recommended to adopt alkali cleaning first, then pickle cleaning, and alkali cleaning.

Pollutants	Chemical cleaning solutions	Cleaning conditions
Carbonate scale	0.2% hydrochloric acid HCl	Temperature ≤35 °C; pH > 2
		Temperature ≤35 °C
		Temperature ≤35 °C; adjust the pH to 3 with ammonia
Sulfate scale	0.1% sodium hydroxide NaOH	Temperature ≤30 °C; pH≤12
Metal Oxide	1.0% sodium dithionite $Na_2S_2O_4$	Temperature ≤30 °C; pH4-6
		Temperature ≤30 °C; pH > 2
		Temperature ≤30 °C; adjust the pH to 3 with ammonia
Colloid	0.1% sodium hydroxide NaOH	Temperature ≤30 °C; pH≤12
Organic matter	0.1% sodium hydroxide NaOH 0.025% sodium dodecylbenzene sulfonate Na-DDBS 0.2% hydrochloric acid HCl	Temperature ≤30 °C; the first step is to use NaOH and Na-DDBS,pH≤12; the second step is to use HCl,pH > 2
Microorganism	0.1% sodium hydroxide NaOH 0.025% sodium dodecylbenzene sulfonate Na-DDBS	Temperature ≤30 °C; pH≤12
		Temperature ≤30 °C; pH≤12

CLEANING STEPS

1. Low-pressure flushing of membrane system with product water.

2. Prepare the relevant cleaning solution in the cleaning water tank (prepare with product water to control the pH and temperature of the cleaning solution).

3. Open and close the corresponding valve to form a circulating medicine washing pipeline; start the cleaning pump and inject the cleaning solution into the membrane element pressure vessel to start the cycle cleaning operation. The cycle cleaning time is (1-2) hours for once.

4. The cycle cleaning starts for 5 minutes, and the cycle cleaning is carried out at the amount of 1/3 of the set flow rate, and then every 10 minutes or so, the cycle flow rate gradually increases from 2/3 of the set amount to the full flow rate for circulation.

5. After the first cleaning, the membrane elements must be rinsed with product water, and then replaced with another cleaning solution for cleaning.

6. Real-time detection of the turbidity and pH value of the concentrated water, when it becomes turbid or the pH value changes more than 0.5 units, the cleaning solution should be supplemented or re-prepared.

7. After cleaning, flush the system with low pressure first, and gradually exhaust and increase the pressure until the water produced is qualified.

8. If the membrane element is seriously clogged, or the flow recovery is not obvious after cleaning, the cleaning solution can be feed into the membrane element pressure vessel, and the cleaning solution can be kept in the membrane shell and soak the membrane element for (6-12) hours before the second time of circulating cleaning.

9. For the cleaning of "multi-stage system", the flushing and soaking process can be carried out in all sections at the same time; but the high-flow cycle cleaning process must be carried out in stages to facilitate the control of the circulation flow during each stage of cleaning.

CLEANING ATTENTIONS

1. Before starting the chemical cleaning, make sure that the chemicals used in the cleaning solution are fully dissolved and mixed.

2. Cleaning the membrane system with "low pressure and large flow" will cause high pressure drop. It should be noted that the maximum allowable pressure drop for the inlet and concentrated water of a single element is 0.1 MPa or 15 psi, and the maximum allowable pressure drop for multi-element pressure vessels is 0.35 MPa or 50 psi.

CLEANING ATTENTIONS (CONT.)

3. Cleaning pH limit: When the cleaning solution pH=1 or 13, it can efficiently clean scales, organic compounds and bio membranes. In the case of this limit pH cleaning, the temperature of the cleaning solution must be controlled in the cleaning process to ensure the membrane components are not damaged.

4. Cleaning temperature limit: during normal chemical cleaning, the temperature of the cleaning solution should be controlled at 86-95 °F (30-35 °C); for extreme cleaning, the temperature of the cleaning solution should be controlled within 86 °F (30 °C); try to avoid chemical cleaning in a low temperature environment, and it should be used the temperature of the cleaning solution is ≥68 °F (20 °C) to ensure cleaning efficiency and prevent precipitation.

5. After the chemical cleaning, before the normal operation of the membrane system is restored, the membrane system must be flushed with the system water or water that meets the requirements of the membrane system inflow. The chemical cleaning is completed only after the residue of the cleaning solution in the system is completely rinsed.

Membrane System Disinfection

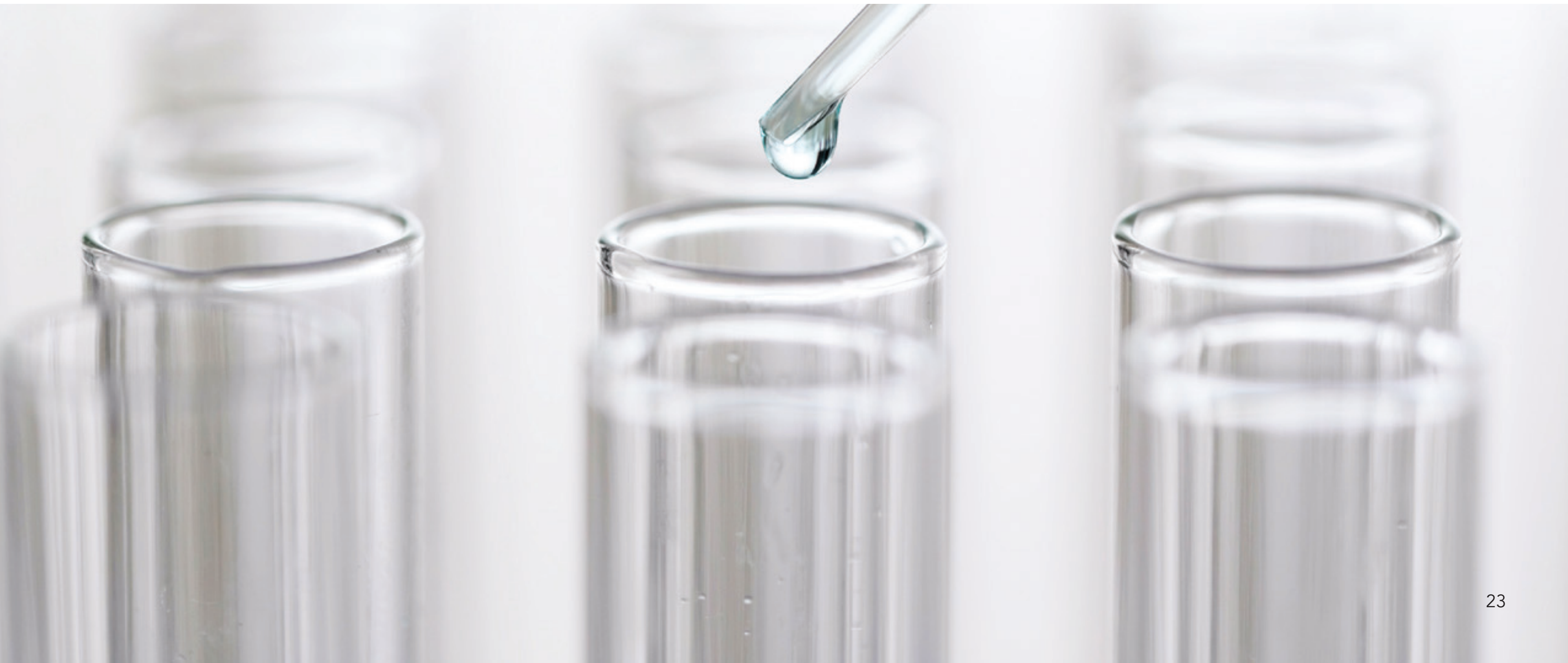
MEMBRANE SYSTEM DISINFECTION

To avoid bacterial reproduction, the membrane system must be disinfected regularly or before the system is shut down for a long time. It is recommended to use 1.0% sodium bisulfite solution for soaking.

DISINFECTION ATTENTIONS

1. The water used to prepare the disinfection solution must be free of residual chlorine or other oxidants;

2. Avoid using oxidizing disinfectants, which may cause oxidative damage to membrane elements.



4. TROUBLESHOOTING OF MEMBRANE SYSTEMS

4. TROUBLESHOOTING OF MEMBRANE SYSTEMS

Common faults of reverse osmosis and nanofiltration membrane systems include: abnormal initial installation performance and system performance degradation after stable operation. Mainly manifested in:

1. The standardized rejection of the system is reduced
2. Systematic standardized permeate flow rate changes
3. Abnormal changes in system operating pressure (pressure differential)

Abnormal changes in system performance need to be analyzed under the standardized operating data to exclude various external factors. Judge the possible cause and location of the abnormality through the abnormal changes of the standardized data, further test to determine the cause of the abnormality, and take corresponding measures. The typical membrane system failure or abnormality will be description this chapter:

Membrane Element Selection and System Design Errors

Common system initial installation performance abnormalities are mainly showed in abnormal of permeate flow and rejection rate. Most of the initial installation abnormalities are related to the selection of membrane elements and system design errors. Common exceptions include: the high salt content of the raw water, led to the system water production cannot meet the design requirements; the membrane element selection (especially the nanofiltration membrane element) causes the system desalination rate to be too low or too high (some mineral water projects), etc. Therefore, it is necessary to understand the condition of the raw water and the user's system water production requirements, and pilot test will be needed if necessary.

Temperature Effect

Temperature is one of the main reasons affecting the permeate flow of membrane elements. Affected by molecular activity, the higher the temperature, the lower the viscosity of water (the temperature correction coefficient increases) and the increase in water flux. In some areas, the low temperature in winter may cause the temperature of the inlet water to decrease, thereby affecting the water production of the system. Therefore, it is recommended to consider the influence of temperature in the design of the system, add a heat exchange device or choose a suitable high-pressure pump according to the actual situation.

Suspended Particulate Contamination

Suspended particulate contamination mainly occurs in the case of pretreatment failures or pretreatment design defects. Such as incomplete washing of multi-media filters, poor quality filter materials, failure of ultrafiltration broken filaments, and paralysis of pretreatment caused by sudden changes in raw water. The fault occurs at the front end of a section of the membrane element (near the high-pressure pump end). The main system operating data is shown below:

Standardization permeate flow	Decline
Standardization rejection	Increase or unchanged
Standardization differential pressure	Increase
Fault Location	Mainly at the front of one stage

Photo of particulate contamination

When particle contamination occurs, it is necessary to check whether the pretreatment is complete and changes in the raw water. and corresponding treatment measures need to take according to the actual situation to ensure that the membrane system inlet water meets the inlet water quality requirements. For details, please refer to Chapter 5.

Organic Contamination

Organic contamination mainly occurs in systems that the raw water are surface water, reclaimed water, wastewater, or contaminated groundwater. It can be confirmed by detecting COD and BOD5 of raw water. Organic contamination can occur in any stage, and alkaline washing normally can be used to restore system performance. The main system operating data performance methods are shown below:

Standardization permeate flow	Decline
Standardization rejection	Increase or unchanged
Standardization differential pressure	Normal
Fault Location	Any location

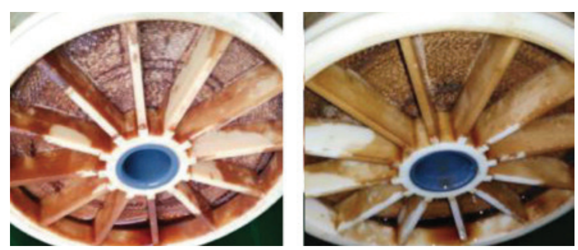


Photo of organic contamination

Organic contamination generally occurs with microbial contamination, and alkaline washing can usually be used to restore system performance. Please refer to Chapter 3. The organic contamination can be alleviated by replacing the pretreatment filter material, and the pretreatment needs to be improved to prevent the organic contamination.

Colloidal Contamination

Colloid contamination mostly occurs in systems that use surface water or contaminated shallow groundwater as water sources. It can be judged by the SDI value of raw water. If the raw water SDI value is high, the possibility of colloidal contamination of the membrane element is very high. The main system operating data is shown below:

Standardization permeate flow	Decline
Standardization rejection	Normal or slightly decreased
Standardization differential pressure	Increase
Fault Location	Mainly at the front of the first stage

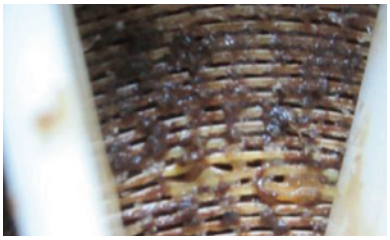


Photo of colloidal contamination

Serious colloidal contamination is generally difficult to clean, and different cleaning schemes should be adopted according to actual conditions for different colloidal contamination. For details, please refer to Chapter 3. When colloidal contamination occurs, it needs to confirm whether the pretreatment system (multi-media filter, ultrafiltration system, etc.), has failure or overload, and optimize the pretreatment system according to the actual situation.

Microbial Contamination

Microbial contamination is one of the most common contamination in the system. It mainly occurs in systems that use raw water as surface water, reclaimed water, wastewater or contaminated groundwater as the water source, and it is generally accompanied by organic contamination (to provide nutrients for microbial reproduction). This abnormality is generally confirmed by the total number of colonies in raw water or produced water. The main system operating data is shown below:

Standardization permeate flow	Decline
Standardization rejection	Normal or slightly decreased
Standardization differential pressure	Increase
Fault Location	Any location

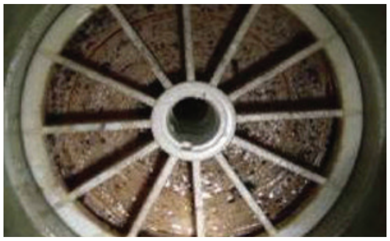


Photo of microbial contamination

Medical washing and disinfection are normally used to solve the abnormal microorganism contamination. For details, please refer to Chapter 3. Due to the strong reproduction of microorganisms, the pollution source must be found for targeted sterilization, otherwise, the microorganisms will multiply again in a short time, which will cause repeated fouling of the system.

Metal Oxide Fouling

Metal Oxide Fouling generally occurs in the system feed water containing iron, manganese, aluminum, etc. Some water supply systems using untreated cast iron pipes will also have metal oxide fouling. The Metal Oxide Fouling occurs predominantly at the front end of the membrane system. The main system operating data is shown below:

Standardization permeate flow	Decline
Standardization rejection	Decline
Standardization differential pressure	Normal or increase
Fault Location	The front end of the first stage

Photo of iron contamination

Iron pollution normally can generally be cleaned by citric acid or sodium dithionite. For details, please refer to Chapter 3. For Metal Oxide Fouling, the measure is to use oxidation-filter equipment such as manganese sand filter or other pretreatment methods to remove metal oxides according to actual condition.

Inorganic Salt Scaling

Inorganic Salt Scaling is one of the most common pollution in the systems. It happens mainly due to the insoluble salt in the concentrated water reaches saturation. It is deposited on the surface of the membrane after precipitation, and it normally happen at the end of the membrane system. In some cases, scaling occurs in a short time (a few hours or even less). The main system operating data is:

Standardization permeate flow	Decline
Standardization rejection	Decline
Standardization differential pressure	Increase
Fault Location	The end of the first stage

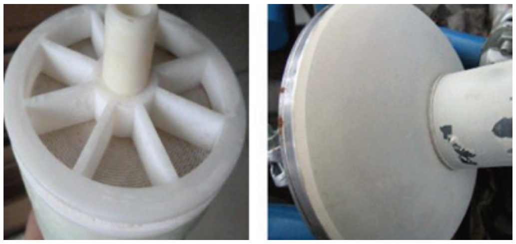


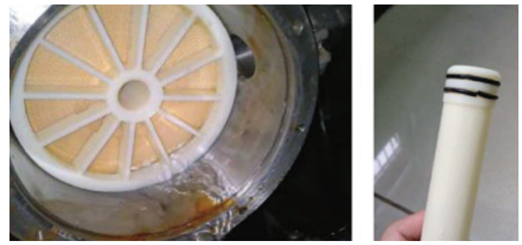
Photo of scaling

The common scaling substances are calcium carbonate, calcium sulfate, barium sulfate, strontium sulfate, calcium fluoride, calcium phosphate, silicate, etc. Different cleaning schemes can be adopted for different fouling substances. For details, please refer to Chapter 3. Serious scaling may cause irreversible damage to membrane elements. Generally, methods such as ion exchange, adding scale inhibitors, reducing the recovery rate, and lowering the pH of the raw water can be used to control the occurrence of scaling.

Leaking of O-Ring

Leaking O-Ring usually occurs in the initial installation and debugging stage of the system or suddenly occurs after system running. Its main showed as a sudden drop in the system's rejection rate. It can be confirmed by detecting the conductivity of the water produced by a single membrane housing and confirm the abnormal point by the probe method experiment. The main system operating data is:

Standardization permeate flow	Increase
Standardization rejection	Decline
Standardization differential pressure	Remains or decline
Fault Location	Any positions



The photo for O-ring leaking

O-ring leakage is mainly caused by poor lubrication of the O-ring when the membrane element is installed or improper installation of the membrane element (the membrane element slides in the membrane housing).

Membrane Element Oxidation

Oxidation of membrane elements generally occurs in systems that use tap water, circulating water, contaminated groundwater and reclaimed water as raw water. In some cases, improper subsequent treatment of oxidizing fungicides, the raw water containing hexavalent chromium, potassium permanganate and other substances will cause oxidation and destruction of membrane elements. The main system operating data is:

Standardization permeate flow	Increase
Standardization rejection	Decline
Standardization differential pressure	Normal
Fault Location	Any positions, specially at the front end of the first stage

The oxidation of the membrane element is irreversible damage to the membrane element and the performance cannot be restored by cleaning. The only solution is to change the membrane element.

Other Abnormalities

MEMBRANE ELEMENT BACK PRESSURE

The membrane element back pressure is mainly for the excessive pressure on the permeate water side (high pressure in the pure water pipeline or system operation error), the membrane sheet separation layer peels off. So the raw water enters the pure water system from where the membrane sheet peels off which makes the system rejection rate drop. The abnormal performance of the system is similar to 0-ring leakage. Abnormal location can be confirmed by probe method. The back pressure of the membrane element can be occurs at any positions.

EXCESSIVE PRESSURE DIFFERENTIAL, WATER HAMMER IMPACT

After the membrane element is fouled, the pressure differential of the membrane element generally increases. When the pressure differential is too large, the Brine Seal Carrier of the membrane element and the FRP (Fiber Reinforced Plastics) of the membrane element may be damaged (burst or broken) or the Concentrate Channel Spacer of membrane element may be washed out. This damage may not change the rejection rate of system in a short time, but it will affect the service life of the membrane element. For such problems, it suggest improve pretreatment to reduce the possibility of membrane elements fouling. The solution like high pressure pump soft-start reduces the impact of water hammer to membrane element.

LUBRICANT

Petroleum lubricants, detergents, etc. may damage the permeate collection tube of the membrane element due to their complex composition. We recommend using silicone lubricant that is NSF 61 approved.

Analysis and Solution for Common Fault

ANALYSIS AND SOLUTION FOR COMMON FAULT

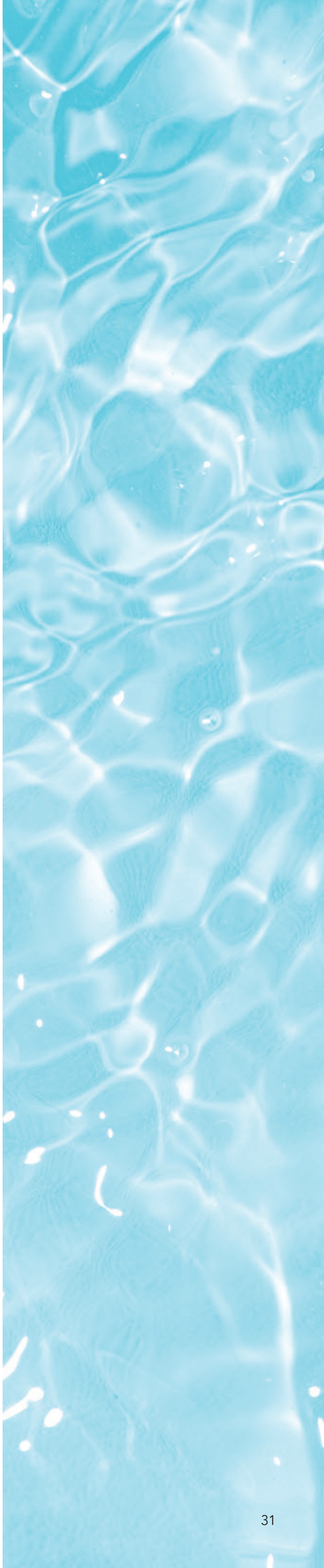
NO.	Permeate Flow	Rejection Rate	Pressure Difference	The Cause of Bug	Solution
1	Decline	Rise	Keep	Membrane Flat Sheet Densification by Water Hammer	Replace Membrane Element; Improving Membrane System
2	Decline	Keep	Keep	Organic Contamination	Chemical Cleaning Improving the Pretreatment
3	Decline	Decline slowly	Rise	Microbial Contamination	Chemical Cleaning; Disinfection; Improving the Pretreatment
4	Decline	Decline	Rise	Scaling or Colloidal Contamination	Chemical Cleaning; Improving the Pretreatment
5	Rise	Decline	Keep	O-ring Leakage	Inspect or Replace the O-ring
6	Rise	Decline	Keep	Back Pressure or Oxidation	Replace Membrane Element

JUDGMENT FOR COMMON SYSTEM CONTAMINATION

NO.	Type of Contamination	Change of Feed Water Pressure	Change of Pressure Difference	Change of Rejection Rate	Possible Fouling Position
1	Inorganic Salt Scaling	Rise	Rise	Decline	The Membrane Element in the end of Final Stage
2	Organic Contamination	Rise	Keep	Rise or Keep	All the Membrane Element
3	Fouling by Metallic Oxides	Rise Quickly	Rise Quickly	Decline Quickly	The Membrane Element in the front of First Stage
4	Biological Contamination	Rise Quickly	Rise Quickly	Decline Slowly	Membrane element in any position
5	Colloidal Contamination	Rise Slowly	Rise Slowly	Decline Slowly	The Membrane Element in the front of First Stage
6	Scaling Contamination	Rise	Rise	Decline	The Membrane Element in the Final Stage
7	Polymerization Silicon Deposits	Rise	Rise	Decline	The Membrane Element in the end of Final Stage

FAILURE ANALYSIS STEPS

1. Confirm whether the membrane system is operating abnormally.
2. Confirm whether the membrane system has been shut down for a long time and whether it has been shut down for maintenance.
3. Confirm whether the membrane system pretreatment or chemical dosing system is normal.
4. Confirm whether the membrane system is used under proper water inlet temperature, TDS or pH conditions.
5. Confirm whether the inlet water flow rate and water recovery rate of the membrane system are normal.
6. Confirm whether the pressure differential of the membrane system (inlet water pressure-concentrated water pressure) is normal.
7. Confirm whether all the instruments have been calibrated.
8. Perform standardized calculations on the production water flow and quality.
9. Measure the quality of the product water section by stage and pressure vessel.
10. Check whether the seal of each pressure vessel is damaged.
11. Check whether the security filter in the membrane system contains pollutants.
12. Check whether the membrane element is contaminated or damaged.
13. Sampling and analyzing the water quality data of the membrane system inlet water, concentrated water, and each stage of water production and total water production.
14. Compare the water quality data obtained from the analysis with the calculated value of the membrane system design.
15. Determine possible pollutants on the basis of changes in water quality, flow rate and pressure drop after standardization.
16. Clean the predicted pollutants and scales.
17. Analyze the pollutants contained in the cleaning solution and the changes in the color and pH of the cleaning solution.
18. Send out the membrane element for non-destructive analysis and determine the cleaning plan.
19. Perform anatomical analysis and laboratory analysis of membrane elements to determine contaminants.



5. FEED WATER QUALITY REQUIREMENTS OF MEMBRANE SYSTEMS

5. FEED WATER QUALITY REQUIREMENTS OF MEMBRANE SYSTEMS

Items		Permissible Value	Probably Consequence of Excessive Standard	Improvement Suggestions
Suspended Solids	Turbidity	< 1.0NTU	Sludge, Colloid Pollution	Flocculation sedimentation, filtration, microfiltration, ultrafiltration
	SDI_{15}	< 5.0		
Metal Oxides	Fe(mg/L)	< 0.05	Iron Pollution	Oxidation + precipitation or filtration
	Mn(mg/L)	< 0.05	Manganese Contamination	Use dispersant
Scale Forming Matter	$CaCO_3$	LSI < 0	Scaling	Decrease Recovery Rate, pH Value, or Add Scale Inhibitor
	Si(mg/L)	< 20		
	Other Insoluble Salt	/		
Organics	Oil	0	Organics and Oil Pollution	Air Flotation,
	TOC(mg/L)	< 5	Organics and microbial Pollution	Activated Carbon Absorption, Filtration
	COD_{cr}(mg/L)	< 15		
	BOD_5(mg/L)	< 10		
pH		3-10	Too Low or too High pH will Accelerate the Aging vate	Regulation of Acid-Base
Temperature		5-45℃	Low Temperature will Easy Produce Scaling of Undissolved Salt High Temperature will Accelerate the Aging Speed of Membrane	Heat Exchanger
Oxidizer	Residual Chlorine (mg/L)	< 0.1	Membrane System will be Oxidized	Reductant or Activated Carbon Absorption
	Ozone and Others	0		

NOTES

1. Membrane has a certain residual chlorine resistance capability (200-1000ppm HR), and when it's in the different temperature, pH value and other conditions, the damage speed of residual chlorine is different to aromatic polyamide membrane. Hence, it must ensures the residual chlorine of feed water under 0.1 mg/L.

NOTES (CONT.)

2. Iron and manganese in feed water cannot be higher than 0.05mg/L, which usually dissolved in water with bivalent or present with insoluble trivalent hydroxide. If the concentration of iron and manganese are higher than 0.05mg/L, and they are oxidized by air to form the Fe $(OH)_3$ and $Mn(OH)_2$, precipitate will be existed in the membrane system when the pH value is higher than standard level.

3. Silicon exists in most natural water bodies; the concentration ranges from (1-100) mg/L, and when the pH of the water body is lower than 9.0, it mainly exists as $Si(OH)_4$. When the pH is low, silicic acid can polymerize to form silica gel. When the pH is high at 9.0, it will separate into SiO_3^{2-} ions, and will form hydrate precipitation with calcium, magnesium, iron or lead.

4. Alkalinity is mainly formed by HCO_3^-. When the pH Value is higher than 8.3, HCO_3^- will transfer to be CO_3^{2-} Raw water will be concentrated in the process of RO and NF system, so $CaCO_3$ is easy to form the scaling matter in the system.

5. If one or more above indicators in non-compliance, which may have following influence for membranes or permanent damage:

- **a.** If one or more above indicators in non-compliance, which may have following influence for membranes or permanent damage.
- **b.** Suspended solid may plug the membrane elements, even following with serious colloidal contamination.
- **c.** An increasing output of COD_{cr} may occur as a result of organic and microbiological contamination.

Temperature Correction Factor for Permeate Flow Table

℃	+0.0	+0.1	+0.2	+0.3	+0.4	+0.5	+0.6	+0.7	+0.8	+0.9
5	2.014	2.007	2.000	1.993	1.986	1.979	1.972	1.965	1.958	1.951
6	1.944	1.938	1.931	1.924	1.917	1.911	1.904	1.897	1.891	1.884
7	1.878	1.871	1.865	1.858	1.852	1.845	1.839	1.832	1.826	1.819
8	1.813	1.807	1.800	1.794	1.788	1.782	1.775	1.769	1.763	1.757
9	1.751	1.745	1.738	1.732	1.726	1.720	1.714	1.708	1.702	1.696
10	1.690	1.685	1.679	1.673	1.667	1.661	1.655	1.650	1.644	1.638
11	1.632	1.627	1.621	1.615	1.610	1.604	1.598	1.593	1.587	1.582
12	1.576	1.571	1.565	1.560	1.554	1.549	1.543	1.538	1.533	1.527
13	1.522	1.517	1.511	1.506	1.501	1.496	1.490	1.485	1.480	1.475
14	1.470	1.464	1.459	1.454	1.449	1.444	1.439	1.434	1.429	1.424
15	1.419	1.414	1.409	1.404	1.399	1.394	1.390	1.385	1.380	1.375
16	1.370	1.365	1.361	1.356	1.351	1.346	1.342	1.337	1.332	1.328
17	1.323	1.319	1.314	1.309	1.305	1.300	1.296	1.291	1.287	1.282
18	1.278	1.273	1.269	1.264	1.260	1.255	1.251	1.247	1.242	1.238
19	1.234	1.229	1.225	1.221	1.217	1.212	1.208	1.204	1.200	1.195
20	1.191	1.187	1.183	1.179	1.175	1.171	1.166	1.162	1.158	1.154
21	1.150	1.146	1.142	1.138	1.134	1.130	1.126	1.122	1.119	1.115
22	1.111	1.107	1.103	1.099	1.095	1.091	1.088	1.084	1.080	1.076
23	1.073	1.069	1.065	1.061	1.058	1.054	1.050	1.047	1.043	1.039
24	1.036	1.032	1.028	1.025	1.021	1.018	1.014	1.011	1.007	1.004
25	1.000	0.997	0.993	0.990	0.986	0.983	0.979	0.976	0.972	0.969
26	0.966	0.962	0.959	0.956	0.952	0.949	0.946	0.942	0.939	0.936
27	0.932	0.929	0.926	0.923	0.919	0.916	0.913	0.910	0.907	0.903
28	0.900	0.897	0.894	0.891	0.888	0.885	0.882	0.879	0.875	0.872
29	0.869	0.866	0.863	0.860	0.857	0.854	0.851	0.848	0.845	0.842
30	0.839	0.837	0.834	0.831	0.828	0.825	0.822	0.819	0.816	0.813
31	0.811	0.808	0.805	0.802	0.799	0.797	0.794	0.791	0.788	0.785
32	0.783	0.780	0.777	0.775	0.772	0.769	0.766	0.764	0.761	0.758
33	0.756	0.753	0.751	0.748	0.745	0.743	0.740	0.737	0.735	0.732
34	0.730	0.727	0.725	0.722	0.720	0.717	0.715	0.712	0.710	0.707
35	0.705	0.702	0.700	0.697	0.695	0.692	0.690	0.688	0.685	0.683
36	0.680	0.678	0.676	0.673	0.671	0.669	0.666	0.664	0.662	0.659
37	0.657	0.655	0.652	0.650	0.648	0.646	0.643	0.641	0.639	0.637
38	0.634	0.632	0.630	0.628	0.626	0.623	0.621	0.619	0.617	0.615
39	0.613	0.610	0.608	0.606	0.604	0.602	0.600	0.598	0.596	0.594

Remark: [Corrected Permeate Flow] = [Standard Permeate Flow at 25°C] + [Temperature Correction Factor corresponding to Feed Water Temperature]

Commonly Used Units and Conversion Relationships in the Membrane Industry

- The actual rejection rate of the system: [1-(TDS of permeate water+ TDS of feed water)]x100%
- System recovery rate: (system permeate water + system feed water) x 100%
- Membrane flux: water permeate per unit area of membrane per unit time

NO.	Project	Unit				
		1	2	3	4	5
1	Volume	L	gal(US)	M^3	mL	$cc(cm^3)$
2	Length/Thicknes	cm	mm	µm	inch	mil
3	Area	m^2	ft^2			
4	Flow	m^3/h	GPD	GPM	L/h	LPM
5	Pressure	bar	psi	MPa	$kg{\cdot}f/cm^2$	
6	Conductivity	µS/cm	mS/cm	S/m	mS/m	
7	Flux	gfd	$L/m^2{\cdot}h$(LMH)			
8	Mass	kg	g	lb		
9	Temperature	℃	℉			
10	Solution concentration	mg/L	mmol/L			

Volume:	1L	= 0.2642gal(US)	= $0.001m^3$	= 1000ml	= $1000cc(cm^2)$
Length/Thickness:	1cm	= 10mm	= 10000µm	= 0.3937inch	= 393.70mil
Area:	$1m^2$	= $10.7639ft^2$			
Flow:	$1m^3/h$	= 6340.13GPD	= 4.4029GPM	= 1000L/h	= 16.6667LPM
Pressure:	1bar	= 14.5038psi	= 0.1MPa	= $1.0197kg{\cdot}f/cm^2$	
Conductivity:	1µS/cm	= 0.001mS/cm	= 0.0001S/m	= 0.1mS/m	
Flux:	1gfd	= $1.6977L/m^2{\cdot}h$(LMH)			
Mass:	1kg	= 1000g	= 2.2046lb		
Temperature:	°F	= 32 + 1.8 x °C			
Solution concentration:	mg/L	= Relative molecular mass x mmol/L			

- **TDS (Total Dissolved Solids)** is the total dissolved solids, which used to measure the total content of all ions in the water, usually expressed in ppm;
- **Ppm means parts per million;** the ppm concentration is the concentration expressed by the mass of solute in the parts per million of the mass of the total solution, also known as the concentration of parts per million; ppm concentration is often used when the concentration is very small. For solutions, ppm generally refers to mass concentration, and ppm is mg /L.

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