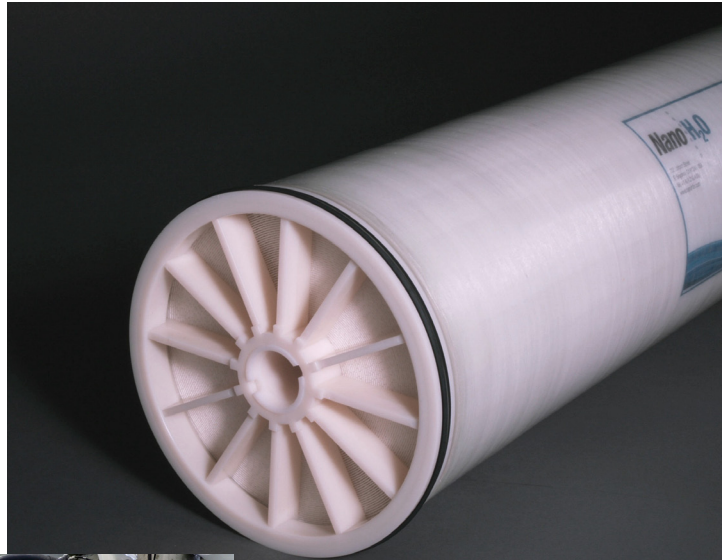


QuantumFlux (Qfx)

Seawater Reverse Osmosis (RO) Element

Technical Manual



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Notice: The use of this product in and of itself does not necessarily guarantee the removal of cysts and pathogens from water. Effective cyst and pathogen reduction is dependent on the complete system design and on the operation and maintenance of the system.

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Receipt of Elements and Short-Term Storage - TB 101

After receipt of NanoH₂O Qfx™ elements, correct handling and storage are necessary to ensure that the elements remain intact prior to installation and use.

Receiving Inspection

After a shipment arrives, conduct a visual inspection of all packages to confirm that:

1. Shipment arrived without damage to the packaging or its contents.
2. All packages listed on the packing list arrived in good order.

Please notify your carrier or freight forwarder and a NanoH₂O Customer Service Representative **IMMEDIATELY** of any damaged goods or product shortages.

Storage

Maintain elements in their original shipping containers and store in a protected area that is **NOT** subject to extreme heat (greater than 40°C/104°F) or freezing temperatures.

- Qfx elements should **NOT** be stored in areas exposed to direct sunlight.
- Qfx elements should **NOT** be stored in areas where damage can occur from moving equipment such as forklifts and pallet jacks.

For long-term (greater than 60 days) storage, periodically re-inspect the shipping containers to ensure that there is no physical damage or leakage. Any leakage may indicate a loss of integrity of the membrane element preservative.

Element loading guidelines provide recommendations to ensure proper and safe installation of NanoH₂O Qfx™ membrane elements in reverse osmosis (RO) system pressure vessels.

System Flushing

Prior to loading the membrane elements, new systems should be thoroughly flushed with pretreated feedwater to ensure the absence of construction debris, solvents, chlorine or other contaminants that may be harmful to the elements.

Pressure Vessel Preparation

The interior walls of the pressure vessels must be thoroughly cleaned prior to loading membrane elements in order to prevent dust, construction debris or other foreign matter from being deposited onto the membrane surface during start-up. Simply hosing down the interior of the vessels with freshwater is NOT adequate to clean the vessels thoroughly. NanoH₂O recommends the use of a sponge ball wrapped in a cloth or towel that has been soaked in a 50% solution of glycerin and water. The cleaning ball may either be pulled through the vessel when attached to a rope or pushed through the vessel when mounted to a PVC flange affixed to an appropriate length of PVC pipe. Use appropriate **CAUTION** to ensure that the inside surface of the vessel is not scratched or damaged during cleaning.

Membrane Element Storage

Qfx elements should be maintained in their original shipping packaging and stored in accordance with “Receipt of Elements and Short-Term Storage - TB 101” guidelines (page 3).

CAUTION

DO NOT use oil, grease, petroleum jelly or other petroleum-based compounds to lubricate O-rings or brine seals. Food-grade glycerin may be used for O-ring and brine seal lubrication either directly or in a water-based solution. Approved lubricants for interconnector O-rings, end adapter O-rings or membrane element brine seals include glycerin, silicon-based Molykote III, or other silicone-based lubricants that do not contain hydrocarbons. Contact Technical Support at NanoH₂O for further assistance.

Vessel Shimming Procedures - TB 103

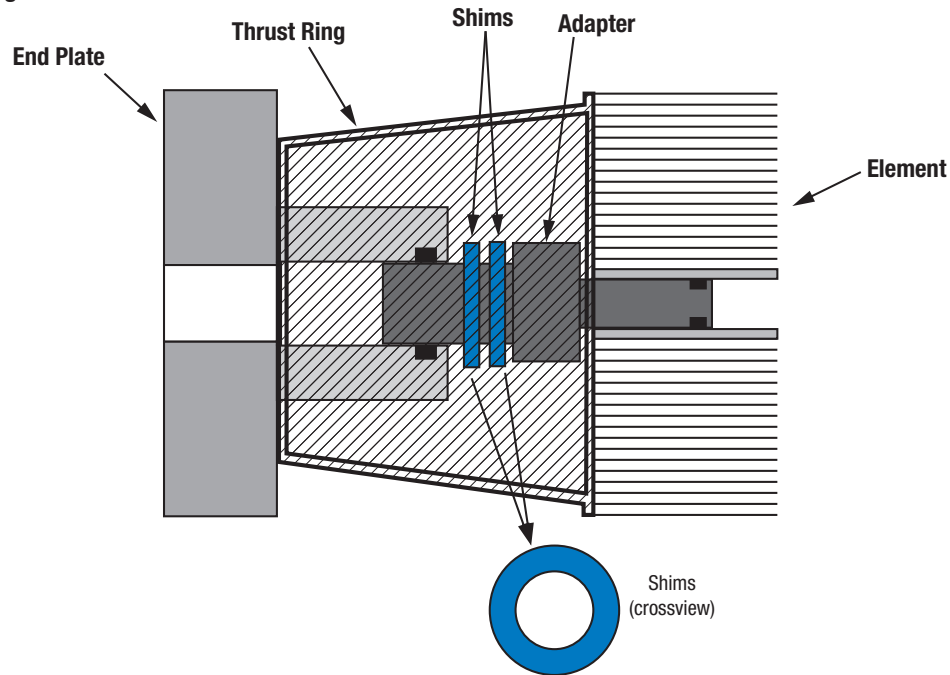
Vessel Shimming

Because the face-to-face end plate dimensions may vary among pressure vessel manufacturers, NanoH₂O **strongly recommends** that the element stack within the pressure vessel be shimmed to remove any excess slack. This slack can result in interconnector uncoupling and excessive stack movement during shutdown and start-up.

To ensure the removal of excess slack from the element stack within each pressure vessel, NanoH₂O recommends the following method:

1. Install the REJECT-side end plate and push the element stack all the way toward the REJECT-end until the element stack is well seated against the REJECT-end end plate.
2. Prepare PVC spacers of varying thickness ranging from 3.17 to 9.52 mm (1/8 to 3/8 inches). These may be cut from a length of PVC pipe with a diameter that will fit over the feed-side adapter.
3. Install as many shims as necessary over the FEED-side inboard adapter until the end plate fits snugly against the shims while allowing the end plate to be installed. If supplied, install thrust ring before placing the end plates. A gap of approximately 6.34 mm (¼ inch) between the end plate and the shims is permissible and should not result in interconnector decoupling or other performance issues (Figure 103.1).

Figure 103.1



Membrane Element Start-up/Shutdown Procedures - TB 104

The first time NanoH₂O Qfx™ elements are placed in service and during normal operational start-up and shutdown, certain precautions MUST be observed to help ensure stable long-term performance from the Qfx elements. Below are the normal procedures and precautions for initial start-up and subsequent operation.

Feedwater Requirements

- **Free Chlorine**

Qfx membrane elements show some resistance to short-term chlorine (hypochlorite) exposure. The free chlorine tolerance of the membrane is < 0.1 ppm. Continuous exposure, however, may damage the membrane and should be avoided. Under certain conditions, the presence of free chlorine and other oxidizing agents will cause premature membrane failure. Since oxidation damage is not covered under warranty, NanoH₂O recommends removing residual free chlorine by pretreatment prior to membrane exposure.

CAUTION

Confirm that feedwater introduced to the membrane elements contains no more than 0.1 ppm of free chlorine. Membrane element damage resulting from operation beyond this limit is irreversible and will void the NanoH₂O product or performance warranty.

- **Turbidity**

Confirm that RO feedwater turbidity and fouling potential, as measured by a 15-minute silt density index (SDI₁₅), are within the limits specified on the Qfx product data sheet or in the NanoH₂O product or performance warranty. Please refer to “Silt Density Index Procedure (SDI₁₅) - TB 107” for more information. During system start-up, spikes of high turbidity may pass through the pretreatment system until the pretreatment system stabilizes. These spikes will result in membrane fouling that decreases permeate flow and requires operation at higher pressures to compensate for the decreased flow.

CAUTION

Membrane elements that have been fouled will suspend and may void (if the foulants cannot be completely removed by chemical cleaning) any product or performance warranty issued by NanoH₂O related to permeate flow and/or operating pressure.

- **Temperature**

Confirm that RO feedwater temperature is within the limits specified on the Qfx product data sheet. Operation at temperatures exceeding 45°C (113°F) under the high pressure conditions required for SWRO can result in the weakening and compression of the porous polysulfone layer supporting the thin-film membrane. This compression can result in compaction that permanently reduces the permeate flow through the membrane. Please contact a NanoH₂O sales representative or technical support team member if you are considering system operation with feedwater temperatures that exceed these limits.

CAUTION

Impaired membrane permeability caused by high temperature compaction will void any product or performance warranty issued by NanoH₂O related to permeate flow and/or operating pressure.

- **Other Feedwater Conditions**

Prior to introducing the feedwater to the membrane elements, confirm that all other feedwater composition, properties and limiting conditions are in full compliance.

CAUTION

Failure to comply with limiting conditions may void any product or performance warranty issued by NanoH₂O.

Membrane Element Start-up/Shutdown Procedures - TB 104

Initial Start-up Requirements

- **Pre-Flushing**

Prior to installing the membrane element(s), the system or train MUST be flushed to remove any entrained air in the pressure vessel (“Membrane Element Flushing - TB 109”).

- **Element Loading**

Confirm that the Qfx™ elements were correctly loaded and that all O-rings and brine seals were properly installed. Confirm that the elements in each pressure vessel were properly shimmed to remove excess slack in the pressure vessel (“Vessel Shimming Procedures - TB 103”)

- **Vent Entrained Air**

Initiate a low pressure flush at 1 - 1.4 bars (15 - 20 psig) to ensure that all air is purged from the membrane elements and pressure vessels prior to ramping to normal operating pressures. The low pressure flush should be performed with the permeate valves open to drain, the concentrate control valve (the valve that controls the ratio of concentrate flow to permeate flow) fully open, and with a soft-start mechanism or variable speed drive.

CAUTION

Failure to remove entrained air can result in mechanical damage to the membrane elements due to high hydraulic forces resulting from water hammer.

Notes:

When flushing a membrane element, the permeate valves should be open to drain and the concentrate control valves should also be fully open to avoid damaging the membrane elements. For any flushing operation to be effective, the volume used for flushing should exceed the liquid hold-up volume of the membrane elements. For standard 8-inch x 40-inch elements, assume the hold-up volume is 37.85 liters (10 gallons) for each membrane element. For standard 4-inch x 40-inch elements, assume the hold-up volume is 11.35 liters (3 gallons) for each membrane element. To ensure the highest quality permeate stream, discard the first hour’s worth of permeate after initial start-up.

Operating Requirements - System Start-up

- **Concentrate Control Valve Operation**

Prior to train or system start-up, confirm that the concentrate control valve is in the fully open position.

CAUTION

NEVER start up a train or system with the concentrate control valve fully or partially closed. After feedwater is introduced to the train or system with the concentrate control valve fully open, slowly close the valve until the desired recovery is achieved. Starting a train or system with the concentrate control valve fully or partially closed can over-pressurize the system, damage the membrane elements, burst piping and create a safety hazard. Train or system permeate recovery should NEVER exceed the maximum safe permeate recovery as recommended by NanoH₂O or by its Q⁺ Projection Software.

- **Control Rate of Pressurization During Start-up**

No train or system should be brought online (pressurized) at a rate faster than 0.7 bar (10 psig) per second.

Membrane Element Start-up/Shutdown Procedures - TB 104

CAUTION

Rapid pressurization of a train or system can cause mechanical damage to the membrane elements. Such damage can include: cracking of the outer fiberglass shell, failure of the anti-telescoping device and membrane telescoping. Mechanical damage to membrane elements caused by overly rapid pressurization or over-pressurization will void any product or performance warranty.

Operating Requirements - System or Train Shutdown

- **Element Flush**

Following system or train shutdown, it is required that the membrane elements be flushed with RO feedwater to remove the high concentration of salts contained in the membrane elements. An RO system or train should NEVER be shut down without immediately flushing the high TDS concentration from the membrane elements.

CAUTION

Failure to remove the high TDS concentration of the hold-up volume in the membrane elements may result in damage to the elements.

Notes:

When flushing a membrane element, the permeate valves should be open to drain and the concentrate control valves should also be fully open to avoid damaging the membrane elements. For any flushing operation to be effective, the volume used for flushing should exceed the liquid hold-up volume of the membrane elements. For standard 8-inch x 40-inch elements, assume the hold-up volume is 37.85 liters (10 gallons) for each membrane element. For standard 4-inch x 40-inch elements, assume the hold-up volume is 11.35 liters (3 gallons) for each membrane element. To ensure the highest quality permeate stream, discard the first hour's worth of permeate after initial start-up.

Membrane Element Operating Precautions - TB 106

To obtain the maximum service life from your Qfx™ membrane elements, certain precautions should be followed to avoid element damage or impaired performance. Additional requirements may be outlined in your product or performance warranty and in other sections of this technical manual. Should there be a conflict between the values and information provided in this manual and in your warranty, the values and information provided in your warranty supersede those outlined in this manual.

Cautions Regarding Feedwater Quality, Operating Limits and Recommended Good Practices

Failure to observe **any** of the following may result in irreversible damage to your membrane elements, shorten the membrane element's useful life and void the product warranty.

- The maximum applied pressure shall NEVER exceed the value outlined in the Qfx product data sheet.
- The maximum permeate water recovery shall NEVER exceed the maximum safe water recovery specified by NanoH₂O's *Q⁺ Projection Software*.
- The RO feedwater shall contain NO more than 0.1 ppm of free chlorine.
- The RO feedwater shall contain NO concentration of oil or grease.
- The RO feedwater shall NEVER exceed a 15-minute Silt Density Index (SDI₁₅) of 5 or an NTU of 1. Please refer to "Silt Density Index (SDI₁₅) Procedure - TB 107" in this manual for more information on how to measure SDI.
- The RO feedwater shall NOT exceed a temperature of 45°C (113°F).
- The membrane elements shall be taken offline and chemically cleaned when the pressure differential (ΔP) reaches 1 bar (15 psi) per element and/or 3.8 bar (55 psi) for the housing.
- Only chemicals approved by NanoH₂O should be used in conjunction with the operation and maintenance of your membrane elements.
- The pH operating range shall be 2-11 pH. The pH cleaning range shall be 1-13 pH.

Cautions Regarding Permeate Valve Operation

RO membrane elements should **NEVER** be exposed to permeate backpressure exceeding the feed or concentrate static pressure. This potential issue is most frequently encountered during system or train shutdown.

The permeate valves **must remain open** during all phases of train or system operation including pre-start-up, flushing, cleaning and normal operation.

CAUTION

Closing the permeate valves during any phase of system or train operation will create a pressure differential across the tail-end membrane elements that can result in ruptured glue lines and an immediate increase in salt passage. Ruptured glue lines cannot be repaired.

The permeate valves may be closed after flushing and cleaning, following a complete system or train shutdown. It is good practice to fully close the permeate valves during extended periods of shutdown to prevent an aerobic environment in the pressure vessels that can lead to biological growth. Be sure to reopen the permeate valve(s) prior to introducing feedwater back into the system or train.

Membrane Element Operating Precautions - TB 106

Cautions Regarding Concentrate Valve Operation

Prior to train or system start-up, confirm that the concentrate control valve (the valve that controls the ratio of concentrate flow to permeate flow) is in the fully open position.

CAUTION

NEVER start up a train or system with the concentrate control valve fully or partially closed. After feedwater is introduced to the train or system with the concentrate control valve fully open, slowly close the valve until the desired recovery is achieved. Starting a train or system with the concentrate control valve fully or partially closed can over-pressurize the system, damage the membrane elements, burst piping and create a safety hazard. Train or system permeate recovery should NEVER exceed the maximum safe permeate recovery as recommended by NanoH₂O or by its Q⁺ Projection Software.

Cautions Regarding the Rate of Pressurization During Start-up

No train or system should be brought online (pressurized) at a rate faster than 7 bars (10 psig) per second.

CAUTION

Rapid pressurization of a train or system can cause mechanical damage to the membrane elements. Such damage can include cracking of the fiberglass outer-shell, failure of the anti-telescoping device and membrane telescoping. Mechanical damage to membrane elements caused by overly rapid pressurization or over-pressurization will void any product or performance warranty.

Chlorine Tolerance

Qfx™ membrane elements show some resistance to short-term chlorine (hypochlorite) exposure. The free chlorine tolerance of the membrane is < 0.1 ppm. Continuous exposure, however, may damage the membrane and should be avoided. Under certain conditions, the presence of free chlorine and other oxidizing agents will cause premature membrane failure. Since oxidation damage is not covered under warranty, NanoH₂O recommends removing residual free chlorine by pretreatment prior to membrane exposure.

CAUTION

Membrane damage caused by oxidation is irreversible and will void your product or performance warranty.

Cautions Regarding the Use of Lubricants

Petroleum-based lubricants should **NEVER** be used in conjunction with Qfx RO membrane elements. Approved lubricants for interconnector O-rings, end adapter O-rings or membrane element brine seals include glycerin, silicon-based Molykote III, or other silicone-based lubricants that do not contain hydrocarbons.

Membrane Element Operating Precautions - TB 106

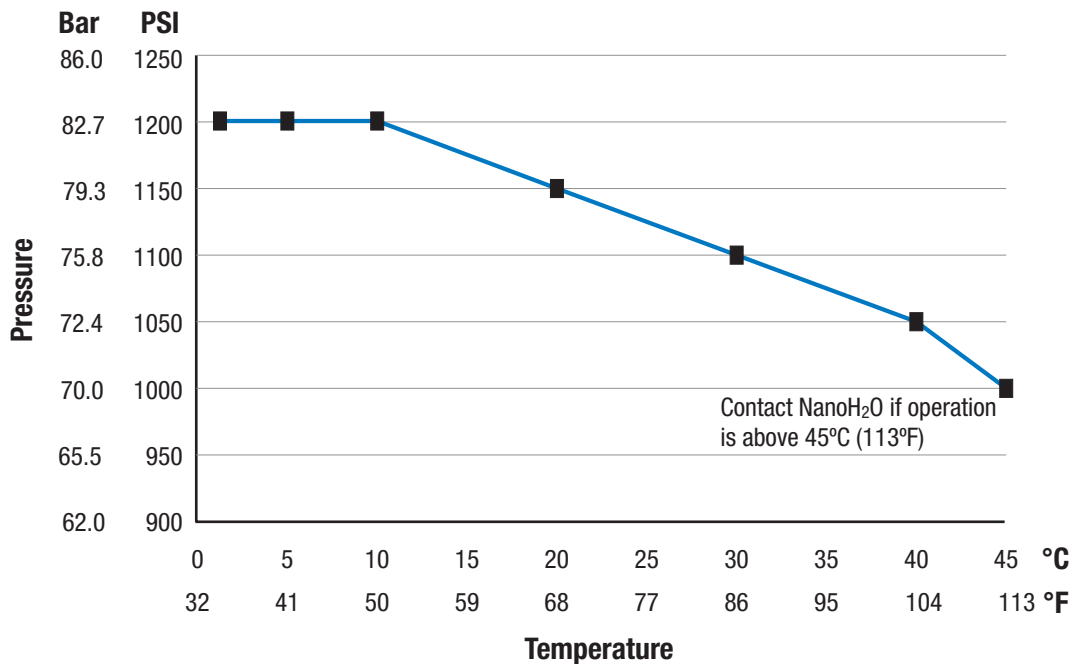
Cautions When Operating at High Temperature and High Pressure

Operation at temperatures exceeding 45°C (113°F) may result in compaction of the polysulfone support layer. Membrane compaction reduces permeability, resulting in higher feed pressure to maintain permeate flow.

CAUTION

Reduction in permeability from compaction caused by operation at feedwater temperatures and pressures that exceed NanoH₂O's recommended limits will void your product or performance warranty. Qfx™ membrane elements should be operated in compliance with the temperature and pressure recommendations outlined in the following graphs. Please contact NanoH₂O Technical Support for additional information.

Temperature vs. Pressure Operation Limits for Qfx Membranes



Membrane Element Flushing - TB 109

Prior to first use, it is strongly recommended that the membrane elements be flushed. Seawater RO membrane elements must also be flushed following system or train shutdown to remove highly concentrated salts from the membrane elements.

Remove Membrane Preservatives

The membrane elements are shipped after being immersed in a 1% bisulfite solution and drained.

After installation, the permeate produced for the first 10 minutes of plant operation should be discharged.

Pre-Flush of RO System at Start-up

Prior to installing the membrane element(s), the system or train **MUST** be flushed to remove any entrained air in the pressure vessel.

Prior to initial flushing, please ensure that the elements are correctly loaded and that all O-rings and brine seals are properly installed. Ensure that the elements in each pressure vessel have been properly shimmed to remove any excess slack in the pressure vessels.

Initiate a low pressure flush at 1 - 1.4 bars (15-20 psig) to ensure that all air is purged from the membrane elements and pressure vessels prior to ramping up the pressure to achieve normal operation. The low pressure flush should be carried out with the permeate valves open to drain, the concentrate control valve fully open and a soft-start mechanism or variable speed drive.

CAUTION

Failure to remove entrained air can result in mechanical damage to the membrane elements due to high hydraulic forces resulting from water hammer.

Notes:

When flushing a membrane element, the permeate valves should be open to drain and the concentrate control valves should also be fully open to avoid damaging the membrane elements. For any flushing operation to be effective, the volume used for flushing should exceed the liquid hold-up volume of the membrane elements. For standard 8-inch x 40-inch elements, assume the hold-up volume is 37.85 liters (10 gallons) for each membrane element. For standard 4-inch x 40-inch elements, assume the hold-up volume is 11.35 liters (3 gallons) for each membrane element. To ensure the highest quality permeate stream, discard the first hour's worth of permeate after initial start-up.

CAUTION

System pressurization and depressurization should be accomplished slowly and should not exceed 0.7 bar/sec (10 psig/sec).

Membrane Element Flushing - TB 109

Post-Flush of RO System at Shutdown

For seawater systems, it is ***strongly recommended*** that highly concentrated salts be removed from the system by flushing after every shutdown.

Following system or train shutdown, it is **REQUIRED** that the membrane elements be flushed with RO feedwater to remove the high concentration of salts contained in the membrane elements. An RO system or train should never be shut down without immediately flushing the high TDS concentration from the membrane elements.

CAUTION

Failure to remove the high TDS concentration of the hold-up volume in the membrane elements may result in damage to the elements.

Notes:

When flushing a membrane element, the permeate valves should be open to drain and the concentrate control valves should also be fully open to avoid damaging the membrane elements. For any flushing operation to be effective, the volume used for flushing should exceed the liquid hold-up volume of the membrane elements. For standard 8-inch x 40-inch elements, assume the hold-up volume is 37.85 liters (10 gallons) for each membrane element. For standard 4-inch x 40-inch elements, assume the hold-up volume is 11.35 liters (3 gallons) for each membrane element.

Silt Density Index (SDI₁₅) Procedure - TB 107

Protecting the Qfx™ membrane elements from particulate fouling minimizes energy use and allows stable long-term product performance. One of the most common methods to determine acceptable RO feedwater quality is the Silt Density Index (SDI). The SDI was developed to assess the membrane fouling potential of RO feedwater. An SDI test measures the time required to filter a specific volume of RO feedwater through a 0.45-micron filter paper at a feed pressure of 2.1 bars (30 psig). The following provides procedures required to determine RO feedwater SDI.

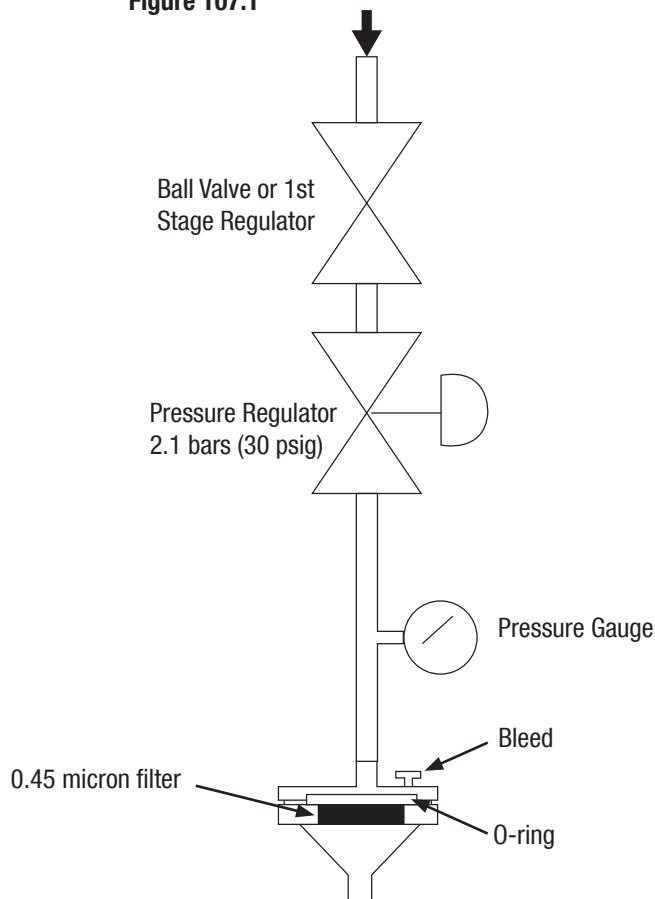
Test Equipment Setup

1. SDI kits may be purchased from NanoH₂O or may be assembled in accordance with Figure 107.1 below. Follow the SDI instructions on equipment setup.
2. Install the test equipment on a sample tap located on the feedwater piping. The sample should be downstream from all chemical dosing points, cartridge filters and immediately before the RO inlet manifold.
3. Install a new 0.45-micron filter pad in the filter housing and adjust the pressure regulator to 2.1 bars (30 psig).

Tips:

- Prior to use, thoroughly flush the test equipment to remove any contaminants to ensure an accurate result.
- Do not touch the filter pad. Use a dull pair of tweezers (to avoid puncturing the filter pad) to remove the pad from the package and place it in its proper position in the filter pad holder.
- Ensure that the O-ring is clean and properly seated.

Figure 107.1



Silt Density Index (SDI₁₅) Procedure - TB 107

Test Procedures

1. Measure the feedwater temperature, the temperature should not vary more than +/- 1°C (34°F) during the duration of the test.
2. Remove any entrained air from the filter holder housing by either opening the bleed valve or loosening the filter holder (depending on the model used) while slightly opening the ball valve. Once the air has bled from the housing, close the bleed valve or the filter housing.
3. Place a 500 ml (17 fl oz.) graduated cylinder under the filter housing to collect the volume of water that passes through the filter pad.
4. Fully open the ball valve and measure the time required (use a good quality stopwatch) to collect 100 ml (3.4 fl oz.) and 500 ml (17 fl oz.).
5. After five minutes, repeat the test. As before, measure the time required to collect a 100 ml (3.4 fl oz.) sample and a 500 ml (17 fl oz.) sample. Record the time intervals with the flow continuing to run through the filter housing.
6. Repeat the test at the 10-minute interval and again at the 15-minute interval.
7. If the time required to collect a 100 ml sample is greater than 60 seconds, plugging will be about 90% and it will not be necessary to continue the test.
8. After the 5, 10 and 15-minute samples have been collected, measure the water temperature to confirm that the temperature has not varied by more than +/- 1°C (34°F).
9. Upon the completion of the test, the spent filter pad should be sealed in a plastic bag, labeled with the time and date of the test and filed for future references.

Calculations

SDI is calculated using the following formula:

$$SDI = P_{30}/T_t = 100 \times (1 - T_i / T_f) / T_t$$

SDI	Silt Density Index
P ₃₀	% plugging at 2.1 bars (30 psig) feed pressure ²
T _t	Total test time in minutes ²
T _i	Time in seconds required to obtain the initial 500 ml (17 fl oz.) sample
T _f	Time in seconds to obtain the final 500 ml (17 fl oz.) sample

Notes:

1. The time required to collect a 500 ml (17 fl oz.) sample should be approximately 5-times greater than the time required to collect a 100 ml (3.4 fl oz.) sample. If the 500 ml (17 fl oz.) sample time is much greater than 5-times that of the 100 ml (3.4 fl oz.) sample, the SDI should be calculated using 100 ml (3.4 fl oz.) sample collection times.
2. The total test time is usually 15 minutes. However, it may be less than 15 minutes if 75% plugging occurs in less than 15 minutes. To obtain accurate SDI measurements, P₃₀ should not exceed 75%. If P₃₀ does exceed 75%, the test should be repeated to obtain T_i in a shorter period of time (T).

A useful diagnostic method to identify membrane performance problems within a pressure vessel is to probe the elements within the pressure vessel in order to identify O-ring or interconnector leaks, locate poorly performing elements, or to identify other problems. Vessel probing involves inserting a length of polyethylene tubing into the vessel permeate channel so that conductivity measurements can be taken from each element within the pressure vessel. If abnormally high conductivity is observed at any individual element, this may be an indication of a poorly performing membrane element, O-ring leak, decoupled interconnector, or other problem.

Setting Up the Equipment

1. Shut down the RO system or train containing the pressure vessel(s) to be probed.
2. Remove the permeate cap from the opposite end of the pressure vessel from where you intend to measure permeate conductivity.
3. Connect a 1¼ inch threaded coupling to the permeate port and thread a 1¼ inch x ½ inch threaded reducer bushing into the coupling. Next, thread onto the coupling a ½ inch nipple and DN 15 (½ inch) ball valve onto the assembly. Finally, thread a ½ inch Parker Fast & Tight male connector for use with DN 10 (3/8 inch) tubing. Remove the metal collar and O-ring from the Fast & Tight fitting.
4. Obtain a length of DN 10 (3/8 inch) O.D. polyethylene tubing. The length of tubing needs to be significantly longer than the length of the pressure vessel being probed.
5. Using a marking pen with permanent ink (non water-soluble ink), place a mark at the point where the furthest membrane element connects to the end adapter. This is the “total length” mark. Then, mark the tubing in 508 mm (20-inch) increments from that point forward. (Black tubing is not recommended as you must be able to observe the markings)

Probing Procedure

1. Close the ball valve on the probe fitting and restart the RO system or put the train back in service.
2. Allow the system or train to run for approximately 15 minutes to stabilize performance.
3. After performance has stabilized, insert the tubing into the Fast & Tight fitting while opening the ball valve. Insert the tubing down the length of the permeate channel until the “total length” mark is reached.
4. After approximately one minute, measure the conductivity of the water coming out of the tubing. Repeat the reading several times to confirm that the values are consistent. Record the conductivity and the location from which it was taken.
5. Retract the tubing 508 mm (20 inches) to the next mark, wait one minute, repeat the conductivity measurement and record the data and the position from which the data was taken. Repeat this procedure until all element positions have been probed. You may want to slightly close the ball valve to better hold the tubing in place. Once the tubing has been removed from the vessel permeate channel, close the ball valve and continue to the next vessel.

Evaluate the conductivity values along the length of the permeate channel for each individual pressure vessel, then compare the trends of vessels operating in parallel. A sudden increase in conductivity where two elements interconnect indicates a feed to permeate leak that may be caused by a leaking O-ring or a disconnected interconnector. Replacing the faulty O-ring or reseating the interconnector can easily resolve the issue. If interconnectors become decoupled, shim the element stack within the pressure vessel. Please refer to “Vessel Shim-ming Procedures - TB 103”.

Data Logging and Performance Normalization - TB 111

In order to properly troubleshoot membrane performance issues, identify system operational issues, develop cleaning and maintenance procedures and ensure the validity of the product/system warranty, it is critical that feedwater quality and system performance data be recorded and filed on a regular basis so that such information is readily available for review in the event of a performance problem or a warranty claim.

Why is Data Collection Important?

Because RO membrane performance can be affected by a variety of factors, such as a change in feedwater quality or a change in operating conditions, the only way to determine whether your membranes are performing as expected is through regular collection and routine analysis of feedwater quality and system performance data. This information can then be evaluated over time to determine whether membrane performance is tracking as expected or if adverse trends develop which then require corrective action. All data collected should be systematically logged and filed for future access to allow analysis of longer-term performance trends that may require troubleshooting or support a warranty claim.

Regular systematic data collection is required to confirm that your membrane products are being operated under their design conditions, to aid in proper maintenance and to enable troubleshooting in the event of a performance issue or problem.

CAUTION

Failure to maintain the minimum data logging requirements identified herein or to make such data available to NanoH₂O upon request may result in voiding your product/system warranty.

Why Normalize Data?

RO membrane performance will vary depending on feedwater characteristics, feedwater composition and operating conditions. Parameters such as feedwater temperature, feedwater TDS, membrane fouling, or system recovery will change key membrane performance characteristics such as feed pressure, permeate flow and permeate quality.

To determine whether changed performance is the result of changed feedwater or operating conditions, or whether it is due to a change in actual membrane performance, operating data must be taken at regular intervals and then “normalized” to baseline reference conditions. Whether changed performance is apparent or actual can only be determined by comparing “normalized” performance over time with baseline performance. To ensure optimized membrane performance and a long service life, it is important that any changes in membrane performance be identified and corrective action be taken as quickly as possible. A complete record of normalized data is therefore essential for users to realize the best performance and longest operating life of Qfx RO membrane elements.

Causes for Changes in Apparent Membrane Performance

Certain changes in the operating parameters of the RO system or train will result in changes in RO membrane performance. Such changes can result in an apparent or actual change in permeate flow or quality. Below is a list of the changed conditions that typically affect RO membrane performance.

Conditions Resulting in Reduced Permeate Flow:

1. A reduction in feedwater temperature will result in a reduction in permeate flow if there is no corresponding increase in the feed pressure. An increase in the feedwater temperature will likewise result in an increase in permeate flow if there is no corresponding decrease in the feed pressure.
2. Decreasing the RO feed pressure will result in a reduction in permeate flow as a consequence of reducing the net driving pressure (NDP) across the membrane elements. NDP is the available effective pressure required to drive permeate through RO membranes. NDP is a function of the applied feed pressure, pressure losses, feed/concentrate osmotic pressure and permeate pressure.
3. Increasing the permeate backpressure will result in a reduction in permeate flow, due to a reduction in the available NDP.

4. An increase in the feedwater TDS will increase the osmotic pressure and result in a loss of permeate flow due to a reduction in the available NDP, unless the feed pressure is also increased.
5. Increasing the system recovery (the ratio of permeate flow to feed flow) will result in an increase in osmotic pressure, which will reduce the NDP, thus a reduction in permeate flow.
6. Membrane surface fouling will cause a decrease in membrane permeability and a subsequent reduction in permeate flow.
7. Fouling of the membrane element's feed/brine spacer will increase the feed/concentrate pressure drop across the membrane elements operating in series, causing a decrease in NDP for the elements at the end of the system and resulting in a reduction in permeate flow.

Conditions Resulting in Increased Permeate Salinity:

8. An increase in the feedwater temperature without a corresponding change in permeate flow will result in an increase in permeate salinity.
9. A reduction in the plant/train permeate flow reduces the rate of water flux through the membrane, causing an increase in permeate salinity because there is less permeate to dilute the salts that have passed through the membrane.
10. An increase in the feedwater salinity will result in an increase in permeate salinity because an RO membrane rejects a fixed percent of the total salts.
11. An increase in the system recovery (the ratio of permeate to feed) will increase permeate salinity because this has the effect of increasing the average salinity of the feed/brine in the system.
12. Membrane surface fouling results in less permeate flow and thereby less permeate to dilute the salts that have passed through the membrane.
13. Mechanical leaks caused by O-ring leaks or failure can allow high TDS feed/brine to leak into the permeate without passing through the membrane or allow feed to bypass an element's brine seal.
14. Membrane surface damage can be caused by exposure to free chlorine.

By normalizing plant data, the reviewer can determine if changes in membrane performance (in either permeate flow or quality) result from operating under different feed pressure, salinity or temperature conditions and, therefore, conclude if changes in performance are only apparent or actual. Actual changes require corrective action to remove surface foulants, locate and correct O-ring leaks, or prevent further membrane damage due to oxidation.

Graphing normalized data over time provides a useful picture of RO system performance and will identify how and when performance may have changed. Adverse changes in performance trends can then be reviewed in light of other data and plant operation logs to determine what happened, when it happened, and what can be done to correct the problem.

Data Logging and Performance Normalization - TB 111

Data Collection Procedures

The following tables identify the data to be regularly collected and the frequency of collection.

NanoH₂O RO Membrane Minimum Logging Requirements

RO Feedwater Characteristics - Required Data

Parameter	Frequency of Collection	Comment or Unit of Measure
Silt Density Index (SDI)	Once per day (every 24 hours)	Please refer to "SDI Procedure TB 107"
Turbidity (NTU)	Once per shift (every 8 hours)	Nephelometric Turbidity Units
Temperature	Once per day (every 24 hours)	°C or °F
Conductivity (µS)	Once per day (every 24 hours)	
Feedwater Chemical Analysis	Once per month	

RO Permeate System or Each Train - Required Data

Parameter	Frequency of Collection	Comment
Conductivity (µS)	Once per day (every 24 hours)	
Flow	Once per shift (every 8 hours)	
Pressure	Once per shift (every 8 hours)	

RO Concentrate System or Each Train - Required Data

Parameter	Frequency of Collection	Comment
Conductivity	Once per day (every 24 hours)	
Flow	Once per shift (every 8 hours)	
Pressure	Once per shift (every 8 hours)	

Operating Conditions for RO System or Each Train

Parameter	Frequency of Collection	Comment
Pressure Differential	Once per day (every 24 hours)	
Cumulative Hours of Operation	Once per day (every 24 hours)	

Operating or Maintenance Events for RO System or Each Train

Event	Frequency of Collection	Comment
System or Train Start-up	As applicable	Record date and time
System or Train Shutdown	As applicable	Record reason for shutdown, date and time
Membrane Cleaning or Flushing	As applicable	Record reason for cleaning, chemical(s) used, method or procedure, concentration, date and time. Record results following cleaning.

Data Normalization Equations

- To obtain normalized permeate flow, use the following equation:

$$Q_n = Q_a * (NDP_n / NDP_a) * (TCF_n / TCF_a)$$

Q_n	Rate of permeate flow (vol/t) normalized to standard conditions
Q_a	Actual flow rate (vol/t)
NDP_n	Net Driving Pressure at standard conditions (expressed as units of pressure)
NDP_a	Actual Net Driving Pressure (expressed as units of pressure)
TCF_n	Temperature Correction Factor for temperature at standard conditions
TCF_a	Temperature Correction Factor for temperature at the actual conditions

- To obtain the Net Driving Pressure, use the following equation:

$$NDP = P_f - \frac{1}{2} \Delta P_{fb} - P_{osm} - P_p$$

P_f	Feed pressure
ΔP_{fb}	Pressure drop between the feed and brine systems
P_{osm}	Osmotic pressure - weighted average
P_p	Permeate pressure

- To obtain the Osmotic Pressure, use the following equation:

$$P_{osm} = CF_{lm} * C_f * 11/1000 * K_{p-cond}$$

CF_{lm}	Log mean concentration factor
C_f	Feed conductivity (μS -cm)
K_{p-cond}	Conductivity to Pressure conversion factor (this constant is a function of the TDS of the sample)

- To obtain the Log Mean Concentration Factor, use the following equation:

$$CF_{lm} = \ln [1 / (1-R)] / R$$

R	Water recovery, expressed as a decimal
R	Permeate flow divided by feed flow (Q_p / Q_f)

Data Logging and Performance Normalization - TB 111

- To obtain the Temperature Correction Factor (TCF), use the following equation:

$$\text{TCF} = \exp \{ K * [1 / (273 + t) - 1 / 298] \}$$

t	degrees Celsius
K	3070 for composite RO membranes

- To obtain normalized Salt Passage, use the following equation:

$$\%SP_n = (EPF_a / EPF_n) * (STCF_n / STCF_a) * \%SP_a$$

$\%SP_n$	Percent Salt Passage normalized to standard conditions
SP_a	Percent Salt Passage at actual conditions
EPF_n	Element Permeate Flow rate at standard test conditions
EPF_a	Element Permeate Flow rate at actual conditions
$STCF_n$	Salt Transport Temperature Correction Factor at standard conditions
$STCF_a$	Salt Transport Temperature Correction Factor at actual conditions

- To obtain the actual Salt Passage, use the following equation:

$$\%SP_a = C_p / C_{fb}$$

C_p	Permeate concentration (expressed in ppm)
C_{fb}	Feed/brine concentration (expressed in ppm) which = the feed concentration (expressed in ppm) multiplied by the log mean

- To obtain the Salt Transport Temperature Correction Factor, use the following equation:

$$\text{STCF} = \exp \{ K * [1 / (273 + t) - 1 / 298] \}$$

t	degrees Celsius
K	5030 for composite RO membranes

Notes:

- Membrane element permeate flow is unique to each model number. Please refer to the Qfx™ product data sheet for the specified flow.
- Please contact NanoH₂O to obtain the temperature correction factor for salt transport. Alternatively, use the TCF provided in the temperature correction equation provided above.
- The equations described above are simplified versions of the actual expressions. As a result, some variation (~10%) can be expected in the normalized flow or salt passage. Better normalization can be accomplished using NanoH₂O's Q⁺ Projection Software .

Biocides for Disinfection and Storage - TB 112

The periodic use of biocides may be required to control or eliminate biological growth in the feed/brine spacer or on the membrane surface, especially in cases of long-term storage. The following is general information on the application, use and handling of generic biocides that are suitable for use with NanoH₂O's membrane products.

Specialty chemical biocide products are formulated and distributed by a number of independent companies and marketed under various trade names. These products have typically been qualified by the chemical manufacturer for safe and effective use with composite polyamide seawater RO membranes. *NanoH₂O makes no representations as to either the efficacy or safety associated with such use and any such use by NanoH₂O Customers is done at the sole risk of the Customer and the chemical manufacturer.*

Below is a list of generic biocides approved for use.

CAUTION

Prior to use, review all applicable Material Safety Data Sheets (MSDS) and follow all manufacturer instructions and applicable governmental regulations with regard to the use, handling and disposal of biocides.

- **Glutaraldehyde**

Glutaraldehyde is an effective biocide and kills most algae at concentrations of 0.1% to 1%. Glutaraldehyde at the concentrations indicated may be used for system or train disinfection and for long-term storage.

- **Formaldehyde**

Formaldehyde is an aqueous solution at concentrations of 0.1% to 1.0%. It is effective in eliminating most types of bacteria and mold (including spores) and may be used to maintain sanitary conditions during long-term storage.

- **Isothiazolin**

Many manufacturers of water treatment chemicals distribute Isothiazolin under the trade name Kathon. Commercially available solutions typically contain 1.5% of the active ingredient Isothiazolin. Please check the product literature to confirm the active ingredient concentration. Kathon is an effective biocide to maintain sanitary conditions in NanoH₂O membrane elements at concentrations of 15 ppm to 25 ppm and may be used for system or train disinfection, or for long-term storage.

- **Sodium Bisulfite**

Sodium Bisulfite may be used to inhibit biological growth in the system or train when dosed daily at concentrations of 500 ppm for 30 to 60 minutes. Sodium Bisulfite at a concentration of 1% may also be used to inhibit biological growth during long-term storage.

- **Hydrogen Peroxide**

A 0.1% to 0.2% solution of hydrogen peroxide (or a solution of hydrogen peroxide with paracetic acid) may be used for system or train disinfection.

CAUTION

Hydrogen Peroxide is a strong oxidizing agent and should not be used when transition metals such as iron or manganese are present in the feedwater. Oxidation of transition metals on the membrane surface will result in irreversible damage causing a reduction in salt rejection. Feedwater temperature should never exceed 25°C (77°F) when exposing membrane elements to a Hydrogen Peroxide solution. Hydrogen Peroxide should NOT be used for disinfection during long-term storage as its efficacy degrades with time.



Returned Goods Authorization Procedure - TB 110

Customers may wish or may have been instructed by NanoH₂O to return product for testing and evaluation, or in support of a warranty claim. The following procedure is provided to assist in the processing of a warranty claim or in the return of goods for any other reason.

Prior to returning goods for testing or evaluation, please complete the Request for Returned Goods Authorization Form (see copy on page 25, or download directly from the web at www.nanoh2o.com) and email the completed form directly to sales@nanoh2o.com, or fax at +1 424.218.4001. You will receive a Returned Goods Authorization (RGA) number by return email within 48 hours after submission of your form. The RGA number **MUST** appear on your shipping documents to ensure that your goods are accepted for delivery and routed to the proper department for processing and evaluation. Delivery will be refused for goods received without a clearly identifiable RGA number.

Goods should be shipped to NanoH₂O as soon as possible following receipt of an RGA number. This helps to ensure that membrane element condition and performance properties do not change as a result of prolonged storage. Goods must be received by NanoH₂O within 30 days (for domestic shipments) or 60 days (for international shipments from) from the date the RGA number is issued. Failure to comply with this requirement may void any warranty claim.

Goods should be prepared for shipment and packaged in accordance with the Packing and Shipping Requirements detailed below.

Packing and Shipping Requirements

DO NOT RETURN GOODS UNTIL YOU HAVE RECEIVED WRITTEN AUTHORIZATION AND A VALID RGA NUMBER FROM NANOH₂O.

- Prior to shipment, membrane elements should be flushed with RO permeate for a minimum of thirty minutes at 6-8 pH to ensure that any liquid contained in the elements is not hazardous and goods can be safely shipped and handled upon arrival at NanoH₂O's facility.
- Prior to shipment, membrane elements should first be preserved in accordance with NanoH₂O's membrane elements storage procedures (see "Receipt of Elements and Short-Term Storage - TB 101").

LIQUIDS CONTAINING STRONG ACID OR ALKALI CLEANING SOLUTIONS ARE CONSIDERED TO BE HAZARDOUS FOR TRANSPORT AND MUST BE REMOVED PRIOR TO SHIPMENT.

- Prior to shipment, membrane elements should be sealed in a leak-proof polyethylene bag and packed in an appropriate cardboard container to keep product hydrated and to protect product from physical damage during shipment.
- Please ship product to the following address:

DURING SHIPMENT, PRECAUTIONS SHOULD BE TAKEN TO ENSURE THAT MEMBRANE ELEMENTS ARE PROTECTED FROM FREEZING OR PROLONGED EXPOSURE TO TEMPERATURES EXCEEDING 40°C (104°F).

NanoH₂O, Inc.
750 Lairport Street
El Segundo, CA 90245
USA

Attn: Technical Service Department
RGA #: _____

Warranty Claim Validation Procedure

Product submitted under a warranty claim will be evaluated as follows:

1. Initial Element Inspection

- An initial visual inspection will be conducted of the core tube, anti-telescoping device, and element outer wrap to determine if element components have been damaged due to improper handling, installation or operation.
- The element will be weighed to determine if it has excessive weight, which would indicate fouling or scaling.
- If the element fails to pass either of the above inspections it will not be approved for warranty replacement.
- A vacuum and/or air test will be performed on the element to determine if the element has a mechanical leak. Elements failing the vacuum and/or air test will be autopsied to determine whether the leak is covered under the applicable workmanship and materials warranty or was caused by improper use, operation or maintenance.
- Elements passing the initial inspection will be wet tested to determine current performance.

2. Element Wet Test:

- The element will be wet tested to determine current salt rejection and permeate flux under standard test conditions.
- The wet test data will be compared with performance data at the time of the initial shipment, ex-factory, and with warranted performance values.

3. Determination

- Elements found to be in accordance with warranted performance will be returned to the Customer “freight collect” and the Customer will be billed a \$250 (USD) evaluation fee for each element returned.
- Elements found to be defective in regards to workmanship or materials will be replaced at no cost to Buyer, subject to the applicable warranty terms and conditions.
- Elements found to be performing below warranted performance with respect to salt rejection, permeate flow or both, will be replaced at no cost to Buyer, subject to the applicable warranty terms and conditions.

General Conditions

Unless other prior arrangements have been made with NanoH₂O, Customer is responsible for all shipping charges of returned product. No product will be accepted for evaluation unless returned freight is prepaid. If requested, Customer will issue a valid purchase order number to NanoH₂O covering all work to be performed, including all analytical work, prior to any work being performed by NanoH₂O.

Should examination of returned goods result in a finding that failure ***WAS NOT*** caused by defect in manufacturing, workmanship or material, goods shall be returned to Customer “freight collect” and Customer will be billed \$250 (USD) per membrane element evaluated.

Should examination of returned goods result in a finding that failure ***WAS*** caused by a defect in manufacturing, workmanship or material, replacement goods will be shipped to the Customer free of charge. Please review your warranty for the terms and conditions applicable to your purchase.

All terms, conditions and specific remedies set forth in the Customer’s applicable warranty shall apply in the processing of all warranty claims. For further questions, please contact NanoH₂O via email at sales@nanoh2o.com or via phone at +1 424.218.4000.



Request for Returned Goods Authorization Form

Date: _____

Customer Name: _____

Customer Address: _____

Email: _____ Phone: _____ Fax: _____

Original Purchase Order #: _____

Original Purchase Date: _____

Plant Location/Shipping From: _____

Goods Being Returned (Model #): _____

Quantity Being Returned: _____

Date Goods were first put into service: _____

Reason For Return (please state whether this is related to a warranty claim, fouling analysis, cleaning study, over-stocking, etc.): _____

Evaluation and/or testing services requested: _____

Purchase Order number covering requested services (if applicable): _____

Have the elements been exposed to hazardous materials or substances? Yes No

If yes, what materials or substances was the element exposed to? _____

What was the feedwater source? _____

Additional Comments: _____



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Changing the economics of desalination