Technical Service Bulletin

January 2020 TSB 105.14

REVERSE OSMOSIS AND NANOFILTRATION MEMBRANE ELEMENT DETAILS AND PRECAUTIONS FOR USE

ELEMENT CONFIGURATION DETAILS

The RO and NF spiral wound elements are made with the basic industry configuration shown in Figure 1.

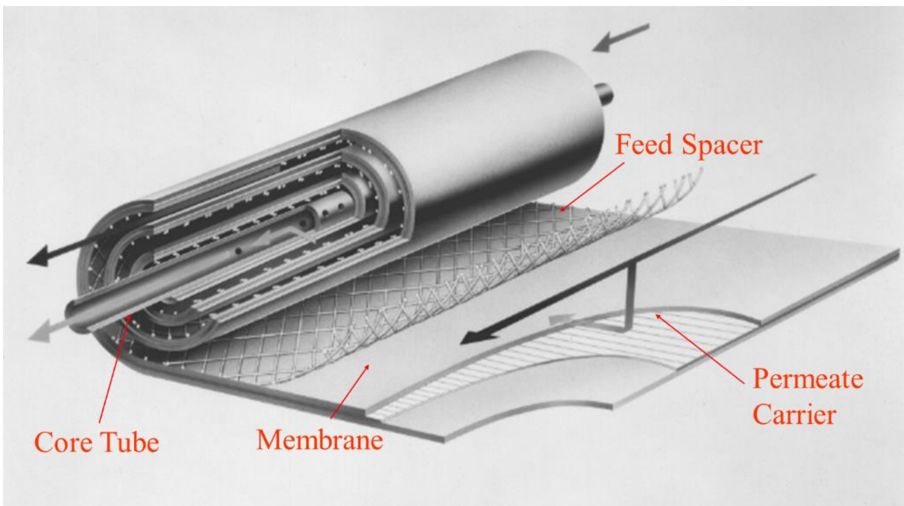


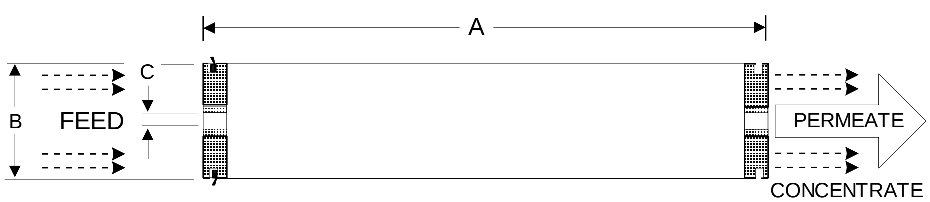
Figure 1. Spiral wound element configuration

The most common product sold is 8-inch diameter, 40-inch long element. General dimensions are shown in Table 1.

Table 1. Typical Spiral Element Dimensions

A, inches (mm)	B, inches (mm)	C, inches (mm)
40.0 (1016)	7.89 (200)	1.125 (28.6)

Where the dimensions are referenced as follows:



The length of the element can vary slightly (for example, a few mm or fractions of an inch), due to the normal tolerances of manufacturing. Sizing of the pressure vessel should take into account these "plus/minus" variations. For detailed values on the element length tolerances, please contact Hydranautics' Technical Department.

Regarding the weight, the values change by product type as shown in Table 2 below. The weights of each product differ by the type because of the density of the materials used in construction. The LD-Type uses a 34-mil feed spacer and is more open than the standard feed spacer used in the MAX element, thus the weight is less. The SWRO element uses a denser permeate spacer to provide greater support when operating at high feed pressures typical for this product. This spacer is denser than the spacer used in a BWRO element.

Again, these weights are not exact, and there can be variations in these values. Typically, that variation would be around +/- one kilogram, or 2.2 pounds. The biggest reason for variation is the amount of retained water in a wet element. It can take a long time to drain all the water from an element. As a result, the weight can vary by one or more kg. It should also be noted that the elements, as shipped from the factory, have less water in them than would typically be achieved by static draining of the element, since our factories use mechanical means to reduce the time needed to remove the excess water.

Weight is often used as a reference value to determine the amount of foulant that may be on an element. For this, we would not typically compare the drained weight of the element to the values below. Instead, it should be compared to a clean element that has been fully wetted and drained similar to the drained element with foulant. If no such clean, reference element is available, we would recommend that you add 1 kg (2.2 pounds) to the weights listed below to account for the extra water that would be held in the element by a static drain.

Table 2. Typical Spiral Element Weights as Shipped from Factory

Element Type	Weight, lbs. (kg)
8040 BWRO – LD TYPE	27.5 (12.5)
8040 BWRO – MAX TYPE	29.8 (13.5)
8040 SWRO – LD TYPE	29.8 (13.5)
8040 SWRO – MAX TYPE	32.0 (14.5)

It should be noted that many other size and style elements are sold. For details on those elements, please contact Hydranautics Technical Department.

OPERATIONAL AND USE GUIDELINES

PRESENCE OF FREE CHLORINE OR OTHER OXIDANTS IN FEED WATER OF THIN FILM (POLYAMIDE) MEMBRANE ELEMENTS

At no time should there be a Free Chlorine or oxidant residual in the feed water. Even very low levels of chlorine or other oxidants in the feed stream can result in irreparable oxidation damage of the membrane. Therefore, operators should ensure that oxidant does not enter the RO system. To ensure that membranes are not harmed by oxidant, Hydranautics recommends that the feed to the RO/NF system is equipped with an ORP (Oxidation- Reduction Potential) meter. The feedwater can then be continuously monitored for the presence of oxidant. Except in wastewater applications where chloramines are used and allowed up to a concentration of 5 ppm, the ORP meter reading should be below 300-350 mV, or better yet to maintain warranty, the maximum ORP mV level should be determined on site by testing where there is no presence of oxidant. the The plant operator should receive a warning that a dangerous level of oxidant is getting to the membrane and should take action, such as adding or increasing the dose of sodium bisulfite (SBS), to reduce the oxidant concentration. It is recommended to measure the residual sulfite to confirm that no chlorine exists and minimize SBS overdosing. A concentration of 1-2 ppm residual sulfite is a good target. If the ORP value reaches the maximum setpoint, the plant should be shut down until the oxidant concentration can be reduced to a safe value. Please contact your system provider for various methods of removing Free Chlorine prior to the membrane system.

ORP value may vary according to feed water type and pH, as indicated in the graph below. Different types of water may present different ORP values at the same pH. For example, seawater at pH of 7 will present ORP of 200 mV and RO permeate will present 400 mV. At pH of 5, both water types will have higher ORP values (300 mV and 500 mV respectively). It is recommended to verify on site ORP value at 0.0 ppm chlorine before setting ORP set point.

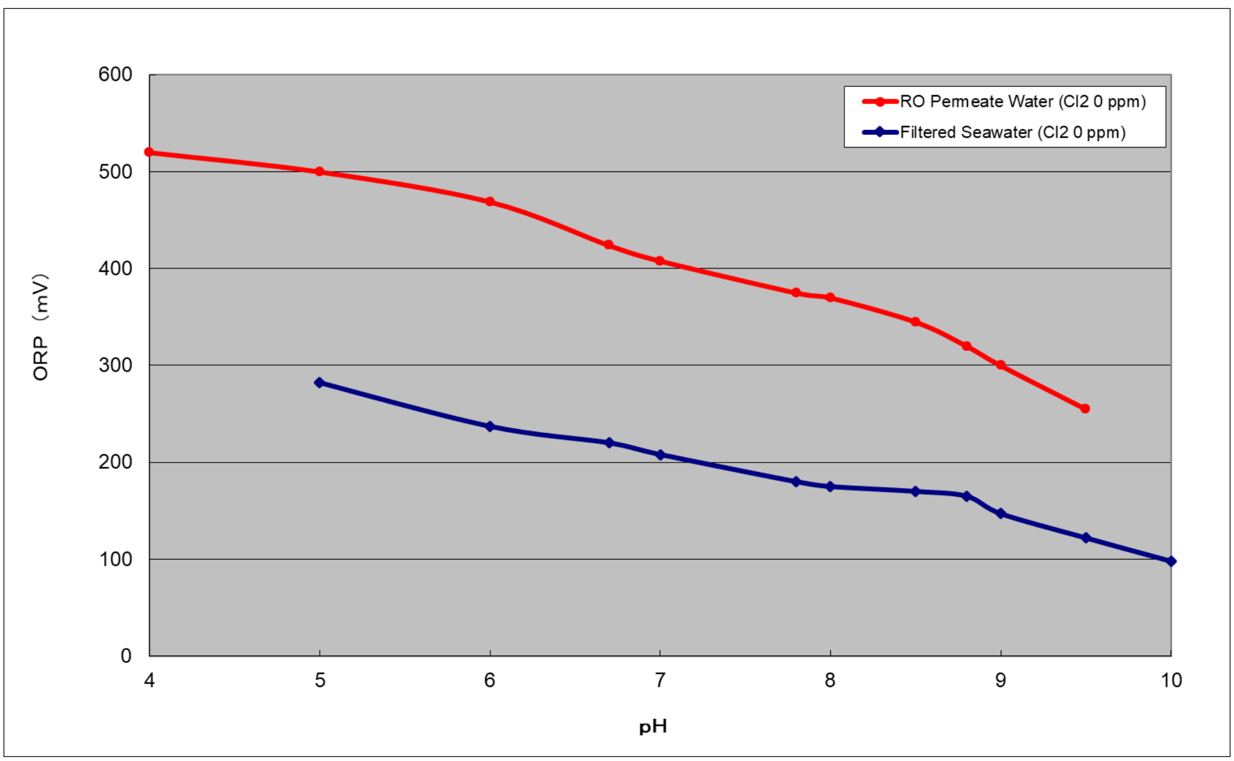


Figure 2: The relationship between pH and ORP on RO permeate and filtered seawater with no chlorine.

It should also be noted that studies have shown that excess amounts of sodium bisulfite can lead to oxidation of the polyamide membrane. Sommariva et al. have reported that polyamide membranes were oxidized at a plant where chlorination/dechlorination with SBS was practiced (Sommariva, C., et al. (2012). *IDA J. Desalination and Water Reuse,* 4(2), 40-44). They concluded that overdosing of SBS can lead to rapid membrane oxidation and loss of rejection. In particular, they found that in addition to excess SBS, there also needed to be oxygen, higher pH and some quantity of transition metal present. Thus, users should take care to dose enough SBS to prevent chlorination of the membrane, but not overdose SBS.

NOTE: The oxidative effects of Free Chlorine are strongly catalyzed in the presence of transition metals such as iron and manganese. If transition metals are present, it is recommended that there be NO Free Chlorine in the feed water.

LUBRICATION OF O-RINGS AND BRINE SEALS

At no time should petroleum or vegetable oil-based lubricants be used when lubricating interconnector O-rings, end adapter O-rings or the membrane element brine seal. Acceptable lubricants include glycerin, silicon-based Molykote III, or other silicone-based lubricants which contain no hydrocarbons. Some core tubes and interconnectors used in our products are made from plastics that can swell, soften, crack or craze due to chemical effects. This can lead to early failure of the element.

PERMEATE BACKPRESSURE PREVENTION

The membrane element shall not, at any time, be exposed to permeate back pressure (where permeate static pressure exceeds concentrate static pressure). There shall be no permeate back pressure at shutdown.

At no time during operation of a membrane element system should the permeate valve(s) be closed. This includes pre-start up flushing, pre-shutdown flushing, cleaning(s) and standard operation.

Closing the permeate valve during any phase of operation causes a pressure differential across the tail end of the system and will likely result in irreparable damage to the glue lines of the tail element(s). This damage will cause immediate increase in salt passage of the system.

NOTE: Permeate valve(s) may be closed during shutdown after the system has been flushed and/or when input of the feed water is stopped. In many cases this is necessary to prevent an aerobic environment in the pressure vessels. The permeate valve (as well as the concentrate) should be fully re-opened prior to re-introducing feed water.

Reference also Technical Service Bulletin 118.

CONCENTRATE VALVE OPERATION TO SET RECOVERY RATE

During startup of any system, the concentrate valve should be in the fully open position. This valve should be moved towards the closed position after start up in order to obtain the desired system recovery. NEVER START A SYSTEM WITH THE CONCENTRATE VALVE CLOSED AND THEN OPENING IT UNTIL THE SYSTEM RECOVERY IS ACHIEVED.

NOTE: System recovery should be set to the design setpoint as recommended by Hydranautics' IMSDesign© Software.

PARTICULATE FREE FEEDWATER

At no time should the membrane be exposed to particulate matter that can accumulate on the surface of the membrane and mechanically damage the polyamide surface. There are many sources of unwanted particulate matter, including insufficient flushing of pipework before start-up, corrosion of metal pumps, pipes, valves or sensors in the feedline, poorly operating pretreatment, and by-pass of the typical 5-micron cartridge filters. Studies have shown that such particles can become lodged between the feed spacer and the membrane. Vibration of the spacer can then cause the particle to be pushed into the membrane and abrade the surface of the membrane (Figure 3). This often leads to mechanical defects which leak feedwater into the permeate side of the element. These particles may be 6 to 100 microns in size. An example of the damage they cause is shown in Figure 4. It is common for such damage to only slightly increase water flow, but greatly increase the salinity of the permeate, because raw feedwater, nearly 1000 times saltier than product water, will leak into the permeate. Users should follow Hydranautics' recommendations for Pre-commissioning and Commissioning, listed in our technical documents or available from Technical Support Personnel.

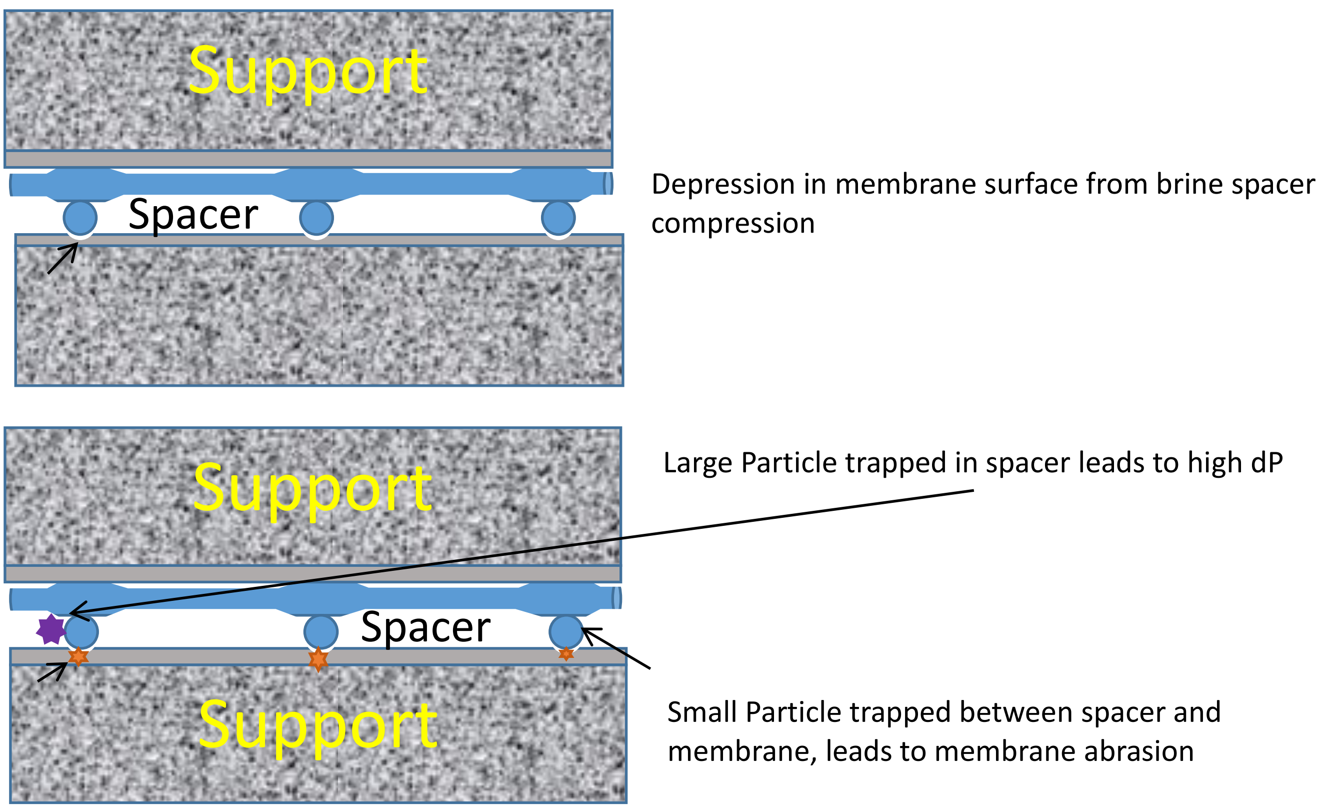


Figure 3. Schematic representation of particulate damage to RO membranes.

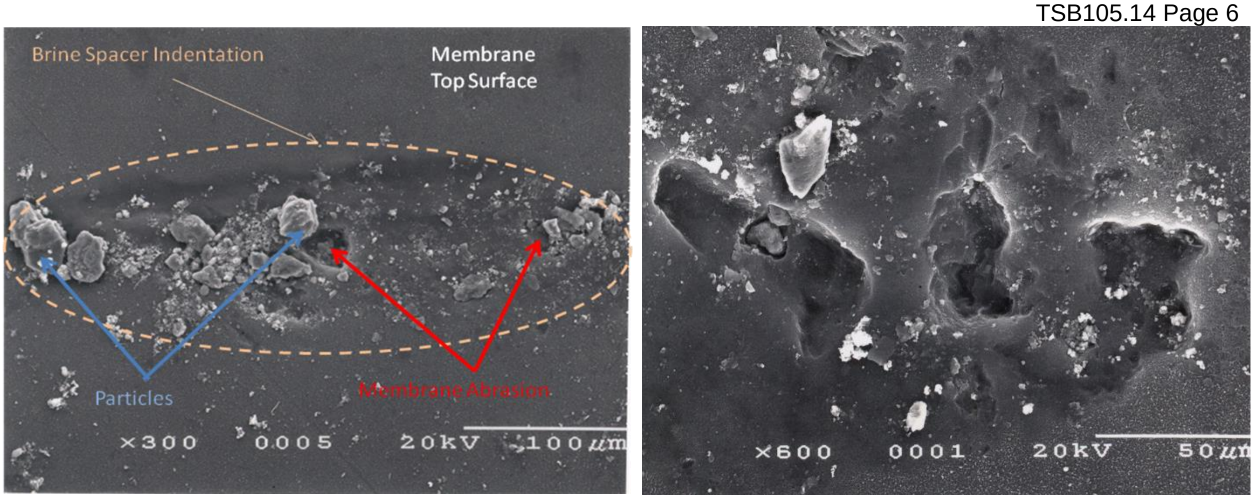


Figure 4. Membrane surface abraded by particles.

SYSTEM PRESSURIZATION

Pressurization of an RO system must be done at a controlled rate. If the system is pressurized too quickly it can result in mechanical damage to the RO membrane elements. Damage to the RO elements can include cracking of the resin outerwrap and/or telescoping of the membrane due to axial stresses caused by the high rate of pressurization. Also, it can cause the resin outerwrap to burst due to momentary pressure differences between the inside of the element and outside of the element shell. Hydranautics recommends that the RO system be pressurized at no more than 10.0 psi (0.69 bar) per second to ensure no damage is done to the membrane element.

SYSTEM DE-PRESSURIZATION

Never (unless an emergency) stop the RO system by directly switching off the High-Pressure Pump (HPP). Before switching off the HPP, pressure should be decreased:

- If system is equipped with a Variable Frequency Drive (VFD) on the HPP, ramp down the VFD to the minimum frequency and then switch off the HPP.
- If system is not equipped with VFD on the HPP, throttle down the HPP discharge valve to a nearly closed position and then switch off the HPP.

If system is equipped with Pressure Exchanger recovery device (ERI PX or DWEER), decrease the pressure by any of the two-means mentioned above until feed pressure is similar to the osmotic pressure of feed water. Then switch off HPP. The reason for this is that the ERD systems have similar flows through the high-pressure outlet (RO feed stream) and high-pressure inlet (RO reject stream). Once the pressure is below the osmotic pressure, the system will not de-pressurize, even if HPP is switched off. To de-pressurize the system at this moment, either let the ERD booster pump run for long time (the pressure will go down very slowly), or de-pressurize using vents.

ADAPTOR AND INTERCONNECTOR ENGAGEMENT (SHIMMING)

All pressure vessels are built with some tolerance in length to account for small differences in the length of the elements. Furthermore, the length of the pressure vessel also changes slightly due to expansion during operation. Therefore, elements must be shimmed to take up free space in the vessel and ensure that all end adaptors and interconnectors are fully engaged in the element's core tube. Insufficient shimming can lead to premature wear of interconnector and end plate adaptor O-rings, disconnections of elements from end plate adaptors, or failure of the permeate core tube. Because vessel expansion may occur during operation and some components may undergo some compression, shims should be rechecked within a few weeks and a few months after plant startup.

It is recommended that the gap between the last O-ring and the end of the core tube counter bore should be about 0.75 inches (19 mm) from the end of the counter-bore in the core tube (Figure 5). It should never be more than 1 inch (25 mm). This is important especially at high pressures and temperatures of operation, where the added stress on the thinner core tube wall can otherwise lead to premature core tube failure (see section below for more detail). Proper shimming of the elements in the vessel will ensure this is done (see TSB 109). It is often possible to see the black marks on the core tube which are due to O-rings rubbing on the inside surface of the core tube. This will help identify the position of the adaptors/interconnectors in the element core tube. (Figure 6)

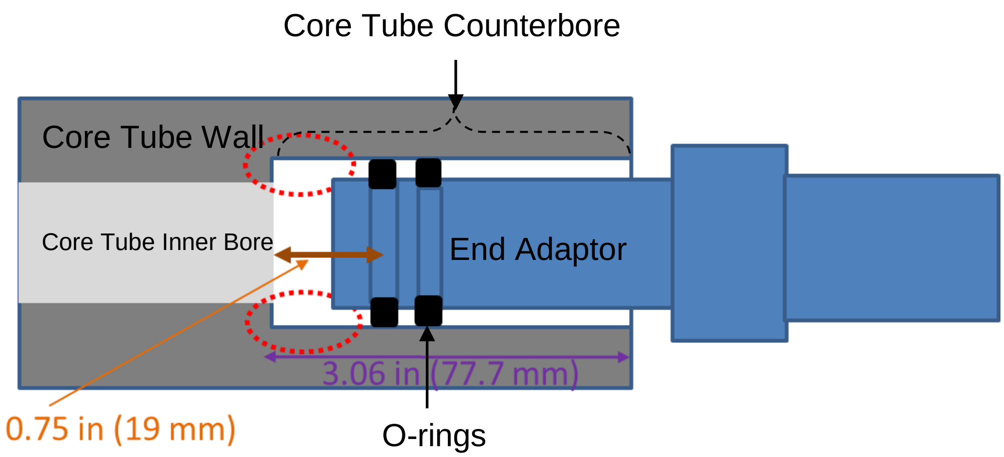


Figure 5. Proper end adaptor assembly position in a core tube.

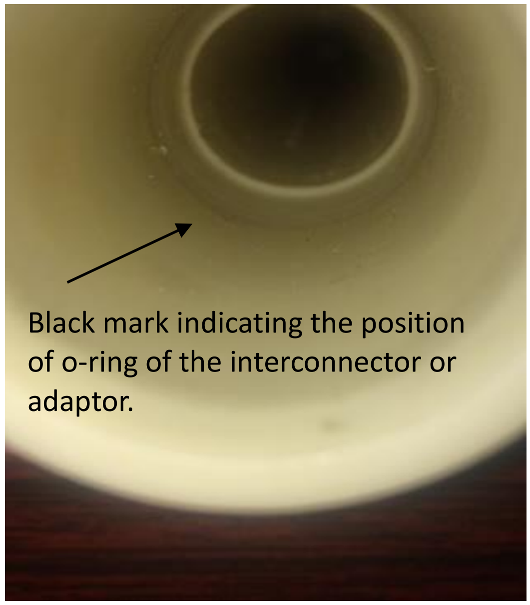


Figure 6. Core tube showing black mark at the position of o-ring seal.

SAFE OPERATION AT HIGH TEMPERATURE AND PRESSURE

Since membranes are made from plastic materials, they are subject to plastic creep under certain high temperature and high pressure operating conditions. For reverse osmosis membranes, the primary concern is that the porous polysulfone support (Figure 7a) may undergo compression at these conditions, which decreases the porosity of the intermediate layer. This results in greater resistance to water flow through this layer. The end result is that the apparent permeability of the composite membrane will decrease and the pressure required to achieve permeation rates at the reference temperature of 25ºC will thus increase. Also, high temperature can cause the polyamide layer to tighten. This results in both lower permeability and lower salt passage. In regards to the element construction, the combination of higher temperature and higher pressure can cause the permeate support to partially collapse and the membrane to emboss in the permeate spacer channels (Figure 7b). Both of these effects will cause more resistance to flow on the permeate side of the element, which in turn causes greater pressure drop. The result is that the operation at standard test conditions will require greater pressure to achieve the specified flow.

Hydranautics recommends that customers operate their systems in accordance to the Temperature-Pressure limitations given in Figure 8. This chart gives the maximum pressure that is allowed for a given feed temperature. The RO elements are designed to run at up to 45ºC, but with pressure limitations. If the operator desires to run at temperatures in excess of 40ºC, they should first contact the Hydranautics Technical Department for advice on safe operation and the potential impact on element productivity.

IMPORTANT NOTICE: Operation of RO elements in excess of these limiting values can potentially cause the permeate core tube to collapse and mechanically fail (Figure 8). In that event, there will be a sudden flow of feedwater into the permeate side of the element. If the high-pressure pump does not shut down immediately, there is potential of very high pressure on the permeate side of the element. This can be a significant safety issue and should be avoided. If operation is desired at higher pressure/temperature combinations, please contact Hydranautics for recommendations of higher strength materials for the permeate core tube.

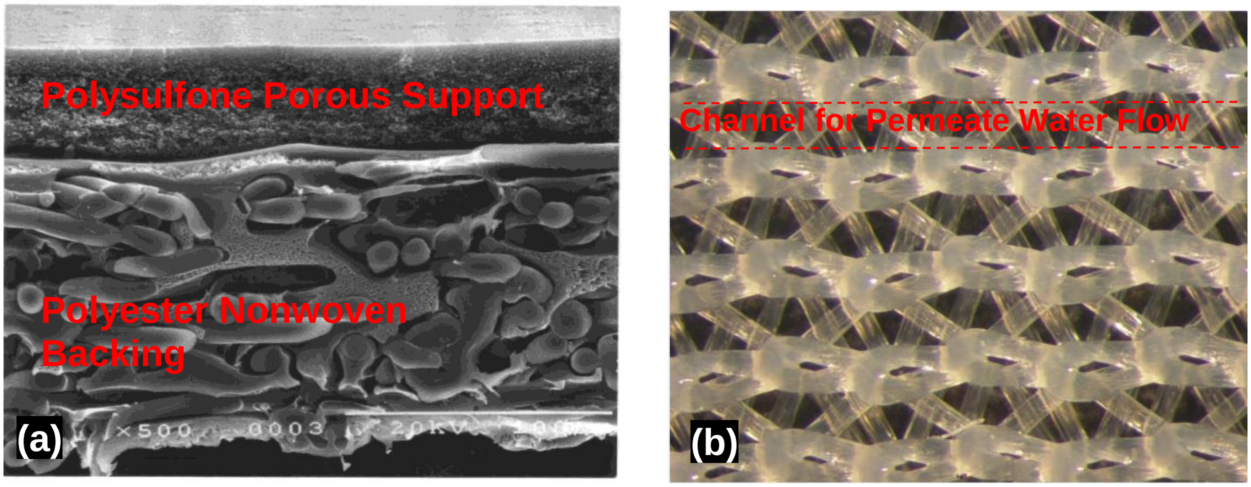


Figure 7. (a) Magnified cross-section of a typical composite polyamide membrane and (b) a top view of a permeate spacer showing channels for water flow.

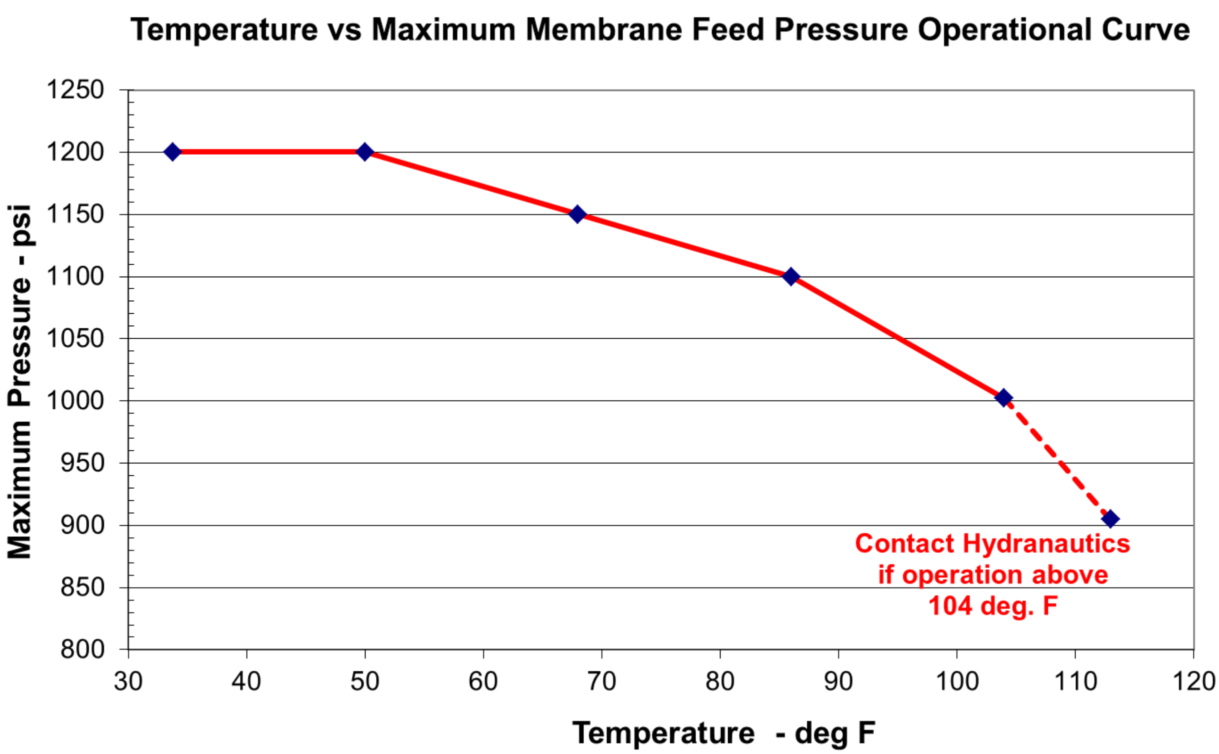


Figure 8a. Temperature versus Pressure Operation Limits for Seawater Membranes with ABS/GF core tubes -English Values.

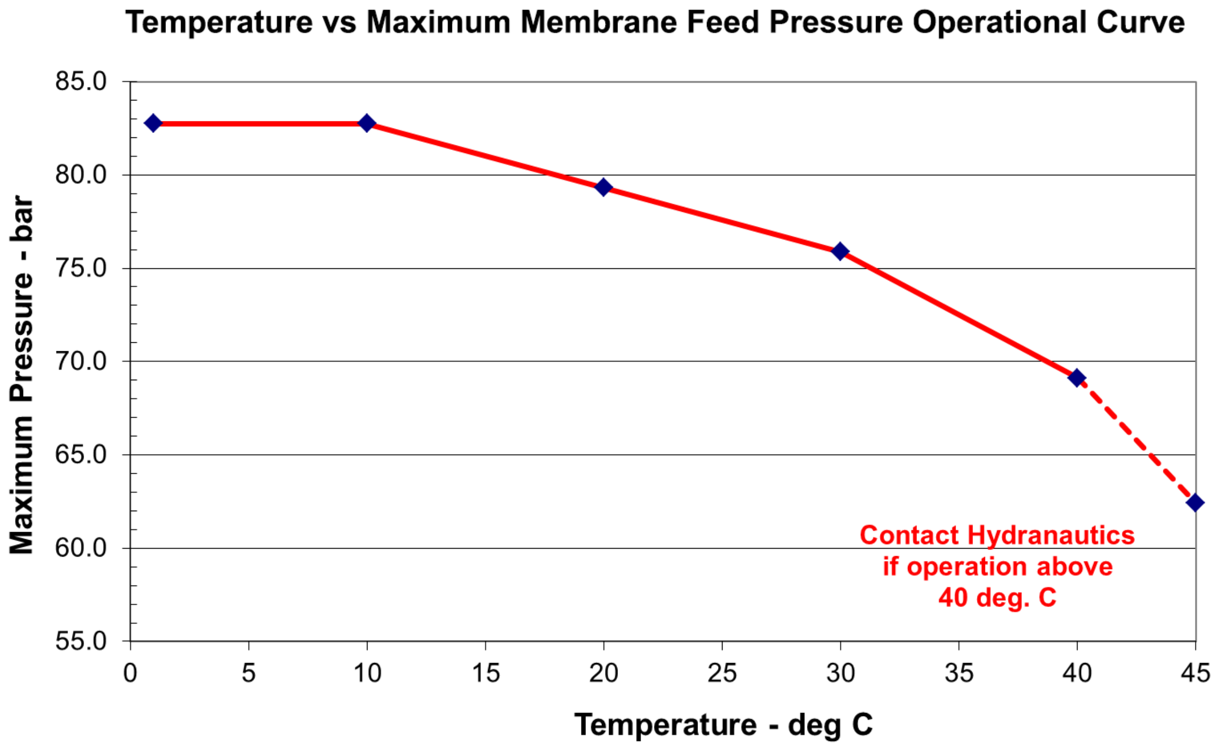


Figure 8b. Temperature versus Pressure Operation Limits for Seawater Membranes* with ABS/GF core tubes - Metric Values.

Figure 9. Permeate core tube collapse and mechanical failure.

Starting in March 2018 seawater elements are being made with PPO type core tubes. In the past, ABS + Glass Fiber was the typical core tube material used for Hydranautics seawater products. The ABS/GF core tube has been an excellent material used for many years in the construction of RO elements, exhibiting good strength, good chemical resistance, and no extractable chemicals that would contaminate the product water. The reason for this current change is to accommodate the growing need in the RO industry to treat very saline water at higher temperatures and pressures. In the past, we have restricted operation of RO systems to stay under the limits shown in Figure 8 above. As a result of changing to the PPO core tube, the pressure/temperature limit of SWRO product can be increased, allowing greater flexibility for operation of the SWRO system (Figure 10).

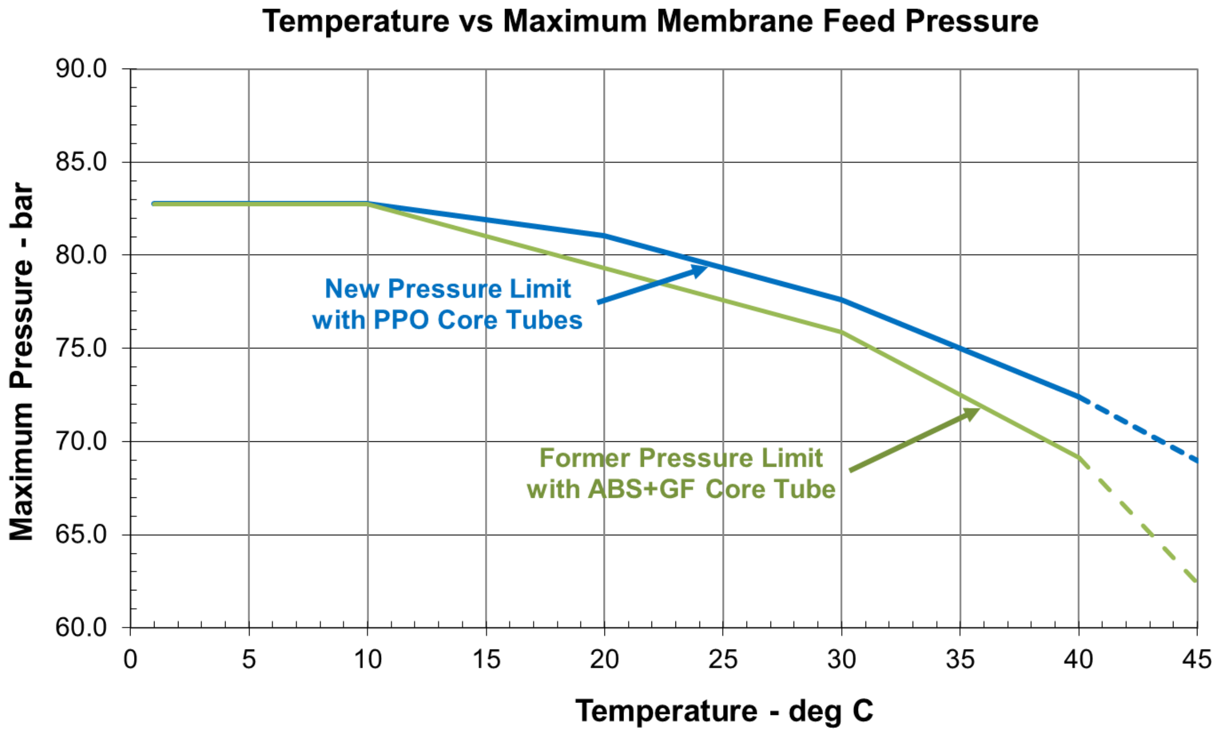


Figure 10. Compare Temperature versus Pressure Operation Limits for Seawater Membranes* with PPO core tubes and ABS+GF core tubes - Metric Values.

The new PPO core tubes will have exactly the same dimensions as the current ABS/GF core tube and can be used interchangeably with elements containing the ABS/GF core tubes. In addition to the superior strength at higher temperatures, PPO also has no extractable contaminants and is compatible with high saline waters. It should be noted, however, that PPO material is more sensitive to the exposure to petroleum products and vegetable oils. These should never be used as lubricants which come in contact with the core tube material, as specified in TSB122 and mentioned above.

*Brackish water elements are made with ABS core tubes and shall not be operated above 600 psi (41.4 bar).