PURIKOR

MEMBRANES

MEMBRANES FOR REVERSE OSMOSIS SYSTEMS

V1.0

28/08/2023

Insallation Manual

Abstract

We appreciate your preference in purchasing our PURIKOR brand reverse osmosis membrane.

With the help of this instruction manual you will be able to carry out a correct installation and keep your equipment in optimal operation, which is why we recommend that you follow the instructions included here.

Keep this manual in a safe place for future reference.

Table of Contents

1. INSTALLATION AND USE OF THE SYSTEM

1.1. INSTALLATION AND DISASSEMBLY

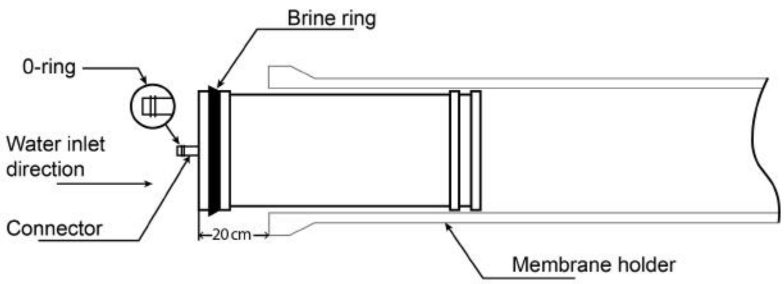
Installation Preparation

1. To record the relative position of each membrane cap and the membrane, a schematic diagram should be prepared to identify the installation position of the membrane cap and membrane. When loading and unloading membranes, fill in the membrane serial number (shown on the label) on the schematic diagram as the membrane number; The schematic diagram indicating the location of the membrane cap and membrane will help track the operating situation of each individual membrane in the system.
2. The following equipment is recommended: safety shoes, rubber gloves, silicone lubricant, glycerin, safety glasses, Allen wrench, pipe pliers, scissors, clean rags, a swab large enough to fill the inside diameter of the membrane cap, etc
3. Carefully check the flow of the water inlet pipe and remove all dust, grease, metal debris, etc. that may exist in the pipe; If necessary, chemically clean the inlet pipe and pressure vessel to ensure that all foreign objects are effectively removed.
4. Carefully check the quality of the inlet water; Before installing the membrane, flush the reverse osmosis system with the water produced by an effective pretreatment system for about 30 minutes and check whether the quality of the system inlet water meets the regulations and check whether there are any leaks in the pipe.
5. Remove all end cap and thrust ring assemblies from all membrane caps, spray clean water through the open membrane caps to remove any dust or debris present on the membrane caps.
6. Before installing the membranes, ensure that all parts and chemicals for system installation and commissioning are complete and that the pretreatment system is operating normally and effectively; Otherwise, please do not open the membranes packaging bag until all the above items have been confirmed.

Load

Open the packaging box and carefully take out the membrane from the packaging bag; Check if the position and direction of the brine seal ring (Y ring) on the membrane is correct (the opening direction of the Y ring should be facing the water inlet direction, as shown in Figure 1.1); Take out all the membranes to be installed and place them in vertical order.

Figure 1.1:



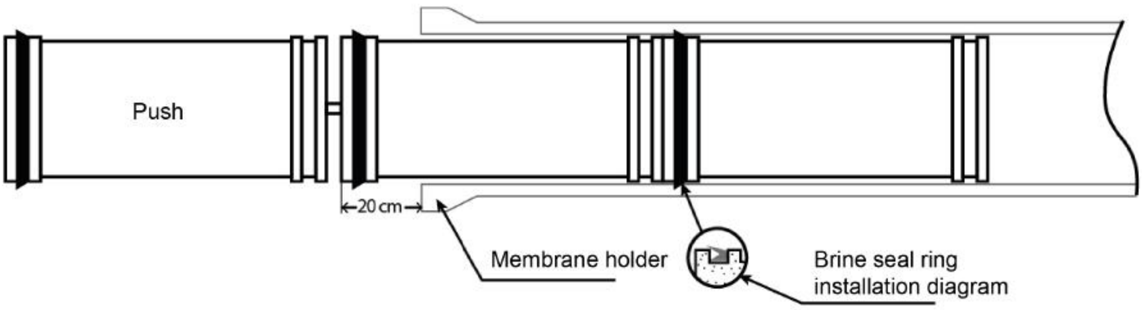
Lubricate the Y-ring seals and coat the tube with a very thin layer of glycerin. Then push the membrane in parallel on the feed water end of the membrane cap (pay attention to put the end first without the Y ring first) to the end of the membrane with Y ring seals which is about 7.87 in to the feedwater end of the membrane cap (as shown in Figure 1.1) Always load membranes at the feedwater end of the membrane holder.

Installation of multiple membranes

Install the interconnector on the permeate tube (as shown in Figure 1.1), lubricate the O-rings of the interconnector and the inside of the product water tube with a very thin layer of silicone lubricant. Check the O-ring for damage and be careful not to twist the O-ring for installation.

As shown in Figure 1.2, hold the membrane (referred to as "push" out of the membrane of the membrane cap and insert the central connector element of the membrane tube that has entered the membrane cap into it (be careful that the weight of the membrane is not supported by the interconnector), and then push the "push" element of the membrane into the membrane cap (be careful not to damage the membrane by collision with the edge of the membrane cap).

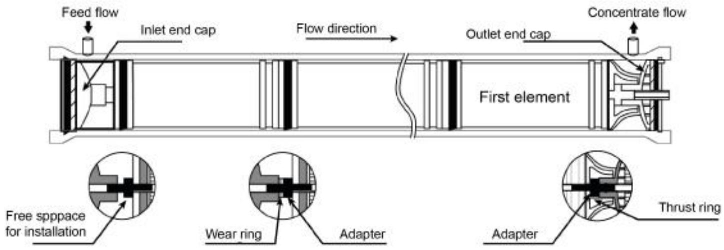
Figure 1.2:



Repeat steps "3" and "4" until the membrane cap is full of membranes.

As shown in Figure 1.3, correctly combine the membrane adapter, thrust ring and concentrated water end plate. Align the concentrated water end plate assembly with the "first" membrane center tube and push it into the membrane cap in parallel. Align with the external connecting tube and secure with screws or retaining ring on the end plate.

Figure 1.3:



Push the membrane from the entry site into the concentrated water, until the "first" membrane is firmly connected with the concentrated water end plate assembly. Then install the end plate on the inlet side.

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

Repeat these steps until all membranes are loaded into the membrane caps.

Disassembly

1. Disconnect the tubing at each end of the membrane cap, remove the connecting components.
2. Remove the head assemblies from each end of the membrane cap.
3. Use a PVC pipe or other disassembly tool to push the membrane from the opposite concentrated water connection end, until the membrane is exposed from the concentrated water end. Note that only one membrane is pushed out at a time. When the membrane is pushed out of the membrane cap, it must be collected in time. Support the membrane to avoid damage to the membrane or personal injury (at the same time, be careful not to let the connector support the weight of the membrane).
4. Soak the removed membrane with "1.0% sodium bisulfite standard protection solution, place it in a clean plastic bag, and seal it for storage."

1.2. REVERSE OSMOSIS SYSTEM OPERATION

Initial start-up

1. The initial start-up of the system is normally carried out just after loading the membranes.
2. For starting-up, the following optional accessories can be part of the on-site equipment: Safety glass, thermometer, pH meter, conductivity meter, ORP meter, water sample bottles, SDI measuring equipment, scale for weighing an item, analysis equipment for water samples total hardness, calcium, total alkalinity, chloride, free chlorine, sulfate, silica, iron and other indications.
3. Before starting up the reverse osmosis system, make sure the entire pretreatment section is operating according to specifications. Perform pretreatment effluent water quality inspection, ensure the following water membrane system indicators are stable or qualified: Stable feed water flow, pollution index (SDI15), turbidity (NTU), residual chlorine and other oxidants, concentration of reducing agent (if used to remove residual chlorine), conductivity, pH, temperature, bacteria count, hardness, etc.
4. Reverse Osmosis System Pre-Start Checklist:
   - All equipment from supply source to membrane, including piping, vessels, instruments and dosing systems, meet anti-corrosion requirements and are compatible with the pH range of daily operations and chemical cleaning.
   - All pretreatment devices have been backwashed or rinsed and are clean.
   - The cartridge filter is installed or replaced with a new filter. Do not use surfactants, lubricants, fabrics, etc.
   - Confirm that the feed water piping has been flushed effectively and all dust, grease, lubricating oil, metal debris, etc. have been removed.
   - The dosing device is in a normal and operational state.
   - If chlorine is used for pretreatment, provisions are in place to ensure complete removal of chlorine prior to the membranes.
   - The planned instrumentation is installed and operational. And it allows the correct operation and monitoring of the pretreatment and RO system.
   - Pressure relief protection is installed and configured correctly.
   - Provisions are in place to prevent the permeate pressure from exceeding the feed/concentrate pressure by more than 0.03 MPa or 4.4 psi at any time.
   - All interlocks, time delay relays and alarms are correctly configured.
   - Ensure that each membrane cap can be sampled individually.
   - Ensure that reverse osmosis systems and each stage of feed water, permeate water, and concentrate water can be sampled.
   - Membrane cap and cleaning pipe are properly connected.
   - The membrane caps are correctly fixed in the bracket.
   - All membrane caps are filled with membranes, or the membrane is securely and effectively fixed in the membrane caps and cannot move. Membrane caps are properly and securely installed with end caps.
   - All membrane caps are connected securely and correctly, especially check the clamp joints and membrane cap joints.
   - The permeate flow control valve is in the open position.
   - The permeate flow by reverse osmosis and nanofiltration membrane devices can be discharged directly.
   - The concentrate flow control valve is in the open position.
   - Adjust the outlet valve and bypass valve of the high-pressure pump to control the inlet water flow of the reverse osmosis and nanofiltration membrane devices to be less than 50% of the normal operating water inlet.
5. Start the sequence of reverse osmosis systems:
   - Check all valves to ensure correct settings. The feed pressure control, permeate control, and concentrate control valves must be fully open.
   - Fill all the vessels at pressure and pipes with permeate water from the qualified low-pressure, low-flow pretreatment system to ensure air is purged from the membrane caps and pipes; Flush

at a gauge pressure of (0.2-0.4) MPa or (30-60) psi; All permeate water and concentrated water should be discharged, and at the same time check all valve pipe connections for leaks during this process.

- The system with a wet membrane must be flushed for at least 30 minutes; The dry membrane system must be flushed continuously at low pressure for 6 hours or more.
- Before starting the high-pressure pump, the inlet control valve between the high-pressure pump and the membrane must be almost completely closed.
- When starting the high-pressure pump, slowly open the outlet water control valve of the high-pressure pump and slowly close the concentrated water control valve. While maintaining the concentrated water flow, pay attention to the increase of permeate water flow and adjust it at any time to achieve the designed permeate flow; Pay attention to checking the operating pressure of the system to ensure that the upper design limit is not exceeded.
- Check if the dosage of all chemical agents is consistent with the design value and determine the pH value of the feed water.
- After the system runs continuously, check the permeate conductivity of each membrane cap to determine if there are leaks or other failures of the membrane and membrane cap O-rings.
- When checking the permeate water quality, open the permeate water supply valve, close the discharge valve, and introduce the permeate water into the water tank.
- Record all data from 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 (list of system parameter monitoring items):

No.	Measurement element	Unit	Minimum detection frequency
1	System permeate flow rate (stage)	m^3 /h	2 times a day
2	System concentrate flow rate	m^3 /h	2 times a day
3	Operational pressure	MPa (psi)	2 times a day
4	1st stage of concentrate pressure	MPa (psi)	2 times a day
5	System concentrate pressure	MPa (psi)	2 times a day
6	TDS Inlet	µS/cm	2 times a day
7	TDS Outlet	µS/cm	2 times a day
8	TDS Concentrated Flow	µS/cm	2 times a day
9	$SDI_{fifteen}$	/	2 times a day
10	Turbidity	NTU	2 times a day
11	Temperature	°C	2 times a day
12	pH	/	2 times a day
13	ORP	mv	1 time every 4 hours
14	Residual chlorine	mg/L	2 times a day

1.3. SHUTDOWN THE REVERSE OSMOSIS EQUIPMENT

Precautions for turning off reverse osmosis systems

1. Stop the high pressure pump.
2. Let reverse osmosis systems operate by rinsing at a low pressure setting of 0.3 MPa or 44 psi to enhance the rinsing effect of the membrane under a high flow concentrated water discharge.
3. Systems should preferably be flushed with permeate water or alternatively with high quality feed water, completely replacing the concentrated water in the membrane holder and membrane until the conductivity of the concentrate matches the conductivity of the feed water.
4. Low pressure discharge water should not contain chemicals used for pretreatment, especially scale inhibitors.
5. When shutting down, make sure the membrane cap is completely filled with high-quality water (best if using reverse osmosis systems), and install check valves on the concentrate water and permeate lines.
6. After flushing the system, the concentrated water discharge valve and the permeate water discharge valve are completely closed.
7. No operation may cause the back pressure on the permeate water side to exceed 0.03 MPa or 4.4 psi.

Membrane storage

1. Most of the membranes are dry type, a small part of wet type membranes are qualified sampling products in the manufacturing process.
2. The wet membrane should be stored in food grade sodium bisulfite 1% standard protective fluid. It is sealed with packaging bag when sold outside the factory. Must be used within 90 days. If it cannot be used, it should be replaced with the same protective liquid.
3. The membrane should always remain moist after being wet, avoid the membrane remaining upright for a long period; If it accidentally dries out, the membrane's water flux can be irreversibly lost.
4. Storage the wet membrane should be immersed in "1.0% sodium bisulfite standard protective fluid" prepared with reverse osmosis water and food grade sodium bisulfite; in winter, it should be added to "1.0% sodium bisulfite of standard protective liquid" to 10% glycerol to prevent freezing; The protective fluid must be replaced every 90 days.
5. Whether dry or wet membranes are used or reused, they should be stored in a vacuum sealed packaging state; The packaged membrane should be stored in its box, and the storage location should be cool, dry and away from direct sunlight.
6. Storage temperature of dry membrane: ≤ 30°C or 86°F (for E series models ≤ 45°C or 113°F), long-term storage after sealing.
7. Storage temperature of wet membrane: 32-86°F (for E series models: 32-113°F).

Reverse Osmosis Systems Shutdown Protection

1. Short-Term Shutdown: If the reverse osmosis system needs to stop working in less than 48 hours, the following protective measures can be taken:
   - Flush the system with membrane permeation water.
   - Fill the membrane cap with the membrane to prevent it from drying out, air entering and microbes growing.
   - Reverse osmosis systems should be flushed according to the above method every 24 hours. If the ambient temperature is higher than 80.6°F, the discharge frequency should be set to once every 12 hours.
2. Extended Shutdown: If reverse osmosis systems must stop operating for more than 48 hours, the following protective measures can be taken:
   - Use chemical cleaning methods to sterilize reverse osmosis systems.
   - Fill the membrane cap with "1.0% sodium bisulfite standard protective fluid" prepared with the membrane to prevent drying, air entry and microbial growth.
   - Check the pH value of the protection fluid regularly and replace the protection fluid when the pH value is less than 3.

2. PRETREATMENT OF REVERSE OSMOSIS SYSTEMS

2.1. IMPORTANCE OF PRETREATMENT

Reverse osmosis or nanofiltration technology is one of several water treatment methods. A complete and effective reverse osmosis or nanofiltration membrane system includes the following three necessary components: raw water pretreatment device, reverse osmosis or nanofiltration membrane device, and aftertreatment device. The main function of reverse osmosis or nanofiltration membrane is to separate or remove water which usually 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 excess 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 matter suspended will gradually accumulate on the membrane.

Internally, membranes become contaminated, blocked and scaled, the operational efficiency of reverse osmosis systems is reduced and permeate water quality is reduced. It can be seen that the operation of reverse osmosis systems fails, in most cases, due to the imperfect functioning of the pretreatment systems. To extend the life of membrane and reverse osmosis systems, the necessary pretreatment devices should be used to effectively remove suspended solids, colloids, microorganisms and other impurities in the raw water, control the precipitation of insoluble salts , ensure the quality of reverse osmosis feed water or nanofiltration membrane device, so that the membrane can work in healthy condition. Additionally, selection of appropriate and necessary pretreatment devices can significantly improve the energy efficiency of reverse osmosis membranes and systems, reduce system downtime, reduce the cleaning frequency of reverse osmosis or nanofiltration membrane devices, and reduce costs. system operations. Therefore, pretreatment is an important and necessary guarantee for the stable operation of reverse osmosis systems.

2.2. ESSENTIAL CONCEPTS

Pure water

Pure water entering reverse osmosis systems generally includes: permeate water from reverse osmosis/nanofiltration system, surface water, groundwater, reclaimed water, seawater or other liquid materials, etc.

1. **Reverse Osmosis/Nanofiltration System 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 the membrane inlet.
2. **Surface water:** The general term of dynamic water and static water on the earth's surface, also called "land water", which includes various liquid and solid water masses, mainly rivers, lakes, swamps, glaciers, polar 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, corresponding pretreatment processes such as flocculation and sedimentation, MF, multimedia UF and sterilization can be used to make the water quality meet the requirements of membrane inlet.
3. **Ground water:** It refers to various forms of gravity water buried below the surface. Groundwater is generally relatively clean, with low suspended solids 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 must choose a suitable pretreatment process according to the actual situation.
4. **Reclaimed water:** Also known as reclaimed water, it refers to water that can be used beneficially after wastewater or stormwater is properly treated to achieve a certain water quality index and meet certain usage requirements. For compliant reclaimed water, refer to the surface water pretreatment plan. The current mature solution is double membrane treatment.
5. **Seawater:** The salt content is generally (25,000 - 35,000) mg/l, which can be understood as surface water with high salt content. Affected by the high salt content of seawater, seawater desalination systems must have extremely high osmotic pressure. To ensure the stable operation of the reverse osmosis system, generally the recovery rate of the seawater desalination system is less than 50%.
6. **Other feeding liquids:** Through combinations of different reverse osmosis systems and nanofiltration systems, different solutes can be separated in some feed liquid. This process is affected by different processes and feed liquids, so you need to test and confirm the proper pretreatment process yourself.

Incrustation

As the permeate flow is continuously drained and raw water is concentrated during the operation of the reverse osmosis system, the undissolved salt exceeds its saturation limit and causes deposition, this phenomenon is called scaling. This phenomenon first appears at the end of the reverse osmosis system and gradually appears on the inlet side as it is caused by the concentration of the raw water. Embedding will occur in a very short time due to incorrect operation (system recovery rate is too high). Common insoluble salts and scales are: $CaCO_3$, $Case_4$, $BaSO_4$, $SrSO_4$, CaF_2, $Ca_3(P.O._4)_2$, (SiO_3^{2-}) etc.

Pollutants

Impurities such as insoluble solids, colloids, organic matter, microorganisms in raw water gradually deposit and adsorb on the surface of the membranes, causing the performance of reverse osmosis systems to decrease. This phenomenon appears mainly on the entrance side. Common fouling are: colloidal and particulate matter (silt, clay, activated carbon dust, 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 destruction of the membrane. After such impurities are cleaned, 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 performance caused by changes in chemical properties in the membrane separation layer. Mainly in the decrease in permeate flow and rejection rate. The main substances that affect the degradation of membranes are oxidants (residual chlorine, potassium permanganate, ozone and other oxidants), too high or too low of the pH value of the cleaning agent, excess temperature, etc.

2.3. CONVENTIONAL PRETREATMENT METHODS

1. **Multimedia filter**

   Multimedia filter is a process in which one or more filter media is used to pass water with higher turbidity through a certain density of granular or non-granular materials under a certain pressure, thus 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. $B.O.D._5$ 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 media filter can refer to some related literature.

2. **Flocculants and coagulants**

   Flocculant is a group with positive electricity (negative) and particles with positive electricity (negative) which are difficult to separate in water close to each other, lower the electric potential, make it unstable, collect the particles through polymerism, and they are separated by physical or chemical methods. Flocculants are mainly used in the fields of water supply and wastewater treatment. There are many varieties of flocculants, from low molecular weight to high molecular weight, from single types to compounds.

   Inorganic flocculants are cheap, but have an adverse effect on human health and ecological environment; Although organic polymer flocculants have small dosage, small foam production, strong flocculation capacity that relieves separated flocs, and good removal effect of oil and suspended solids, but the residual monomers of this type of polymer will cause malformations, cancer, mutation, which limits its application; Microbial flocculants have no secondary pollution, are easy to use, and have attractive application prospects, so they can completely or partially replace traditional inorganic polymers and synthetic organic polymer flocculants in the future.

3. **MF, UF**

   Microfiltration (MF) and ultrafiltration (UF) can effectively remove insoluble solids suspended in water. Under a certain pressure, small molecular weight solutes and solvents pass through a special membrane with a certain pore size, the macromolecular solutes are impermeable and on one side of the membrane, so the macromolecular is partially purified. Ultrafiltration technology is a type of membrane separation technology. It is a process in which under external pressure, colloids, particles and high molecular weight substances are retained, water and small solute particles pass through the membrane. The MF/UF should be cleaned/backwashed regularly to restore performance after use.

4. **Precision filter**

   Precision filter (also known as safety filter), the cylinder shell is generally made of stainless steel, the interior uses PP cast, wire burning, folding, titanium filter, activated carbon filter and other tubular filter elements as elements filter elements, select the filter element according to different filter media and design process to meet the effluent quality requirements. Precision filters are typically used as the last pretreatment process to protect high-pressure pumps and membrane from impact damage and fouling caused by welding slag, particles, impurities, etc. It is normally recommended to select a precision of 5 μm. The filter element of the precision filter should be replaced regularly according to the pressure difference or use time (service life should not exceed three months). It is not recommended to reuse the filter to avoid contamination with microorganisms and bacteria.

2.4. SDI (COLLOID, PARTICLE)

Sedimentation density index (SDI) is one of the important parameters of water quality indicators. Shows the content of particles, colloids and other objects that block purification equipment in the water. You 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 an industry-recognized standard test method. SDI value is one of the important indicators to measure the input water of reverse osmosis system in the water treatment process. It is the primary solution for inspecting whether the output water of pretreatment systems meets the input water standard of reverse osmosis systems. It is very important for the operation of the system. The SDI value measures the flow attenuation through a 47 mm diameter, 45 µm pore membrane. Colloid is easier to block the membrane than particles (such as sand, scale, etc.) with a pore of 0.45 µm. The flow attenuation is converted to a value between 1 and 100, which is the SDI value, the lower the SDI value, the less water blocking it causes to the membranes. Considering economy and efficiency, most membrane manufacturers recommend that the SDI value of the influent be no more than 5.

(ASTM4189-95) SDI Measurement

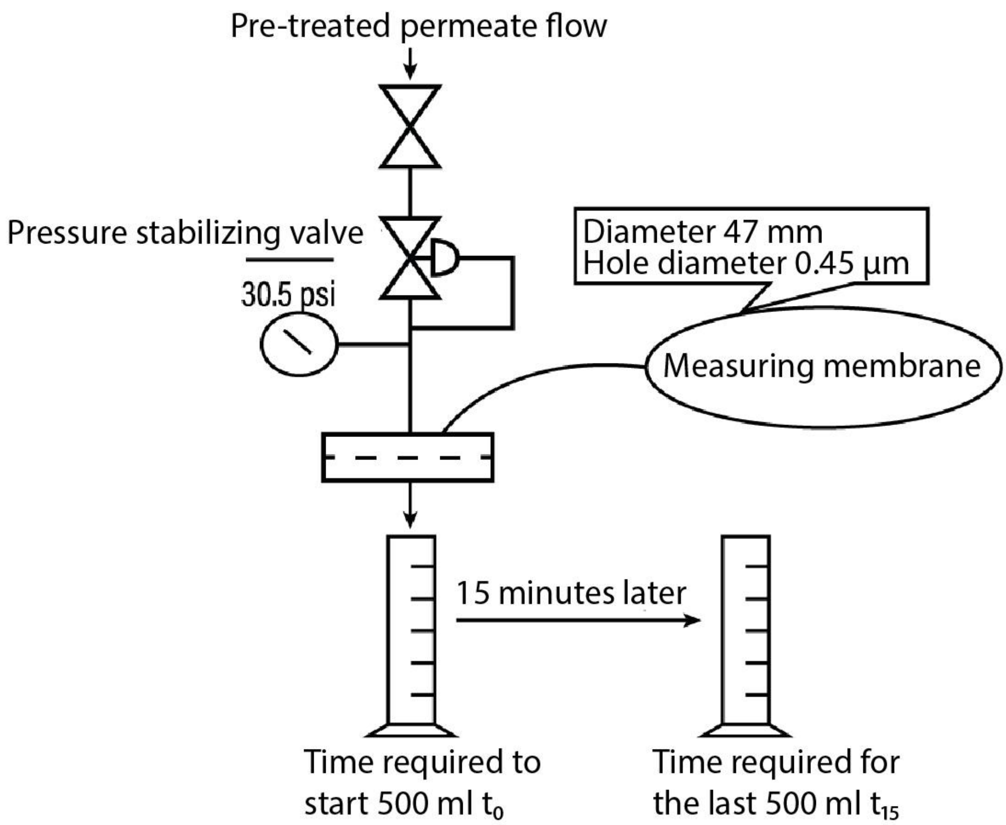
The SDI measurement is based on the measurement of the blocking coefficient (PI,%). The measurement is to continuously add the water (under a certain pressure 0.2MPa or 30 psi) to the Φ47mm 0.45µm microporous filter membrane, record the time T, (seconds) to filter 500 ml of water and the time T, (seconds)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

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

"15" means 15 minutes. When the contaminants in the water are high, it can take 100mL, 200mL, 300mL of water to filter. The interval time can be changed to 10 minutes, 5 minutes, etc. The "15" in the calculation formula is adjusted to 10 or 5 as appropriate.

Measurement steps

1. Connect the SDI analyzer to the sampling point (do not install the membrane).
2. Open the analyzer valve and flush the system thoroughly for several minutes.
3. Close the analyzer valve and then use blunt forceps to place the 0.45 µm filter membrane on the filter holder.
4. Confirm that the O-ring is in good condition, place the O-ring on the filter membrane accurately, and then cover the upper half of the filter membrane fitting and fix it with bolts.
5. Open the valve slightly and slowly loosen 1-2 wing bolts to remove air from the filter membrane when water flows.
6. Make sure the air is completely discharged and keep the water flow continuous, tighten the valve again.
7. Open the valve fully and adjust the pressure regulator, until the pressure stays at 0.2 MPa or 30 psi (if the pressure can't reach 0.2 MPa or 30 psi, then try the current pressure, the pressure can't be lower at 0.1 MPa or 15 psi).
8. Use a suitable container to collect the water sample and begin recording with a chronometer when the water enters the container. The time to collect 500 ml of sample water is T_i (seconds).
9. When the sample water flows 15 minutes (including the time to collect the initial water of 500 ml), use the container to collect 500 ml of sample water again and record the time as T_f.
10. Close the ball valve, loosen the valve on the microporous membrane filter container and remove the membrane from the filter for storage.
11. Dry the microporous filter and microporous membrane support orifice plate.
    Figure 1.4:



Basic SDI principle diagram

Calculation method

1. If the feed water pressure is 0.2 MPa or 30 psi during measurement, substitute the data obtained during the measurement process into the following formula to calculate the SDI value: SDI = $[(1-T_i/T_f) * 100] / 15$
   Where T_i: time required for the first 500 ml sample collection (unit: second) T_f: Time required for the second 500 ml sample collection (unit: second).
2. When the pressure value cannot reach 0.2 MPa or 30 psi during the measurement process, the existing pressure value can be used instead, but the measured SDI value must be converted to the value one under conditions of 0.2 MPa or 30 psi . The method is the following:
   $\%Pp = (1-T_i /T_f) * 100$ (%Pp is the blocking index at a non-standard pressure of 0.2 MPa or 30 psi)
   SDI = %Pp30 / 15

2.5. SCALE PREVENTION

For salinity in concentrated water less than 1%, the possibility of $CaCo_3$ scale formation can be judged by the LSI_c value.

$LSI_C = pH_C - pH_s$

Where: pH_C is the pH value of the concentrated water; pH_s is the pH value when $CaCo_3$ It is saturated.

When $LSI_c \geq 0$, $CaCO_3$ It will have scale.

Most untreated raw water has an LSI value$_c$ positive. To avoid $CaCO_3$ scaling, measures such as adding scale inhibitor or resin softening to the feed water of the reverse osmosis system should be used.

Softening by softener (ion exchange method)

Ion exchange refers to the exchange of ions in a solid ion exchanger with others in a dilute solution to achieve the purpose of extracting or removing some ions in solution. Ion exchange resin is the main part of the softening system. In reverse osmosis system, ion exchange resin is generally used to remove hardness and alkalinity from water and prevent scale formation in reverse osmosis system. Strong acid cationic resin can be replaced with Na+ ions or remove scale cations with Ca^{2+}, Ba^{2+} and Sr^{2+}in water. The saturated resin can be regenerated with salt (NaCl). Proper operating conditions and timely resin regeneration can effectively eliminate the risk of carbonate and sulfate scale in the system, and can also reduce TDS in water. But it should be noted that ion exchange can cause changes in the pH value of the water.

Adding scale inhibitor

Fouling can decrease permeate flow rate and increase salt passage, which can affect the normal operation of reverse osmosis/nanofiltration systems and shorten membrane life. Scale inhibitor is a kind of agent that can disperse insoluble inorganic salts in water and prevent or interfere with the precipitation and formation of scale. They can be used to control carbonate, sulfate and calcium fluoride scale. In general, there are three different types of scale inhibitors: sodium hexametaphosphate (SHMP), organophosphonates with compound and mainly environmentally friendly phosphorus-free PAPEMP. The choice of scale inhibitor can be based on the models recommended by pharmaceutical manufacturers.

The dose of scale inhibitor: the dose of general water quality is 3-5 ppm (standard solution). It is recommended that the quality of the recovered water be 8 ppm - 10 ppm. The specific doses should also be determined according to the static or dynamic scale inhibition experiment of feed water quality and the scale inhibitor manufacturer's calculation software to ensure the application effect of scale inhibitor.

It should be noted that overdose should be avoided, because excessive scale inhibitors are also membrane contaminants. At the same time, ensure 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 contaminate the surface of the scale. membrane.

Setting system operating parameters

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

2.6. CONTROL OF MICROORGANISM INCRUSTATIONS

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

Disinfection

Microbial contamination will seriously affect the performance of membranes, which is mainly due to the gradual decrease of water flux and gradual increase of operating pressure difference, and the slow decrease of salt rejection. To avoid microbial contamination, raw water is usually sterilized.

The fungicide can effectively control the growth of microorganisms in the reverse osmosis 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. Oxidizing bactericides destroy the enzyme system of bacteria with the function of agenic oxidation to achieve the purpose of sterilization. Common oxidizing bactericides include sodium hypochlorite, ozone, hydrogen peroxide, etc. Since oxidizing bactericides include sodium hypochlorite, ozone, hydrogen peroxide, etc.

Since oxidizing bactericides have strong oxidizing properties, reductant such as sodium bisulfite should be added when the reverse osmosis system is working. Real-time detection is required to ensure that the feed water does not contain residual chlorine. Non-oxidizing bactericides mainly rely on penetration into bacteria or after being hydrolyzed in water and form a complex precipitation with some bacterial components to achieve sterilization effect. Commonly used non-oxidizing bactericides include DBNPA, isotizolinone, etc.

Oxidant removal

Although oxidant bactericides can inactivate microorganisms quickly and effectively, oxidants can also destroy the separation layer of membranes and shorten the service life. Therefore, the oxidation-reduction potential of the feedwater must be closely monitored to ensure that the oxidant in the crude oil is removed. Special attention to tap water (existence of chlorine), reclaimed water (certain sterilization step), UF (backwash sterilization, etc.), circulating water (certain oxidizing agents), contaminated groundwater, surface water, etc. usually removed by reducer. In some small systems, activated carbon devices can be used to remove oxidants from the water.

Sodium bisulfite

Sodium bisulfite is the common reducer and bactericide that 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 3 mg/L of sodium bisulfite to restore 1 mg/L of free chlorine.

2.7. PREVENTION OF ORGANIC POLLUTION

Organics with complex chemical properties and chemical composition commonly exist in various waters and can be found with different types and concentrations, which will directly or indirectly affect the physical, chemical and biological properties of the water. Once organics enter the reverse osmosis system, they gradually adhere to the membrane surface as the raw water concentrates, causing the permeate flow of the reverse osmosis system to attenuate.

Under certain special circumstances, it will cause an irreversible loss of membrane flux. Therefore, adopt flocculation, ultrafiltration, adsorption and other methods to remove organic matter from the reverse osmosis system.

Organic contamination is similar to colloid contamination. Alkaline cleaning and other cleaning methods can be used when cleaning the system. In the application of some reverse osmosis systems for both water loss and material separation, practical or small tests should be carried out according to each liquid to determine the restorative ability of the membrane, after the cleaning caused by the organic contamination and the feasibility of separating the material.

2.8. PREVENTION OF POLLUTION BY IRON, MANGANESE AND OTHER OXIDES

When there is a high content of iron or manganese ions in the pure water (more than 0.05 mg/L), iron (manganese) contamination may be present in the reverse osmosis system, due to the effect of chemical properties, frequency of iron contamination is obviously higher than that of manganese contamination. The main methods to prevent iron contamination are to control the contact between pure water and air or oxidant, to reduce the pH value of pure water. Generally speaking, we can remove iron and manganese ions in water through ion exchange, flocculation, advanced oxidation and then filtration, synchronous oxidation method, etc.

2.9. SUMMARY OF PRETREATMENT OPTIONS

Options	Difficult dissolved salts	Iron and manganese	Microorganism	Organic material	Oxidizer	High SDI	Silicate
Flocculation				Possible		Effective	
Scale inhibitors	Effective						
Ion exchange	Effective						
System control							Effective
MF/UF			Possible	Effective		Effective	Effective
Activated carbon				Effective	Effective		
Restore					Effective		
Rust sterilization			Effective				
Oxidation Filtration		Effective					

3. Mesh portafilters

3.1. CLEANING THE REVERSE OSMOSIS SYSTEM

Cleaning tips

Reverse osmosis system cleaning method: Physical and chemical cleaning.

Physical cleaning is a “washing” process. It refers to the use of "low pressure and high flow" water at the entrance of the membrane concentration channel to remove contaminants and deposits adhering to the membrane surface. Typical discharge pressure is less than 60 psi (0.4 MPa), flush 8-inch membranes with feedwater at 7.2 - 12 m^3/h, 4 inch membranes with feed water at 1.8 - 2.5 m^3/h.

Physical washing will be done frequently. After the reverse osmosis system has been operating for some time, the reverse osmosis and nanofiltration membranes will become contaminated with mineral scale, biological matter, colloidal particles, and insoluble organic components.

Deposits accumulate on the membrane surfaces during operation, which will not cause a drop for normalized permeate flow and normalized salt rejection, separately, or both elements must be chemically cleaned when the parameters mentioned below occur, physical washing can no longer restore the performance of reverse osmosis and nanofiltration membrane.

- Normalized permeate flux drops by 10% to 15% or more.
- The normalized pressure difference (between feed pressure and concentrate pressure) increases by 15% or more.
- Normalizing the salt passage increases 10-15% or above.

Physical cleaning is recommended before chemical cleaning.

Confirmation of embedding type

Before chemical cleaning, it is important to determine the type of fouling on the membrane surface. The best way to determine the type of fouling is to perform chemical analysis of the debris collected on the SDI test diaphragm to determine the major types of contaminants and then perform specific chemical cleaning.

In the absence of chemical analysis, according to the determination of SDI, the color and density of the residue on the flat sheet of the membrane can be measured, and then the fouling can be classified.

For example, if it is brown, there may be incrustations from iron scales. If it is white, probably silicon scale, sandy clay, calcium scale, etc.

The appearance of the lens is characteristic of inorganic colloid and calcium scale. Biofouling or organic material is usually viscous, except in odor analysis.

Choice of cleaning agents

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

- If the raw water has greater hardness, the membranes are more prone to fouling with scale, they are usually cleaned with acidic chemicals; Raw water with organic content is likely to cause organic contamination on the membrane, generally alkaline chemicals will be used for cleaning.
- When the system is dominated by salt scale, it is recommended to drain first and then clean with alkali; When the system is mainly contaminated by organic matter, it is recommended to adopt alkali cleaning first, then brine cleaning and alkali cleaning.

Pollutants	Chemical cleaning solutions	Cleaning conditions
Carbonate scale	0.2% hydrochloric acid HCl	Temperature ≤ 95°F; pH > 2
	0.5% phosphoric acid H_3PO_4	Temperature ≤ 95°F
	2.0% citric acid $C_6H_8O_7$	Temperature ≤ 95°F; Adjust pH to 3 with ammonia
Sulfate scale	0.1% Sodium hydroxide NaOH 1.0% Tetrasodium EDTA EDTA-4Na	Temperature ≤ 86°F; pH ≤ 12
	0.1% Sodium hydroxide NaOH 0.025% Sodium Dodecylbenzenesulfonate Na-DDBS	
Oxide	1.0% Sodium Dithionite $Na_2S_2O_4$	Temperature ≤ 86°F; pH 4 - 6
	0.5% Phosphoric acid H_3PO_4	Temperature ≤ 86°F; pH > 2
	2.0% Citric acid $C_6H_8O_7$	Temperature ≤ 86°F; Adjust pH to 3 with ammonia
Colloid	0.1% Sodium hydroxide NaOH 0.025% Sodium Dodecylbenzenesulfonate Na-DDBS	Temperature ≤ 86°F; pH ≤12
Organic material	0.1% Sodium hydroxide NaOH 0.025% Sodium Dodecylbenzenesulfonate Na-DDBS 0.2% Hydrochloric acid HCl	Temperature ≤ 86°C The first step is to use NaOH and Na-DDBS, pH ≤ 12 The second step is to use HCl > 2
	0.1% Sodium Hydroxide NaOH 1.0% Tetrasodium EDTA EDTA-4Na 0.2% Hydrochloric acid HCl	Temperature ≤ 86°F The first step is to use NaOH and EDTA-4Na, pH ≤ 12 The second step is to use HCl, pH > 2
Microorganism	0.1% Sodium hydroxide NaOH 0.025% Sodium Dodecylbensulfonate Na-DDBS	Temperature ≤ 86°F; pH ≤12
	0.1% Sodium hydroxide NaOH	

Cleaning steps

1. Low pressure washing of reverse osmosis systems with produced 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 media flushing pipeline; Turn on the cleaning pump and inject the cleaning solution into the membrane holder to start the cleaning cycle operation. The cleaning cycle time is (1-2) hours for one time.
4. The cleaning cycle begins for 5 minutes, is carried out at an amount of 1/3 of the set flow rate, and then approximately every 10 minutes, the cycle flow rate is gradually increased from 2/3 of the set flow rate to the full flow rate for circulation.
5. After the first cleaning, the membrane should be rinsed with product water and then replaced with another cleaning solution.
6. Real-time detection of turbidity and pH value of 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, first flush the system with low pressure and gradually extract and increase the pressure until the produced water is qualified.
8. If the membrane is severely clogged, or the flux recovery is not obvious after cleaning, the cleaning solution can be introduced into the membrane holder and the cleaning solution can be kept in the membrane rack and soak the membrane. for (6-12) hours before the second circulating cleaning time.
9. For "multi-stage system" cleaning, the rinse and soak process can be performed on all sections at the same time; but the high flow cycle cleaning process should be carried out in stages to facilitate control of circulation flow during each cleaning stage.

Cleaning attention

1. Before beginning chemical cleaning, make sure the chemicals used in the cleaning solution are completely dissolved and mixed.
2. Cleaning the reverse osmosis system with "low pressure and high flow" will cause a large pressure drop. It should be noted that the maximum allowable pressure drop for inlet and concentrated water of a single element is 0.1 MPa or 15 psi, and the maximum allowable pressure drop for membrane holders with multiple membranes is 0.35 MPa or 50 psi.
3. Cleaning pH limit: When the solution pH = 1 or 13, it can efficiently clean scale, organic compounds and biomembranes. In the case of this pH-limiting cleaning, the temperature of the solution must be controlled in the cleaning process to ensure that the membrane components are not damaged.
4. Cleaning temperature limit: During normal chemical cleaning, the solution temperature should be controlled at (86-95)°F; for extreme cleaning, the temperature of the solution should be controlled within 86°F; Try to avoid chemical cleaning in a low temperature environment, and solution temperature ≥ 68°F should be used to ensure cleaning efficiency and avoid precipitation.
5. After chemical cleaning, before normal operation of the reverse osmosis system is restored, the system must be flushed with system water or with water that meets the inlet flow requirements of the reverse osmosis system. Chemical cleaning is completed only after the cleaning solution residue in the system has been completely flushed.

3.2. REVERSE OSMOSIS SYSTEM DISINFECTION

System disinfection

To prevent bacterial growth, the reverse osmosis system should be disinfected regularly or before the system is shut down for an extended period. It is recommended to use 1.0% sodium bisulfite solution for soaking.

Disinfection care

- The water used to prepare the disinfectant solution must be free of residual chlorine or other oxidants.
- Avoid using oxidizing disinfectants, which can cause oxidation damage to the membrane.

4. TROUBLESHOOTING

Common failures of reverse osmosis and nanofiltration systems include: abnormal performance of initial installation and degradation of system performance after stable operation. It manifests itself mainly in:

- System rejection is reduced.
- Systematic changes in permeate flow rate.
- Abnormal changes in system operating pressure (pressure differential). Abnormal changes in system performance should be analyzed under the operation data to exclude various external factors. Judge the possible cause and location of the abnormality through the abnormal changes of the data, conduct further tests to determine the cause of the abnormality, and take corresponding measures. Typical failure or abnormality of reverse osmosis system will be described below.

4.1. MEMBRANE SELECTION AND SYSTEM DESIGN ERRORS

Common abnormalities in the initial installation performance of the system are mainly shown in abnormal permeate flow and rejection rate. Most initial installation anomalies are related to membrane selection and system design errors.

Common exceptions include: high salt content of raw water, leading to system water production unable to meet design requirements; The selection of membrane (especially nanofiltration membrane) makes the desalination rate of the system too low or too high (some mineral water projects), etc.

Therefore, it is necessary to understand the raw water condition and water production requirements of the user's system and, if necessary, a pilot test will be needed.

4.2. EFFECT OF TEMPERATURE

Temperature is one of the main reasons that affect the permeate flux of membranes.

Affected by molecular activity, the higher the temperature, the lower the water viscosity (temperature correction coefficient increases) and the increase in water flow.

See more details at: Appendix 1 "Temperature Correction Factor Table for Permeate Flow" [31]

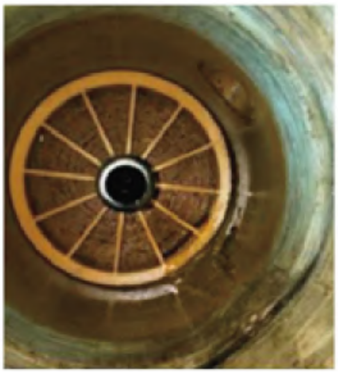
4.3. POLLUTION BY SUSPENSIONED PARTICLES

Suspended particle contamination occurs mainly in the case of pretreatment failures or defects in pretreatment design.

Such as incomplete washing of media filters, poor quality filter materials, failure of broken ultrafiltration filaments, and pretreatment paralysis caused by sudden changes in raw water.

The failure occurs at the front end of a section of the membrane (near the high pressure pump end). The main system operating data is shown below:

Permeate flow	Decreases
Rejection	Increase or no change
Pressure diferencial	Increase
Fault location	Mainly in front of a stage




When particle pollution occurs, it is necessary to check whether the pretreatment is complete and the changes in the raw water, and the corresponding treatment measures should be taken according to the actual situation to ensure that the input water of the reverse osmosis system meet incoming water quality requirements.

For more information, see: "INLET WATER QUALITY REQUIREMENTS FOR MEMBRANE SYSTEMS [29]"

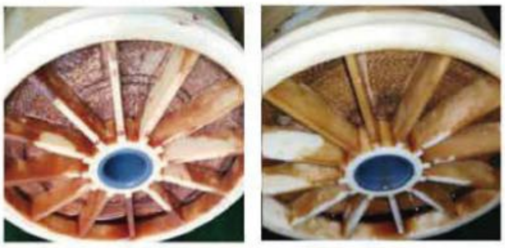
4.4. ORGANIC POLLUTION

Organic contamination occurs primarily in systems in which the raw water is surface water, reclaimed water, wastewater, or contaminated groundwater.

It can be confirmed by detecting COD and BOD_5 of raw water. Organic contamination can occur at any stage and an alkaline flush can usually be used to restore system performance.

The main methods of system operating data performance are as follows:

Permeate flow	Decreases
Rejection	Increase or no change
Pressure diferencial	Normal
Fault location	Any location



Organic contamination usually occurs with microbial contamination, and an alkaline wash can usually be used to restore system performance. See more details at: "CLEANING THE REVERSE OSMOSIS SYSTEM [19]".

Organic contamination can be eliminated by replacing the pretreatment filter material, and it is necessary to improve pretreatment to avoid organic contamination.

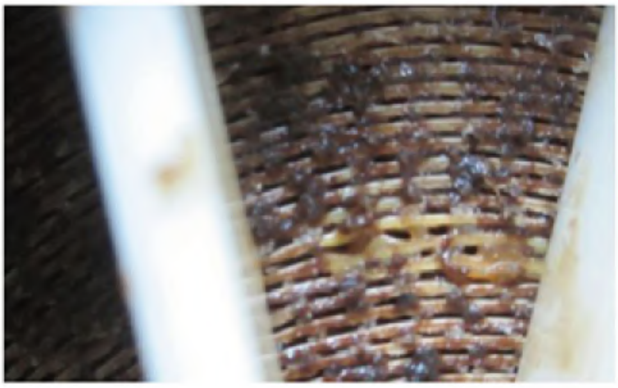
4.5. COLLOIDAL CONTAMINATION

Colloidal contamination occurs primarily in systems that use surface water or contaminated shallow groundwater as a supply source.

It can be judged from the SDI value of raw water. If the SDI value of raw water is high, the possibility of colloidal contamination of the membrane element is very high.

The main system operating data is shown below:

Permeate flow	Decreases
Rejection	Normal or slightly decreased
Pressure diferencial	Increase
Fault location	Mainly in the front of the first stage



Severe colloidal contamination is generally difficult to clean, and different cleaning schemes should be adopted according to the actual conditions for different colloidal contamination. For more information, see: "CLEANING THE REVERSE OSMOSIS SYSTEM [19]".

When colloidal contamination occurs, it is necessary to confirm if the pretreatment system (multimedia filter, ultrafiltration system), etc., has faults or overload, and optimize the pretreatment system according to the actual situation.

4.6. MICROBIAL CONTAMINATION

Microbial contamination is one of the most common in the system.

It mainly occurs in systems that use raw water such as surface water, reclaimed water, wastewater or contaminated groundwater as a supply source, and is usually accompanied by organic contamination (to provide nutrients for microbial reproduction).

This anomaly is usually confirmed by the total number of colonies in raw water or produced water. The main system operating data is shown below:

Permeate flow	Decreases
Rejection	Normal or slightly decreased
Pressure diferencial	Increasing
Fault location	Any location

Medical washing and disinfection are normally used to solve contamination by abnormal microorganisms. For more information, see: "CLEANING THE REVERSE OSMOSIS SYSTEM [19]".

Due to the strong reproduction of microorganisms, the source of contamination must be found for specific sterilization; Otherwise, the microorganisms will multiply again in a short time, resulting in repeated fouling of the system.

4.7. RUST SCALES

Rust scale generally occurs from system feed water containing iron, manganese, aluminum, etc.

Some water supply systems that use untreated cast iron pipes will also have a rust scale. It occurs predominantly at the front end of the reverse osmosis system. The main system operating data is shown below:

Permeate flow	Decreases
Rejection	Decreases
Pressure diferencial	Normal or increased
Fault location	At the top of the first stage

Iron contamination can usually be cleaned with citric acid or sodium dithionite. For more information, see: "CLEANING THE REVERSE OSMOSIS SYSTEM [19]".

For metal rust scale, the measure is to use oxidation filter equipment, such as manganese sand filter or other pretreatment methods, to remove metal oxides according to the actual condition.

4.8. INORGANIC SALT INCAUSTATIONS

Inorganic salt incrustations is one of the most common contaminations in systems.

It occurs mainly due to the insoluble salt that the concentrated water reaches at saturation.

It is deposited on the membrane surface after precipitation and typically occurs at the end of the reverse osmosis system. In some cases, scaling occurs in a short time (a few hours or even less). The main operating data of the system are:

Permeate flow	Decreases
Rejection	Decreases
Pressure diferencial	Increases
Fault location	At the end of the first stage

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 more information, see: "CLEANING THE REVERSE OSMOSIS SYSTEM [19]".

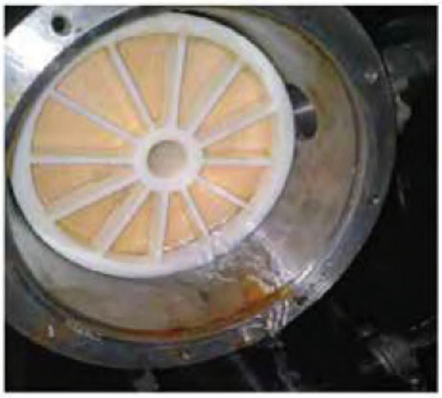
Severe scaling can cause irreversible damage to the membrane. Generally, methods such as ion exchange, adding scale inhibitors, reducing the recovery rate, and lowering the pH of raw water can be used to control the occurrence of scale.

4.9. O-RING LEAKS

O-ring leaks usually occur at the initial installation and debugging stage of the system or occur suddenly after the system is in operation.

It first shows up as a sudden drop in the system's rejection rate. It can be confirmed by detecting the conductivity of water produced by a single membrane cover and confirm the abnormal point by probe method experiment. The main system operating data is:

Permeate flow	Increase s
Rejection	Decreases
Pressure diferencial	Maintains or decreases
Fault location	Any location




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 slips on the membrane cover)

4.10. OXIDATION

Membrane oxidation generally occurs in systems that use tap water, circulating water, contaminated groundwater, and water reclaimed as raw water.

In some cases, improper post-treatment of oxidizing fungicides, raw water containing hexavalent chromium, potassium permanganate and other substances will lead to oxidation and destruction of membrane elements. The main operating data of the system are:

Permeate flow	Increases
Rejection	Decreases
Pressure diferencial	Normal
Fault location	Any location, especially in front of the first stage

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

4.11. OTHER ANOMALIES

Membrane back pressure

The back pressure of the membrane is mainly due to the excessive pressure on the permeate water side (high pressure in the pure water pipe or system operation error), the separation layer of the membrane sheet is peeled off. The raw water then enters the pure water system from where the membrane sheet is detached, causing the rejection rate of the system to decrease.

Abnormal system performance is similar to O-ring leakage. The abnormal location can be confirmed by the probe method. Membrane backpressure can occur at any location.

Excessive pressure differential, water hammer impact

After the membrane element becomes dirty, the pressure difference 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 plastic) of the membrane element may be damaged (burst or broken) or the concentrated channel spacer of the membrane element may be washed out. This damage may not change the rejection rate of the system in a short time, but it will affect the life of the membrane element.

For such problems, he suggests improving pretreatment to reduce the possibility of membrane fouling. The solution, such as soft start of the high-pressure pump, reduces the impact of water hammer on the membrane.

Lubricant

Petroleum lubricants, detergents, etc. They can damage the membrane permeate collection tube due to their complex composition. Therefore, we only recommend using glycerin (glycerol).

4.12. ANALYSIS AND SOLUTION OF COMMON FAULTS

Analysis and solution of common faults

No	Permeate flow	Rejection rate	Pressure diferencial	Cause of the error	Solution
1	Decreases	Increases	It keeps	Densification of the flat membrane sheet due to water hammer	Replace the membrane Improving the reverse osmosis system
2	Decreases	It keeps	It keeps	Organic contamination	Chemical cleaning Improving pretreatment
3	Decreases	Decreases little	Increases	Microbial contamination	Chemical cleaning Disinfection Improving pretreatment
4	Decreases	Decreases	Increases	Colloidal contamination or scale	Chemical cleaning Improving pretreatment
5	Increases	Decreases	It keeps	O-ring leak	Inspect or replace O-ring
6	Increases	Decreases	It keeps	Back pressure or oxidation	Replace the membrane

Trial for contamination of the common system

No	Pollution type	Feed water pressure change	Change in pressure differential	Rejection rate change	Possible location of the fault
1	Organic Salt Embedding	Increases	Increases	Decreases	At the tip of the final stage
2	Organic contamination	Increases	It keeps	Increases or remains the same	Throughout the membrane
3	Rust scale	Increases rapidly	Increases rapidly	Decreases rapidly	On the front of the first stage
4	Biological contamination	Increases rapidly	Increases rapidly	Decreases rapidly	Any location
5	Colloidal contamination	Increases slowly	Increases slowly	Slowly decreases	On the front of the first stage
6	Fouling contamination	Increases	Increases	Decreases	At the end of the stages
7	Silicon polymerization tanks	Increases	Increases	Decreases	At the end of the last stage

Failure analysis steps

1. Please confirm if the reverse osmosis system works abnormally.
2. Please confirm if the reverse osmosis system has been turned off for a long time and if it has been turned off during maintenance.
3. Please confirm if the pretreatment of the reverse osmosis system or the chemical dosing system is normal.
4. Confirm if the reverse osmosis system is used under proper inlet water temperature, TDS or pH conditions.
5. Please confirm if the inlet water flow rate and water recovery rate of the reverse osmosis system are normal.
6. Confirm if the pressure differential of the reverse osmosis system (inlet water pressure - concentrated water pressure) is normal.
7. Confirm if all instruments have been calibrated.
8. Perform standardized calculations on the flow and quality of production water.
9. Measure product water quality section by stage and membrane holder.
10. Check if the seal of each pressure vessel is damaged.
11. Check the reverse osmosis system safety filter for contaminants.
12. Check if the membrane is contaminated or damaged.
13. Sampling and analysis of water quality data of reverse osmosis system input 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 value calculated from the reverse osmosis system design.
15. Determine potential contaminants based on changes in water quality, flow rate, and pressure drop after standardization.
16. Clean scale and expected contaminants.
17. Analyze contaminants contained in the cleaning solution and changes in the color and pH of the cleaning solution.
18. Submit the membrane for non-destructive analysis and determine the cleaning plan.
19. Perform anatomical analysis and laboratory analysis of the membrane to determine contaminants.

5. INLET WATER QUALITY REQUIREMENTS FOR MEMBRANE SYSTEMS

Items		Allowable value	Probable consequence of an excessive standard	Improvement suggestion
Suspended solids	Turbidity	< 1.0 NTU	Mud, colloidal contamination	Sedimentation by flocculation, filtration, microfiltration, ultrafiltration
	SDI_{15}	< 5.0		
Oxides	Fe (mg/L)	< 0.05	Iron contamination	Oxidation + precipitation or filtration
	Mn (mg/L)		Manganese contamination	Use dispersant
Scale-forming material	$CaCO_3$	LSI < 0	Scale	Decrease recovery rate, pH value, or add scale inhibitor
	Si (mg/L)	< 20		
	Other insoluble salt	/		
Organic	Oil	0	Organic and oil pollution	Air flotation
	TOC (mg/L)	< 5	<Organic and microbial contamination	Activated carbon absorption, Filtration
	COD_{cr} (mg/L)	< 15		
	BOD_5 (mg/L)	< 10		
pH		3 - 10	A pH that is too low or too high will accelerate aging	Acid-base regulation
Temperature		39.2°F - 113°F	Low temperature will easily produce scale from undissolved salt. High temperature will accelerate the aging speed of the membrane	Heat exchanger
Oxidizer	Residual chlorine (mg/L)	< 0.1	The reverse osmosis system will oxidize	Absorption of activated or reducing carbon
	Ozone and others	0		

NOTE

1. The membrane has a certain ability to resist residual chlorine (200 ppm - 1,000 ppm RH), and when under different temperatures, pH values and other conditions, the damage rate of residual chlorine is different from aromatic polyamide membrane. Therefore, it should ensure the residual chlorine of feed water below 0.1 mg/L
2. Iron and manganese in feed water cannot be more than 0.05 mg/L, which is usually dissolved in water with insoluble divalent or trivalent hydroxide. If the concentration of iron and manganese is greater than 0.05 mg/L and the air oxidizes them to form $Fe(OH)_3$ and $Mn(OH)_2$, will have precipitated in the reverse osmosis system when the pH value is higher than the standard level.
3. Silicon exists in most natural water bodies, the concentration varies from (1 - 100) mg/K, and when the pH of the water body is less than 9.0, it exists mainly 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 a precipitation of hydrates 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 be transferred to be CO_3^{2-}. The raw water will be concentrated in the RO and NF system process, so it is easy to extract $CaCO_3$ of the embedding matter in the system.
5. If one or more of the above indicators do not meet, it may have the following influence to the membranes or permanent damage:
   - The suspended solid can clog the membrane, even after severe colloidal contamination.
   - A growing production of COD_{cr} can occur as a result of organic and microbiological contamination.

6. APPENDIX 1: TEMPERATURE CORRECTION FACTOR TABLE FOR PERMEATE FLOW

°C	+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

Note: [Corrected permeate flow] = [Standard permeate flow at 25°C] / [Temperature correction factor corresponding to inlet water temperature]

7. APPENDIX 2: COMMONLY USED UNITS AND CONVERSION RATIOS IN THE MEMBRANE INDUSTRY

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

No.	Project	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5
1	Volume	L	gal (US)	m^3	mL	cc (cm^3)
2	Length/Thickness	cm	mm	µm	inches	mil
3	Area	m^2	ft^2			
4	Flow	m^3/h	gpd	gpm	L/h	L/min
5	Pressure	bar	psi	MPa		
6	Conductivity	µS/cm	mS/cm	S/m	mS/m	
7	Fluid	gfd	L/m^2.h(LMH)			
8	Mass	kg	g	lb		
9	Temperature	°C	°F			
10	Solution concentration	mg/L	mmol/L			

Volume:	1L	= 0.2642 gal(US)	= 0.001m^3	= 1 000 mL	= 1 000 cc (cm^2)
Length/Thickness:	1cm	= 10 mm	= 10 000 µm	= 0.3937"	= 393.70 mil
Area:	1m^2	= 10.7639 ft^2			
Flow:	1 m^3/h	= 6 340.13 gpd	= 4.4029 gpm	= 1 000 L/h	= 16.6667 l/min
Pressure:	1 bar	= 14.5038 psi	= 0.1MPa	= 1.0197 kg-f/cm^2	
Conductivity:	1 µS/cm	= 0.001 mS/cm	= 0.0001 S/m	= 0.1 mS/m	
Fluid:	1 gfd	= 1.6977 L/m^2.h/KMH)			
Mass:	1kg	= 1 000g	= 2.2046 lb		
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 is used to measure the total content of all ions in water, usually expressed in ppm.
- Ppm (parts per million) means parts per million; The ppm concentration expressed by the mass of solute in parts per million of the mass of the total solution, also known as parts per million concentration; The ppm concentration is often used when the concentration is very small. For solutions, ppm generally refers to mass concentration and ppm is mg/L.