HYDRAMEM®
HIGH PERFORMANCE MEMBRANES

Operation, Maintenance and Handling Manual for HYDRAMEM RO/NF Membrane Elements

Version: JUL 2019

Contents

Introduction

To increase the efficiency and life of reverse osmosis and nano filtration (RO/NF) systems, effective pretreatment of the feed water is required. Selection of the proper pretreatment will maximize efficiency and membrane life by minimizing:

- Fouling
- Scaling
- Membrane degradation

Optimizing:

- Product flow
- Product quality (salt rejection)
- Product recovery
- Operating & maintenance costs

Fouling is the accumulation of foreign materials from feed water on the active membrane surface and/or on the feed spacer to the point of causing operational problems. The term fouling includes the accumulation of all kinds of layers on the membrane and feed spacer surface, including **scaling**. More specifically, colloidal fouling refers to the entrapment of particulate or colloidal matter such as iron flocs or silt, biological fouling (biofouling) is the growth of a biofilm, and organic fouling is the adsorption of specific organic compounds such as humic substances and oil on to the membrane surface. Scaling refers to the precipitation and deposition within the system of sparingly soluble salts including calcium carbonate, barium sulfate, calcium sulfate, strontium sulfate and calcium fluoride.

Pretreatment of feed water must involve a total system approach for continuous and reliable operation. For example, an improperly designed and/or operated clarifier will result in loading the sand or multimedia filter beyond its operating limits. Such inadequate pretreatment often necessitates frequent cleaning of the membrane elements to restore productivity and salt rejection. The cost of cleaning, downtime and lost system performance can be significant.

The proper treatment scheme for feed water depends on:

- Feed water source
- Feed water composition
- Application

The type of pretreatment system depends to a large extent on feed water source (i.e., well water, surface water, Municipal and Industrial wastewater). In general, well water is a consistent feed source that has a low fouling potential. Well water typically requires a very simple pretreatment scheme such as acidification and/or antiscalant dosing and a 5-μ m cartridge filter.

Surface water, on the other hand, is a variable feed water source that is affected by seasonal factors. It has a high fouling potential, both microbiological and colloidal. Pretreatment for surface water is more elaborate than pretreatment for well water. Additional pretreatment steps often include chlorination, coagulation/flocculation, clarification, multimedia filtration, dechlorination, acidification and/or antiscalant dosing.

Industrial and municipal wastewaters have a wide variety of organic and inorganic constituents. Some types of organic components may adversely affect RO/NF membranes, inducing severe flow loss and/or membrane degradation (organic fouling), making a well-designed pretreatment scheme imperative.

Once the feed water source has been determined, a complete and accurate analysis of the feed water should be made. The importance of a feed water analysis cannot be overemphasized. It is critical in determining the proper pretreatment and RO/NF system design.
Finally, the application often determines the type or extent of RO/NF pretreatment required. For example, pretreatment in an electronics application might be much more sophisticated than for a municipal system due to the different product water quality requirements.

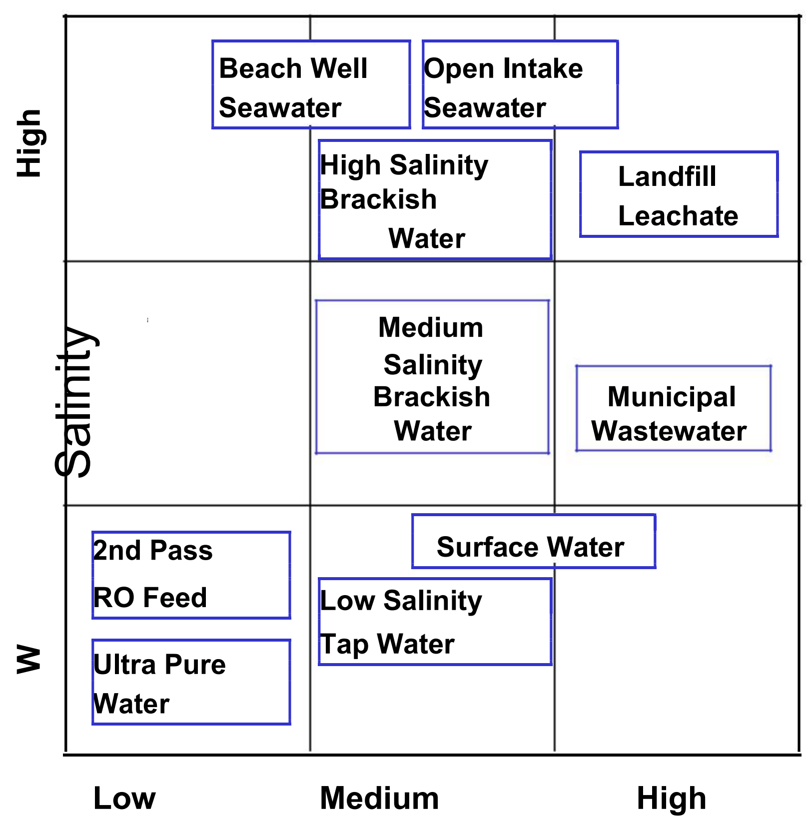
Pretreatment is a continuous water treatment process upstream of a continuous membrane process. Water treatment chemicals may be dosed continuously or intermittently during operation of the RO/NF system

Feed water Type and Analysis

The major water types being treated by RO/NF can be roughly characterized from the total dissolved solids (TDS) content and the organic load (total organic carbon, TOC), see Figure 2.1.

- Very-low-salinity, high-purity waters (HPW) coming from the first RO systems (double-pass RO system) or the polishing stage in ultrapure water (UPW) systems with TDS up to 50 mg/L.
- Low-salinity tap waters with TDS up to 500 mg/L.
- Medium-salinity groundwater with high natural organic matter (NOM) and TDS up to 5,000 mg/L.
- Medium-salinity brackish waters with TDS up to 5,000 mg/L.
- Medium-salinity tertiary effluent with high TOC and biological oxygen demand (BOD) levels and TDS up to 5,000 mg/L.
- High-salinity brackish waters with TDS in the range of 5,000 – 15,000 mg/L. Seawater with TDS in the range of 35,000 mg/L.

Figure 2.1 Major water types being treated by RO and NF



Seawater

Seawater with TDS of 35,000 mg/L is considered standard seawater constituting, by far, the largest amount of water worldwide. The composition is nearly the same all over the world. The actual TDS content may, however, vary within wide limits from the Baltic Sea with 7,000 mg/L to the Red Sea and Arabian Gulf with up to 45,000 mg/L. The actual compositions can be proportionally estimated from the standard seawater composition (Table 2.1). The water from seashore wells, however, depending on the soil, influx from inland, etc., can often have salinity and composition quite different from water taken from the sea itself.

Table 2.1 Standard seawater composition

Ion	Concentration (mg/L)
Calcium	410
Magnesium	1,310
Sodium	10,900
Potassium	390
Barium	0.05
Strontium	13
Iron	< 0.02
Manganese	< 0.01
Silica	0.04 – 8
Chloride	19,700
Sulfate	2,740
Fluoride	1.4
Bromide	65
Nitrate	< 0.7
Bicarbonate	152
Boron	4 – 5
Other	
TDS	35,000 mg/L
pH	8.1

In Table 2.2 and Table 2.3, some chemical and physical characteristics of seawaters with different salinity are shown.

Table 2.2 Inorganic composition of seawater with different salinity

Water	K (ppm)	Na (ppm)	Mg (ppm)	Ca (ppm)	HCO_3 (ppm)	Cl (ppm)	SO_4 (ppm)	SiO_2 (ppm)
Standard seawater - 32,000 ppm	354	9,854	1,182	385	130	17,742	2,477	0.9
Standard seawater - 35,000 ppm	387	10,778	1,293	421	142	19,406	2,710	1.0
Standard seawater - 36,000 ppm	398	11,086	1,330	433	146	19,960	2,787	1.0
Standard seawater - 38,000 ppm	419	11,663	1,399	456	154	20,999	2,932	1.0
Standard seawater - 40,000 ppm	441	12,278	1,473	480	162	22,105	3,086	1.1
Standard seawater - 45,000 ppm	496	13,812	1,657	539	182	24,868	3,472	1.2
Standard seawater - 50,000 ppm	551	15,347	1,841	599	202	27,633	3,858	1.4

Table 2.3 Salinity and conductivity of seawaters

Location	Salinity TDS ppm	Conductivity K µS/cm	Factor K/TDS µS/(cm·ppm)
South Pacific	< 36,000	< 51,660	1.43 – 1.44
Gran Canaria (Atlantic Ocean)	37,600	53,280	1.42
Sardinia (Mediterranean Sea)	40,800	57,240	1.40
Bahrain	42,500	59,350	1.40
Egypt (Red Sea)	44,000	62,990	1.38

The characteristic features of seawater have to be considered in the design and operation of the pretreatment and the reverse osmosis process. As a consequence of the high salinity of seawater involving a high osmotic pressure, the recovery of the system is limited to typically 40 – 50% in order to not exceed the physical pressure limits of the membrane element, or to limit the energy consumption associated with higher feed pressures at higher recoveries, or to limit the salinity and/or the boron concentration in the product water. Seawaters from open intakes may cause biofouling of the RO membranes if no bio fouling prevention measures are in place.

Brackish Water

The composition of brackish waters is of extremely wide variation, and a water analysis is a must for a good process design.

Several examples of brackish water analyses are given in Table 2.4.

In brackish water treatment, the factor limiting recovery is mainly of a chemical nature (i.e., precipitation and scale formation by compounds such as calcium carbonate or calcium sulfate) . The potential for biofouling is also another limiting factor in brackish water treatment. A number of methods are available to assess the biological fouling potential. In industrial and municipal wastewater treatment, a wide variety of organic and inorganic constituents may be present. Thus, the limiting factors are sometimes governed by additional characteristics of feed waters, for example the organic matter or the phosphate scaling potential.

Table 2.4 Examples of brackish water composition

Parameter	Unit	Well water[a]	Well water[b]	Lake water[c]	Surface water[d]	Pretreated tertiary effluent[e]
Calcium	mg/L	84	113	54	102	40 – 64
Magnesium	mg/L	6	2.7	23	11	
Sodium	mg/L	36	23	87	20	150 – 200
Potassium	mg/L	3.3	2	6.6	4	
Iron	mg/L	< 0.05	0.2	0.05	ND – 015	0.02 – 0.09
Manganese	mg/L	0.01	0.1	< 0.01	< 0.01	< 0.05
Barium	mg/L	0.07	0.1	0.09		0.01 – 0.1
Strontium	mg/L	0.7	1	1		0.2 – 1
Ammonium	mg/L	< 0.05			0.3	22 – 66
Aluminum	mg/L	0.02		0.02	ND – 0.15	0.03
Chloride	mg/L	45	52	67	33	150 – 500
Bicarbonate	mg/L	265	325	134	287	48.8 – 97.6
Sulfate	mg/L	24	8	201	56	120 – 160
Nitrate	mg/L	4.3	4	<1.0	15	40 – 60
Fluoride	mg/L	0.14	0.7		0.25	0.7 – 0.7
Phosphate	mg/L	< 0.05	0.6	0.01	1.2	6.1 – 12.2
Silica	mg/L	9	11	3.1	7 – 17	6 – 10
Hydrogen Sulfide	mg/L		1.5			ND
TDS	mg/L	478	377	573	400	500 – 1,300
TOC	mg/L	1.5	10	3.6	2.4	20 – 30 (COD)
Color	Pt	< 5	40		< 5	13 (Hazen)
Turbidity	NTU				2 – 130	0.4 – 1.7
pH		7.5	7.4	8.2	8	6.6 – 7.4
Conductivity	µS/cm	590		879	400 – 700	700 – 2,200
Temperature	°C	12	23 – 28		3 – 25	25 – 35

a. Well water: Germany
b. Well water: The Turnpike Aquifer in Florida (design of the Boynton Beach, FL Membrane Softening Water Treatment, Proc. AWWA Annual Conference, Eng. And Op., 139 (1992))
c. Lake Mead, Nevada (2000)
d. River Oise, France
e. Tertiary effluent: industrial water in Jurong Island, Singapore (Water Reclamation – The Jurong Island Experience – SUT Seraya using Fouling Resistant RO Membrane to Reclaim Wastewater, IDA, Bahrain (2002))

With such wide variation in feed water quality, the first step is to know the water characteristics. Before a projection of an RO or NF system design can be run, a complete and accurate water analysis must be provided. A water analysis form (Table 2.5) must be completed and balanced to electroneutrality (i.e., anion and cation concentrations must be identical when stated in terms of the calcium carbonate equivalent). If the water analysis is not balanced, the addition of either Na+ or Cl– to achieve electroneutrality is recommended.

Table 2.5 Water analysis for RO/NF

Sample identification: ....

Feed source: ....

Conductivity: .... pH: .... Temperature (°C): ....

Feed water analysis:	NH_4^+	....	CO_2	....
Please give units (mg/L as ion	K^+	....	CO_3^{2-}	....
or ppm as $CaCO_3$ or meq/L)	Na^+	....	HCO_3^-	....
	Mg^{2+}	....	NO_3^-	....
	Ca^{2+}	....	Cl^-	....
	Ba^{2+}	....	F^-	....
	Sr^{2+}	....	SO_4^{2-}	....
	Fe^{2+}	....	PO_4^{2-}	....
	Fe (tot)	....	S^{2-}	....
	Mn^{2+}	....	SiO_2 (colloidal)	....
	Boron	....	SiO_2 (soluble)	....
	Al^{3+}	....		

Other ions: ....

TDS (by method): ....
TOC: ....
BOD: ....
COD: ....
AOC: ....
BDOC: ....

Total alkalinity (m-value): ....
Carbonate alkalinity (p-value): ....
Total hardness: ....
Turbidity (NTU): ....
Silt density index (SDI): ....
Bacteria (count/ml): ....
Free chlorine: ....
Remarks: ....
(odor, smell, color, biological activity, etc.) ....

Analysis by: ....

Date: ....

Ba2+ and Sr2+ must be analyzed at the 1 µ g/L (ppb) and 1 mg/L (ppm) level of detection, respectively. It is also important that the temperature be given as a range rather than an absolute value. Temperature variation can impact the scaling potential of an RO system, especially when silica and bicarbonate levels in the feed water are high.
After the membrane system is in service, the feed water should be analyzed on a regular basis so that the pretreatment and the plant operation can be adjusted accordingly. Many standards are available for water analysis techniques. It is recommended to use the standards of ASTM International (www.astm.org) or the latest edition of *"Standard Methods for the Examination of Water and Wastewater"/1/*.

A guide for water analysis for reverse osmosis applications is given in ASTM D 4195 /*2*/; this can be applied to nanofiltration as well. A listing of the relevant ASTM procedures and Standard Methods for the Examination of Water and Wastewater are given in Table 2.6.

Table 2.6 Standard procedures relevant to water analysis for RO/NF applications

	ASTM	**Standard Methods /*1*/**
Calcium and magnesium	D 511	3500-Ca, Mg
Chloride	D 512	4500-Chloride
Carbon dioxide, bicarbonate, carbonate	D 513	4500-Carbon dioxide, 2320
Phosphorus	D 515	4500-P
Sulfate	D 516	4500-Sulfate
Aluminum	D 857	3500-Al
Manganese	D 858	3500-Mn
Silica	D 859	4500-Silica
Dissolved oxygen	D 888	4500-O
Iron	D 1068	3500-Fe
Fluoride	D 1179	4500-Fluoride
COD	D 1252, D 6697	5220
Residual chlorine	D 1253	4500-Cl
pH	D 1293	4500-pH value
Lithium, potassium, sodium	D 1428, D 3561	3500-Li, Na, K
Ammonia nitrogen	D 1426	45---NH_3
Particulate and dissolved matter	D 1888	2560
Turbidity	D 1889	2130
Total organic carbon (TOC)	D 2579, D 4129, D 4839, D 5904	5310
Arsenic	D 2972	3500-As
Boron	D 3082	4500-B
Strontium	D 3352	3500-Sr
Practices for sampling water	D 3370	1060
Nitrite – nitrate	D 3867	4500-Nitrogen
Silt density index	D 4189	
Barium	D 4382	3500-Ba
Microbiological contaminants in water	F 60	
Oxidation-reduction potential (ORP)	D 1498	2580
BOD		5210
AOC		9217

Start-up check lists for RO system commissioning

1. Checks before commissioning

1) Prior to fitting membrane elements and directing water into the RO system, make sure all fittings are tight (in particular Victaulic® joints and pressure vessel's end closures), all instruments and components are operating properly, and feed water matches requirements for RO elements to be installed. In particular, check the following parameters:

- Cleanliness of system; clean according to HM-OMM-200 where necessary
- Fouling Index (SDI 15)
- Turbidity (NTU)
- Absence of chlorine and other oxidants
- Sufficient bisulphite surplus (if used for chlorine removal)

If chlorine dioxide is used for raw water sanitation, a combination of bisulfite dosing and activated carbon should be used for reliable removal of oxidants. Experience has shown that bisulfite dosing alone will not suffice in this situation.

- Absence of flocculants, in particular cationic compounds, originating from raw water pretreatment.

Filter Cartridges must be free of surfactants, lubricants and textile aides. Either order them accordingly or, if unsure, flush them properly according to guidelines of cartridge manufacturer.

Before installing **HYDRAMEM** RO elements and pumping pre-treated water to pressure vessels, verify all dust, grease, oil, metal residues etc. have been removed from pipe installation. If necessary, clean & flush piping and pressure vessels before installation of RO elements. Then Install RO elements.Instructions for installation and pre-commissioning system cleaning, see section HM-OMM-310

2) After element installation, purge air from piping system, including headers and RO vessels for minimum one hour with pre-treated feed water at low feed pressure, with brine valve fully opened. Pay attention not to exceed flush flow rates when venting air from piping as per vessel diameter.

8" vessel: 40 l/min

4" vessel: 10 l/min

Pressure drop (feed to brine) across a pressure vessel / a single RO element must never exceed the following values:

Element type BWE	Per vessel	Per single element
8“	0.4 MPa (0.34 MPa)	0.15 MPa (0.10 MPa)
4“	0.4 MPa (0.34 MPa)	0.15 MPa (0.10 MPa)

3) After bleeding air from system, initial trial run can commence according to design operating parameters

In particular, check and adjust the following parameters to design value:

- Permeate flow rate
- Recovery ratio
- Operation pressure

Prior to final evaluation of trial run, operate for min. two hours at design operating conditions.

During trial run, drain out the permeate & brine. Operate smaller systems with internal concentrate recirculation at lower system recovery without using the recirculation.

4) Check quality of permeate and system performance as following:

Check the permeate conductivity for each vessel. If conductivity of permeate is found above specification, check O-rings, brine seals etc. of the vessel affected, and change parts if necessary. Log all data and corrective measures taken.

Data to be logged in particular:

- Feed: Feed pressure, temperature, TDS (conductivity), pH, fouling index (SDI_{15}), turbidity (NTU), chlorine (not detectable[*])
- differential pressure across each RO bank
- Brine: Brine flow, TDS (conductivity), Ph
- Permeate: Permeate flow of each bank and total system, TDS (conductivity) from each vessel and total system
- In case of $NaHSO_3$ dosing for chlorine removal, min 0.5 mg/l . HSO_3 must be detectable in brine at anytime. It is recommended to take water samples for analysis of individual ions
- Compare operation results with projected data.
- A typical data log sheet is shown in section MEM-OMM-130.

2. Regular start-up checks in daily operation

1) Check feed water quality to meet recommendations for applied membrane elements.

2) Flush RO system with pre-treated feed water at low feed pressure prior to start of high pressure pump.

3) Regulating valve between high-pressure pump discharge and membranes should be nearly closed at HPP start-up to avoid water hammer.

4) Gradually increase feed pressure and feed flow rate to RO elements while throttling brine flow rate. Avoid excessive flow rates and differential pressures across RO banks during start up!

5) Adjust RO operating parameters to targeted permeate and brine flow rates. Do not exceed design recovery ratio (= permeate flow/feed water flow) during any stage of operation.

6) Drain out the permeate until required water quality is obtained.

3. High pressure pump (HPP) start-up procedures

This section describes typical start-up procedures, sorted by type of HPP.

RO systems will usually employ one of these four different types of high-pressure pumps:

1) Plunger (displacement) pump system with constant speed motor (fig. 420.1)

1. Open brine control valve (V_B), to approx. 50 %.
2. Open relief loop valve (V_R).
3. Close feed pressure control valve (V_F), if installed.
4. Start high pressure pump (HPP).
5. Slowly open V_F and close V_R until brine flow reaches design value.
6. Close V_B until brine flow starts decreasing. Feed pressure now starts to increase.
7. Check feed pressure, pressure drop and permeate flow.
8. Repeat procedure 5-7 step by step until permeate and brine flow match design.

2) Centrifugal pump system with constant speed motor (fig. 420.2)

1. Open brine control valve (V_B), to approx. 50 %.
2. Open minimum flow valve (V_M).
3. Close feed pressure control valve (V_F). If no (V_M) is installed, throttle to minimum flow.
4. Start high pressure pump (HPP).
5. Slowly open V_F until brine flow reaches design value (observe note!).
6. When minimum flow for HPP is reached, close V_M (if installed).
7. Close VB until brine flow starts decreasing. Feed pressure now starts to increase.
8. Check feed pressure, pressure drop and permeate flow.
9. Repeat procedure 5-7 step by step until permeate and brine flow match design.

In case excessive brine flow is obtained at point 4 (watch ΔP), brine flow control valve V_B must be throttled from step (1)

3) Centrifugal pump system with constant speed motor and soft start (fig. 420.3)

1. Open brine flow control valve (V_B).
2. Throttle feed pressure control valve (V_F) to approx. 10 %.
3. Start high pressure pump (HPP), (see note (A) and (B)).
4. Slowly open V_F until design brine flow is reached.
5. Close V_B until brine flow starts decreasing. Feed pressure now starts to increase.
6. Check feed pressure, pressure drop and permeate flow.
7. Repeat procedures 4 – 6 step by step until permeate and brine flow match design.

Note (A): In case excessive brine flow is obtained, (watch □P), brine flow control valve (V_B) should be set to throttled position in advance.

Note (B): In order to avoid excessive feed flow, feed valve is to be throttled from the beginning

4) Centrifugal pump system with frequency controlled motor (fig. 420.4)

1. Open brine flow control valve (V_B)
2. Start high pressure pump (HPP) at minimum frequency (speed)
3. Increase speed of HPP until design brine flow is reached
4. Close VB until brine flow starts decreasing. Feed pressure now starts to increase
5. Check feed pressure, pressure drop and permeate flow.
6. Repeat procedures 3 – 5 step by step until permeate and brine flow match design.

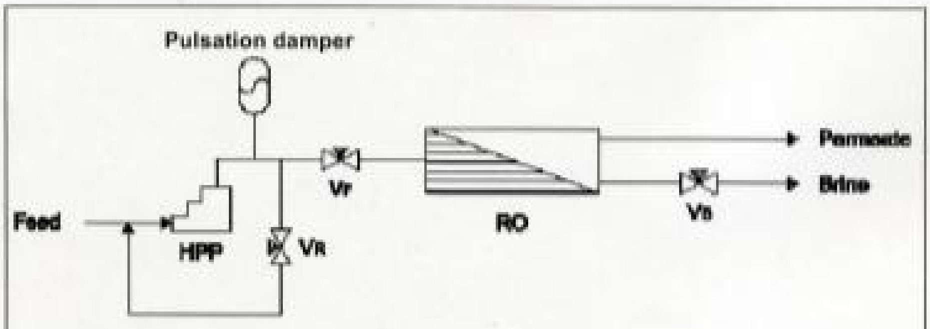


Fig. 420.1 : Plunger (displacement) pumps system with constant speed motor

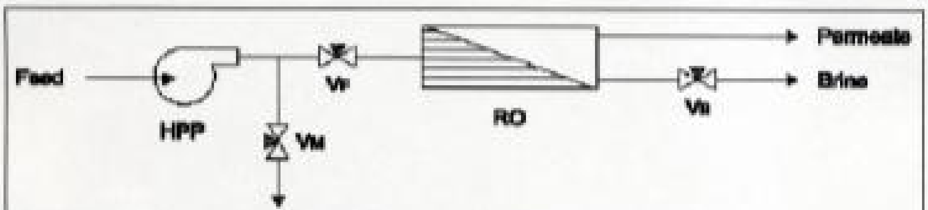


Fig. 420.2 : Centrifugal pump system with constant speed motor

Fig. 420.3 : Centrifugal pump system with constant speed motor and soft start

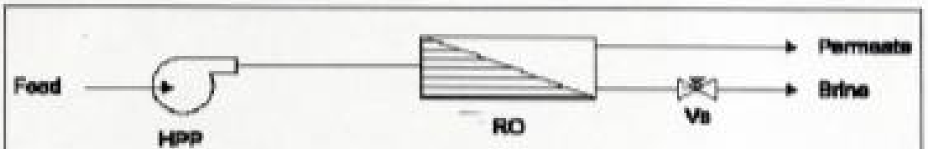


Fig. 420.4 : Centrifugal pump system with frequency controlled motor

Note: Above fig. 410.1 – 420.4 are for general explanation of high-pressure pump start-up procedures, hence some of the necessary equipment and instruments are not shown.

Operation Monitoring Methods for RO System

Monitoring of RO performance is a fundamental prerequisite to ensure reliable, high-availability performance. Regular records will provide a solid basis for troubleshooting and handling of complaints.

1. Monitoring

Operating data to be logged and logging periods are listed in Tables A1 to A3. Table B

summarizes typical water analysis items for periodical check-up.

Table C summarizes items for scheduled or situation-related maintenance.

2. Regular Monitoring and Check Points

When feed water quality and operating parameters: pressure, temperature, and recovery, are constant, permeate flow rate and permeate quality should be within ±5 % of their values intended, without substantial fluctuations or trends to change performance.

If a.m. parameters are subject to change, perform regular ‚normalization‘ in order to enable a comparison of nominal and actual values.

Frequency of normalizations will depend on extent and frequency of variations in feed quality and operating conditions.

This will also apply prior to any maintenance works affecting general operating parameters. If necessary, correct operating conditions.

3. Logbook

Log all operation relevant events with time and date, especially where the following „key factors“ are involved or could change.

Parameters	Key factors affecting performance
Permeate quality	Feed water quality (the total sum of the ions present) – Composition of feed water (monovalent and polyvalent ions) – Feed pH – Temperature – Pressure – Recovery (conversion) ratio
Permeate flow rate	Feed water quality (total ions, colloids and suspended solids; fouling tendency (SDI_{15}) – Temperature – Pressure – Recovery (conversion) ratio

4. Normalization of Permeate Quality

In order to effectively evaluate system performance it is necessary to „normalize“ daily actual operating data obtained to a set of standard conditions (Normalization = efficiency comparison of the current measured values), and compare these data with:

a) Measured values at initial operation or

b) (upon commissioning) with projection data.

Normalized values will allow to determine if the system runs according to projection. If system performance deviates, they help in determining correct corrective measures (e.g. cleaning).

Salt rejection and **salt passage** are defined and calculated as follows:

$$\text{salt passage (\%)} = \frac{\text{permeate concentration}}{\text{average feed water concentration}} \text{ x } 100\ (\%) \qquad (1)$$

$$\text{salt rejection (\%)} = 100 - \text{salt passage} \qquad (2)$$

$$\left(\begin{array}{l}\text{average feed}\\ \text{water concentration}\end{array}\right) = \frac{\text{feed water concentration}}{\text{recovery ratio}} \text{x} \ln\left(\frac{1}{1 - \text{recovery ratio}}\right) \qquad (3)$$

(or - somewhat less precisely -)

$$\left(\begin{array}{l}\text{average feed}\\ \text{water concentration}\end{array}\right) = \left(\frac{\text{feed water concentration} + \text{brine concentration}}{2}\right) \qquad (3')$$

where

$$\text{recovery ratio } (\%)^{*1} = \frac{\text{permeate flow rate}}{\text{feed flow rate}} \tag{4}$$

and

$$\text{concentration} = \text{TDS or conductivity}^{*2} \tag{5}$$

*1 Recovery results as decimal value

*2 It is simpler to use a summarized parameter instead of the chemical concentrations expression for the feed water. Most practically, use conductivity, (see Fig. 430.1 and Fig. 430.2)

Above calculation will compensate fluctuations of feed water concentration and recovery ratio. It is recommended, however, to maintain recovery within ±2 % of intended value for the system.

Further to this, the salt passage obtained through equation (1) must be normalized considering fluctuations or change of (treated) feed pH, temperature and operation pressure as follows:

$$\text{normalized salt passage } (\%) = \text{salt passage } (\%) \times CC_H \times CC_T \times CC_P \times CC_C \tag{6}$$

where

1. CC_H is a correction factor for feed water pH,
2. CC_T is a correction factor for feed water temperature, is a
3. CC_P correction factor for feed water pressure, and
4. CC_C is an additional correction factor for feed concentration.

5. Normalization of Permeate Flow Rate

The Normalized Permeate Flow Rate can be calculated according to the following equation:

$$NPFR = \frac{NDP_S}{NDP_D} \times TCF \times QP_D \tag{7}$$

where

$$NDP = \text{feed pressure} - \tfrac{1}{2} \times \text{pressure drop} - \text{permeate pressure} - \varnothing P_{OSM} \tag{8}$$

and

NPFR = Normalized permeate flow rate

NDP	=	net driving pressure
$\mathbf{NDP}_S$	=	net driving pressure at standard or design conditions
$\mathbf{NDP}_D$	=	actual net driving pressure
$\mathbf{QP}_D$	=	current permeate flow rate
$\mathbf{\text{Ø}P}_{osm}$	=	Average osmotic pressure
		feed water osmotic pressure corresponding to average feed water concentration from eq. (3) or (3').
TCF	=	Temperature correction factor (characteristic of membrane type used in the system)
		This adjusts the current permeate flow rate to the value at 25 °C.

As long as the RO system is operating under reasonably constant conditions, NDP calculation according to eq. (8) may be replaced by the following equation (9):

$$\text{NDP} = \textbf{feed pressure - constant value} \qquad (9)$$

where

$$\textbf{constant value} = \tfrac{1}{2} \text{ x } \textbf{pressure drop} + \textbf{permeate pressure} + \text{Ø}P_{OSM} \qquad (10)$$

For multi-bank systems, the normalization must be done for each bank separately. Multi-bank calculations in a single step can yield inaccurate results.

6. Variations of operation data from nominal value

As a guideline, the following tolerance is applicable for deviations:

Items	Accepted deviation *)	
	(A)	(B)
Normalized salt passage	± 20 %	± 5 %
Normalized permeate flow rate	± 5 %	± 2 %

*) These values are the percentages of variation of determined value from the mean value by

(A) = data read by varying persons

(B) = Single operator precision

7. Precautions and useful information for monitoring operating data

Daily monitoring of operating parameters provides a solid basis for evaluation of RO system performance.

Recognize deviant performance trends for salt passage, permeate flow rate or pressure drop. This enables timely selection of appropriate countermeasures, avoiding irreversible damage to membrane elements or other system components.

1) Guidelines for maintenance (considerations for cleaning) are described in HM-OMM-200

2) Troubleshooting guides are described in HM-OMM-400 section

3) Typical signs of system performance change are shown in section HM-OMM-130

4) In order to evaluate actual system status and to detect trends early, a systematic – graphical - monitoring chart (example see Fig.430.3) of normalized performance data is recommended.

For large projects and special applications, quality of plant monitoring can be a criterion for system warranties which have to be agreed upon.

8. RO System Operation Parameters and Check Points

Table A1: Softened drinking or well water, ØSDI < 2, peak 3; ØNTU < 0.3, peak 0.5

Parameters	Online Monitoring (Continuously)	Daily (Data sheet)	Periodically (1)	Alarm & safety system
1. Date & Time of data logging		x		
2. Total operating hours		x		
3. Number of vessels in operation			X	
4. Feed water conductivity	✓(2)	x		
5. Total hardness		x		X
6. Feed water pH			X	
7. Feed water FI (SDI_{15})		x		
8. Feed water temperature	✓(3)	x		✓(3)
9. Feed water pressure	x	x		X
10. Feed water chlorine concentration	✓(4)	✓(4)		✓(4)
11. Brine surplus of HSO^{3} (□□0.5 mg/l) *		x		X
12. Feed water individual ion concentration			✓(6)	
13. Brine conductivity		x		
14. Brine pH			X	
15. Pressure drop of each bank		x		X
16. Brine flow rate		x		X
17. Total permeate conductivity	x	x		X
18. Permeate conductivity of each vessel			✓)	
19. Permeate pressure	✓(5)	x		✓(5)
20. Total permeate flow rate	x	x		X
21. Permeate flow rate for each bank		x		
22. Permeate individual ion concentration			✓(6)	
23. Total recovery ratio		x		
24. Recovery ratio for each bank			X	
25. Normalized salt passage			X	
26. Normalized permeate flow rate			X	

*) HSO_3 surplus in brine if raw water is chlorinated

Notes:

(1) Log these parameters monthly from initial start-up operation. In case of trouble shooting or fluctuating operating conditions, the operating party is requested to check these parameters more frequently, depending on particular situation.

(2) In case of significant fluctuations

(3) In case of high fluctuations or heat exchanger systems

(4) If chlorine is detected in feed water, plant must be stopped immediately and flushed with chlorine-free water.

(5) In case of fluctuating pressure > 0.5 bar, closed permeate loop or (automatic) valve □□risk of water hammer.

(6) Recommended procedure is water analysis of individual ions, comparing results with projected data. Required typical ions are listed in Table B

Table A2: Drinking or well water, ØSDI < 3, peak 4; ØNTU < 0.3, peak 0.5

Parameters	Online Monitoring (Continuously)	Daily (Data sheet)	Periodically (1)	Alarm & Interlock System
1. Date & Time for data logging		x		
2. Total operating hours		x		
3. Number of vessels in operation		x		
4. Feed water conductivity	x(2)	x		
5. Feed water pH	x(3)	x		x(3)
6. Feed water FI (SDI_{15})		x		
7. Feed water turbidity (NTU)			X	
8. Feed water temperature	x(4)	x		x(4)
9. Feed water pressure	X	x		X
10. Feed water chlorine concentration	x(5)	x(5)		x(5)
11. Antiscalant concentration in feed wa-		x(8)		X
12. Brine surplus of HSO^3		x		x(5)
13. Indiv. ion concentrations feed water			x(6)	
14. Brine conductivity		x		
15. Brine pH	x(3)	x		
16. Pressure drop of each bank		x		X
17. Brine flow rate	X	x		X
18. Total permeate conductivity	X	x		X
19. Permeate conductivity of each vessel			X	
20. Permeate pressure	x(7)	x		x(7)
21. Total permeate flow rate	X	x		X
22. Permeate flow rate for each bank		x		
23. Permeate individual ions			x(6)	
24. Total recovery		x		X
25. Recovery for each bank			X	
26. Normalized salt passage			X	
27. Normalized permeate flow rate			X	

*) HSO_3 - surplus in concentrate □= 0.5 ppm in case of chlorinated raw water

Notes:

(1) Log these parameters monthly from initial start-up of operation. In case of trouble shooting or fluctuating operating conditions, the operating party is requested to check these parameters more frequently, depending on particular situation

(2) In case of significant fluctuations

(3) In case of high fluctuations or acid dosing

(4) In case of high fluctuations or heat exchange system

(5 If there is any possibility of chlorine content in feed water

(6) Recommended is water analysis of individual ions, comparing results with projected data. Required typical ions are listed in Table B

(7) In case of fluctuating pressure > 0.5 bar, closed permeate loop or (automatic) valve □□risk of water hammers

(8) Volumetric recording of daily consumption, divided by total daily feed flow.

Table A3: Surface water/tertiary effluent, Ø SDI < 4, peak 5; Ø NTU < 0.3, peak 1.0

Parameters	Online Monitoring (Continuously)	Daily (Data sheet)	Periodically (1)	Alarm & Interlock System
1. Date & Time for data logging		x		
2. Total operating hours		x		
3. Number of vessels in operation		x		
4. Feed water conductivity	x	x		
5. Feed water pH		x		X
6. Feed water FI (SDI_{15})		x		X
7. Feed water turbidity (NTU)	x	x		X
8. Feed water temperature	x	x		X
9. Feed water pressure	x	x		X
10. Feed chlorine concentration	x	x		X
11. Feed antiscalant concentration		x		X
12. Brine surplus of HSO_3^- (□□0.5 mg/l)		x		X
13. Indiv. ion concentration feed water			x(2)	
14. Brine conductivity		x		
15. Brine pH	x	x		
16. Pressure drop of each bank	x	x		X
17. Brine flow rate	x	x		X
18. Total permeate conductivity	x	x		X
19. Permeate conductivity of each vessel			X	
20. Permeate pressure		x		X
21. Total permeate flow rate	x	x		X
22. Permeate flow rate for each bank		x		
23. Indiv. ion concentration permeate			X(2)	
24. Total recovery ratio		x		X
25. Recovery ratio for each bank			X	
26. Normalized salt passage			X	
27. Normalized permeate flow rate			X	

*) HSO_3^- surplus in concentrate if raw water is chlorinated

Notes:

(1) Log these parameters monthly from initial start-up of operation. For trouble shooting or with fluctuating operating conditions, additional check-ups are required, depending on particular situation

(2) Recommended procedure is water analysis of individual ions, comparing results with projected data. Required typical ions are listed in Table B

Table B: Typical Water Analysis Items

Items		Feed Water	Permeate
1. Conductivity (25°C)	(µS/cm)	x(1)	X
2. Total dissolved solids	(TDS)	x	X
3. pH (25°C)		x	X
4. Chloride	(Cl^-)	x(1)	X
5. Nitrate	(NO_3^-)	x	X
6. Bicarbonate	(HCO_3^-)	x(1)	X
7. Sulfate	(SO_4^{--})	x	X
8. Phosphate	(PO_4^{---})	x	
9. Fluoride	(F^-)	x	
10. Sodium	(Na^+)	x	X
11. Potassium	(K^+)	x	X
12. Ammonium	(NH_4^+)	x	
13. Calcium	(Ca^{++})	x(1)	X
14. Magnesium	(Mg^{++})	x(1)	X
15. Strontium	(Sr^{++})	x	
16. Barium	(Ba^{++})	x	
17. Iron as Ion	(Fe^{++})	x	
18. Manganese	(Mn^{++})	x	
19. Silicate	SiO_2	x	X
20. Silicic acid	SiO_3^{--}	x	X
21. Chemical oxygen demand	COD	x	
22. Biological oxygen demand	BOD	x	
23. Total Organic Carbon	(TOC)	x	X
24. Carbon Dioxide	(CO_2)	x	
25. Hydrogen Sulfide	(H_2S)	x	
26. Temperature	°C	x	

Note:

Above table is for reference only. Selection of required ions for analysis will also depend on feed water quality and required permeate quality.

(1) These values constitute the minimum information required for a qualified RO lay-out. Ions not analyzed will not be available for calculation of scaling potentials.

Table C: RO System Maintenance Items Recorded

Items	Frequency & Procedure
1. Instruments (1) pressure sensors & indicators (2) System control devices (3) Safety shut-down facilities	Regular calibration and maintenance should be performed according to the maintenance manual supplied by engineering of system manufacturer.
2. Cartridge Filter Change ***Use only pre-washed filter catridges free of surfactants and textile aides***	Record date changed, differential pressure of old and new (clean) cartridges, and pore size, material and working of filter catridges used.
3. RO system cleaning As a minimum, record the following: (1) Type of cleaning solution and its concentration (2) Conditions during cleaning (pres- sure, temperature, flows, pH, con- ductivity)	Perform according to maintenance manual supplied by system manufacturer. **HYDRAMEM** guidelines and instructions are given in HM-OMM-200
4. Membrane Treatment upon shutdown Record preservation method, concentra- tion of conservation solutions, operating conditions before shut down and dura- tion of shut-down/conservation.	Perform according to system manufacturer's operating manual. HYDRAMEM guidelines & instructions are given in HM-OMM-300

Record details, observations and comparison data of maintenance works, also on associated components, with RO log.

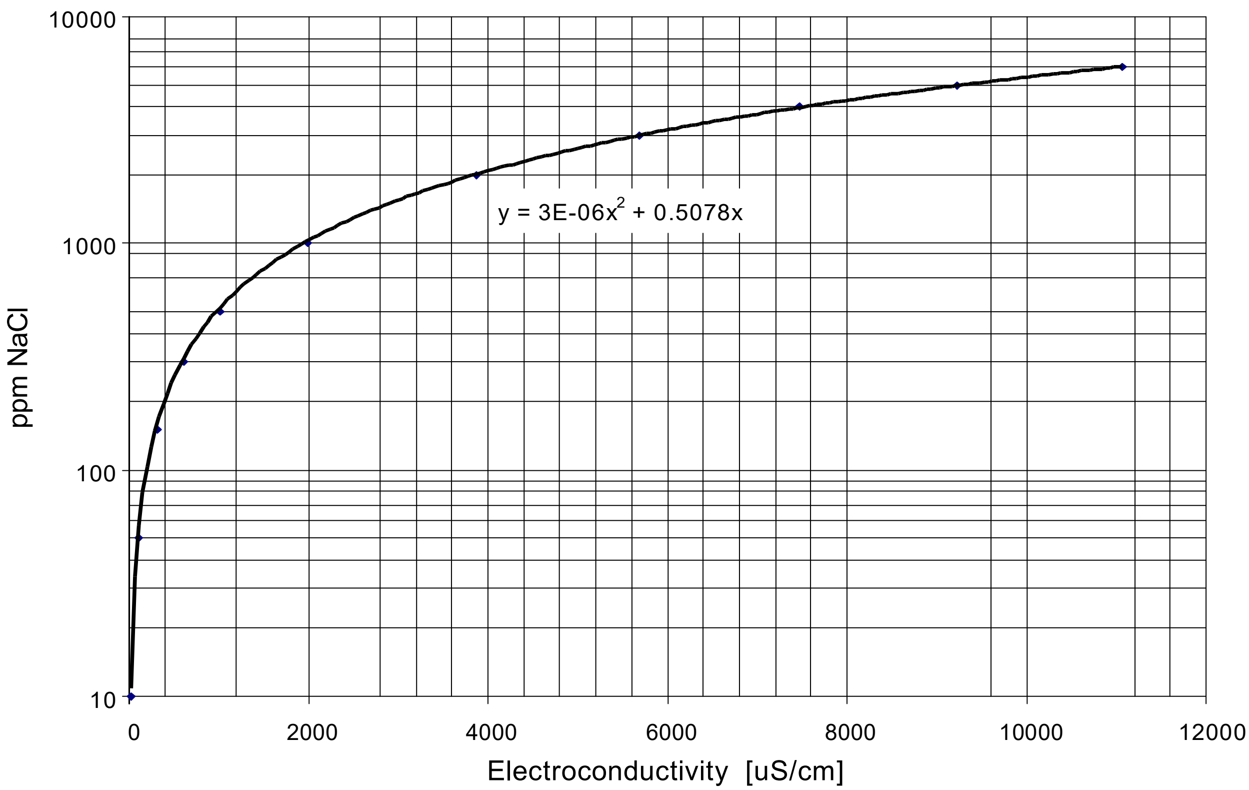


Fig. 430.1: Conductivity / NaCl concentration conversion factors at 25 °C

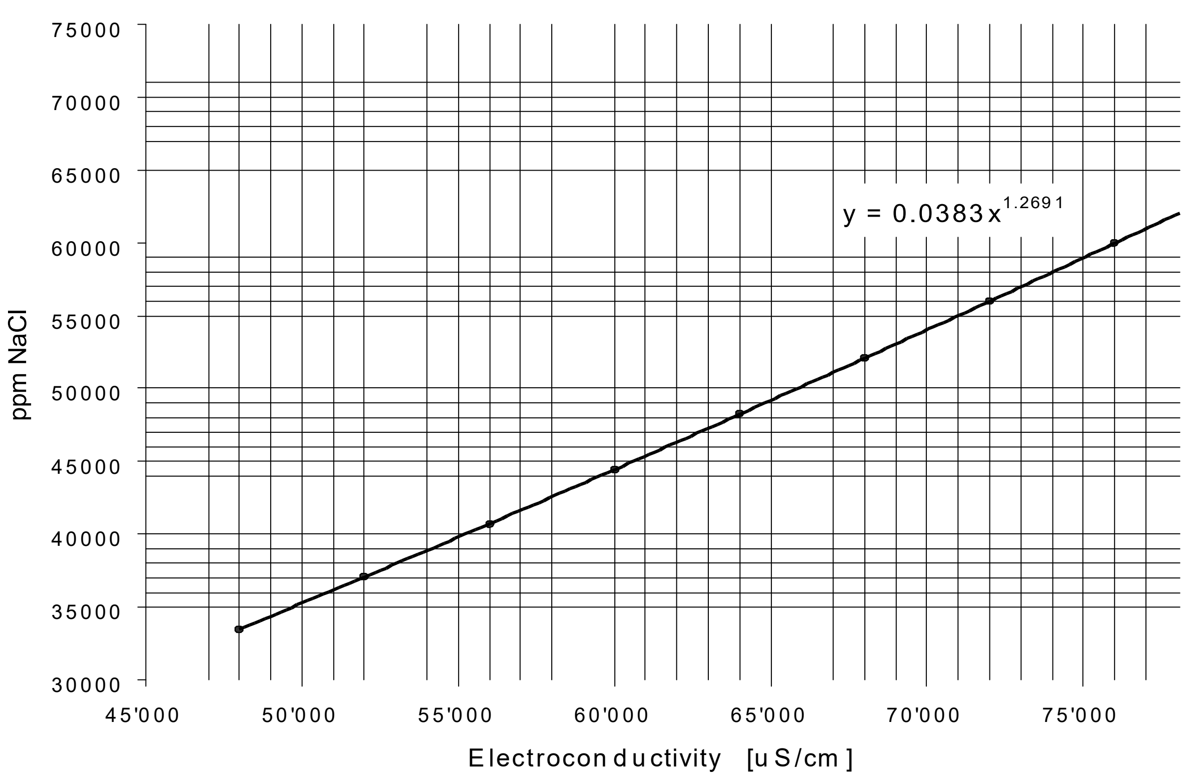


Fig. 430.2: Conductivity / NaCl concentration conversion factors at 25 °C

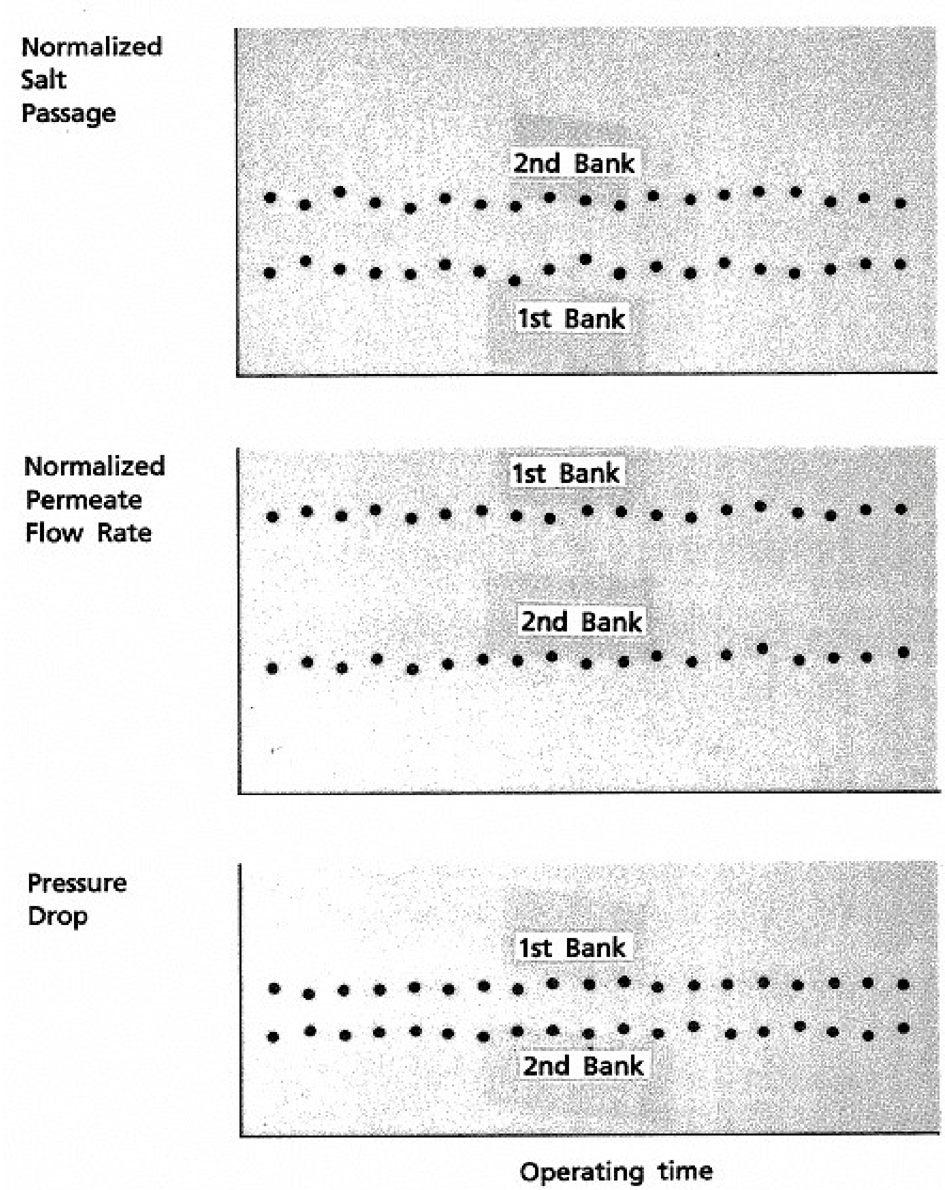


Fig. 430.3: Typical monitoring chart for RO system

Note:

Daily monitoring is recommended. Watch out for performance change trends. In this example, no performance change is observed.

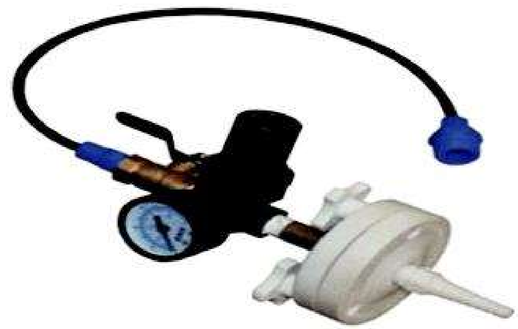
Procedure for Measuring Silt Density Index (SDI)

The Silt Density Index, or most commonly referred as SDI, is a popular method of determining feed water quality of reverse osmosis membrane systems. SDI is a measurement of the fouling potential of suspended solids. Typically reverse osmosis systems require SDI to be below 5.0 in sea water systems, and below 4.0 in brackish systems*. SDI values are reported as SDIX, where X is the total time, reported in minutes, required to obtain the final sample.

In essence, the SDI measurement is a simple, pressure regulated test to measure the flow decline, or decline in filtration rate of the feed water through a 0.45μ filter. Though easy in theory, the procedure and operation requires practice to get accurate results.

General Rules for Conducting SDI Test

- Ensure that the 'O' ring is clean and in good condition.
- Prior to installing the filter, flush the equipment to remove contaminants.
- Carefully load membrane filter to avoid any damage.
- Ensure all air is purged from inlet side of filter housing.



Procedure

1) Purge any air in the filter holder. This can be achieved by opening the bleed valve or loosening the filter holder while cracking the ball valve. After purging, close the bleed valve or the holder.
2) Place 500 ml graduated cylinder under the filter apparatus to measure the time it takes to fill.
3) Open the ball valve fully, verifying that the regulator is set at 30 psi, and measure the time it takes to fill the graduated cylinder up to 100 ml and 500 ml from the time the valve is opened. Record these values, leaving the valve open and letting the flow continue**.
4) Subsequent measurements should be conducted at five minutes, ten minutes and fifteen minutes from the time the ball valve was initially opened. Again, record the time it takes to fill 100 ml and 500 ml, leaving the valve open and letting the flow continue until completion of the test. ***

Note: *Verify with the membrane manufacturer and/or system designer as to the specific SDI limits for your site.*
The time to collect 500 ml of water should be approximately five times greater than the time to collect 100 ml. If it takes longer than this to collect 500 ml, the test should be conducted using only 100 ml collection time.
If the pressure exceeds 75% of 30 psi set point, re-run the test utilising a shorter time (typically 5 or 10 minutes).

SDI is calculated using the following formula:

SDI15 = (1-Ti/Tf) / Tt* 100

where SDI15 = Silt Density Index at 15 minutes

Tt = total test time in minutes

Ti = initial time in seconds to obtain 500 ml sample

Tf = time required in seconds to obtain 500 ml at 15 minutes (or less)

Cleaning Procedure for HYDRAMEM RO Membrane Elements

Once RO system is commissioned and starts running continuously there is a possibility of the membranes getting scaled or fouled due to the impurities present in the water. Based on feed water quality, the plant design, pre treatment scheme/equipments and operation and maintenance practices, the scaling and fouling can be rapid in some cases and user need to be vigilant about such occurrences.

Effects of Scaling and Fouling on Membrane System

	Normalised Permeate Flow (NPF)	Salt Passage (SP)	Pressure Drop (delta P)
Scaling	Reduction in NPF	Increase in SP	Moderate increase delta P
Colloidal Fouling	Normal reduction in NPF	Slight increase in SP	Gradual increase in delta P
Bio Fouling	Reduction in NPF	Increase in SP	Sharp increase in delta P
Organic Fouling	Sharp reduction in NPF	Increase in SP	Moderate increase in delta P

When to Clean
Membrane cleaning is a vital part of any membrane maintenance program. It is important to clean the membrane in initial stage of scaling or fouling. It is very difficult to clean membrane which is extremely fouled or scaled and such membrane may get irreversibly damaged while cleaning.

Cleaning is recommended when one or more of the following parameter changes by more than 10% after data normalization.

- Decrease in normalised permeate flow
- Increase in product water conductivity or salt passage
- Increase in feed water pressure
- Increase in delta P across the RO block

Effective cleaning requires some knowledge of scalant or foulant and the cleaning options available.

Impurities which can cause scaling and fouling are:

- Calcium carbonate
- Calcium sulfate
- Barium or strontium
- Metal oxides (iron, manganese, copper, nickel, aluminum, etc.)
- Silica
- Inorganic colloidal deposits
- Mixed inorganic/organic colloidal deposits
- Natural Organic Matter (NOM)
- Synthetic organic materials
- Carryover of Pretreatment chemical (e.g. Antiscalant/dispersants & cationic polyelectrolytes)

  Biological (bacterial slime, algae, mold, or fungi

Method to Identify Scalant & Foulant by Deposit Analysis

Collect deposit from cartridge filter , ro pressure tube with the help of plastic scraper and dry them and analyse as mentioned below to identify the correct scalant/foulant.

- Take 1 gm of dry powder deposit and treat with conc. HCl. Filter the solution and wash the residue with DI water. Further dry the residue and weighed. Difference in weight gives acid soluble deposits which are present on membrane surface. High amount of acid soluble indicate deposit is of scales like $CaCO_3$, metal hydroxide etc. The filtrate is analysed for soluble ions like Fe, Al, Ca etc. to determine the nature of acid soluble deposits.
- Dry residue from the above step is burned in muffle furnace and residue is weighed. Reduction in weight is volatile organics. High amount of volatile organic indicates organic deposits / biological growth.
- Residue after burning is treated with hydrofluoric acid and heated in muffle furnace. The difference in weight is silica. High amount of silicates indicates presence of sand like substance into the systems.
- Once the scalant or foulant is identified, the cleaning chemical can be selected and cleaning carried out effectively.

Selection of Cleaning Chemicals

1. A low pH cleaning solution (target pH of 4) of 2.0% (w/w) citric acid is useful in removing inorganic scale (e.g. calcium carbonate, calcium sulfate, barium sulfate, strontium sulfate) and metal oxides/hydroxides (e.g. iron, manganese, nickel, copper, zinc), and inorganic-based colloidal material.

2. This is a high pH cleaning solution (target pH of 10.0) of 2.0% (w/w) STPP (sodium tripolyphosphate) and 0.8% (w/w) Na-EDTA (sodium salt of ethylene diamine tetraacetic acid). It is specifically recommended for removing calcium sulfate scale and light to moderate levels of organic foulants of natural origin. STPP functions as an inorganic-based chelating agent and detergent. Na-EDTA is an organic-based chelating agent that aids in the sequestering and removal of divalent and trivalent cations and metal ions.

3. This is a high pH cleaning solution (target pH of 12.0) of 2.0% (w/w) of STPP (sodium tripolyphosphate) and 0.025% (w/w) Na-DDBS (sodium salt of dodecylbenzene sulfonate). It is specifically recommended for removing heavier levels of organic foulants of natural origin. STPP functions as an inorganic-based chelating agent and detergent. Na-DDBS functions as an anionic detergent.

General precautions to be taken pre, post and during cleaning

1. The complete cleaning system, starting from cleaning solution tank , cartridge filters, flexible and fix pipes need to be flushed with clean water before starting the cleaning.
2. Always use new set of cartridge filters associated with cleaning system for every cleaning.
3. Permeate valve of individual pressure tube as well as main permeate outlet valve need to be kept open during cleaning.
4. Use the optimum cleaning parameter such as pH, temperature and contact time to get the membranes clean. This will optimize the life of the membranes.
5. Always clean the membranes in the pH range of 4 to 10, if the desired results are not obtained then only go for higher pH range of 2 to12.
6. While selecting cleaning chemical (proprietary chemical or generic chemical) make sure that the chemical is compatible with HYDRAMEM RO elements.
7. Throughout the cleaning i.e. chemical cleaning as well as flushing, the direction of flow should be maintained same ass the feed water flow 8. The pH meter needs to be calibrated before starting cleaning.
8. In case of multi stage system, cleaning should be always done stage wise to maintain high velocity of cleaning solution and foulants from one stage should not be allowed to flow to next stage.

It is always recommended to record the major operating parameters before and after completing the chemical cleaning of RO Membrane to understand the effectiveness of chemical cleaning.

Membrane Cleaning Procedure

The RO membrane elements can be cleaned in place, in the pressure tubes by re-circulating the cleaning solution across the RO Block at low pressure and relatively high flow. There is no fix cleaning procedure for membrane cleaning, the procedure changes based on prevalent situation. The approximate time to clean one RO Block is between 4 to 8 hrs.

General Cleaning Procedure for RO Membrane is as follows:

Low Pressure Flushing: Perform low pressure flushing by using DI water or RO Permeate at approximately 4 kg/cm^2 pressure for around 30 minutes or till the flushing water completely replaces feed water or brine water which was present inside the RO Pressure tube.

Chemical Preparation: Fill the chemical preparation tank with RO Permeate or DI water and mix the selected cleaning chemical as per given quantity. Adjust the pH of the cleaning solution as per guide lines. Record the pH, turbidity and conductivity of cleaning solution.

Chemical Circulation: At the start of re-circulation, drain the water till the concentrated cleaning solution start coming out flexible hose. This needs to be done to avoid the dilution of concentrated cleaning solution. After that couple the flexible hose to RO Unit and start recirculation. For the first 5 minutes, slowly throttle the flow rate to 1/3 of the maximum design flow rate. This is to minimise the potential plugging of the feed path with a large amount of dislodged foulants. For the second 5 minutes, increase the flow rate to 2/3 of the maximum design flow rate, and then increase the flow rate to the maximum design flow rate. Check the pH, turbidity and conductivity of cleaning solution after each circulation step, if the pH drops by 0.5 units, then adjust the pH of the solution to the initial level. If the cleaning solution turbidity, conductivity and Iron content increases significantly than the initial startup values; the cleaning solution should be drained and new solution prepared to continue with cleaning to improve cleaning efficiency. Continue re-circulation for 30 minutes keeping the record of pH, Turbidity and conductivity.

Chemical Socking: Stop the recirculation close the respective valves and sock the entire RO block for 30 minutes in cleaning solution. In typical cleaning, each socking and re-circulation cycle consist of 30 minutes. This can be change based on recommendations of specialty chemical supplier.

Repeat the Socking and recirculation step to get the best results.

Low pressure Flushing: After cleaning, open the drain valve of cleaning chemical tank and drain the cleaning chemical if any. Fill the tank with RO Permeate or DI water and start the flushing the RO block and allow the water to drain. Continue this low pressure flushing till the pH of flushed water is the same as the RO Permeate or DI water

HYDRAMEM Membrane Storage Procedure

This document provides guidelines for storing of HYDRAMEM composite polyamide RO Membrane Element.

Storage procedure is divided in three categories based on the duration of storage, which are:

- Short term storage in place
- Long term storage in place
- Storage before installation

Short term storage in place
Short term storage is when RO plant is not in operation for more than 5 days but less than a month with RO element in place.

Follow instructions mentioned below for short term preservation:

5) Flush the RO unit with feed water at lower pressure, to remove air pockets from pressure tube and distribution pipes, till feed water conductivity equals reject water conductivity. Instead of feed water the system can also be flushed with permeate. Permeate has added benefit as it may help remove built up foulants and to some extend scales also.
6) Once the complete RO unit is flushed, close all the relevant valves to prevent the air from entering the RO unit.
7) Follow the above two steps after every 5 days.

Long term storage in place
Long term storage is the one when the RO plant is not in operation for more than 30 days with RO element in place. It is always recommended to clean the RO/NF system before preserving it for longer period.

Follows instructions mentioned below for long term preservation:

1) Flush the RO unit with permeate water at lower pressure, to remove air pockets from pressure tube and distribution pipes, till feed water conductivity and reject water conductivity is equal.
3) Prepare 1 % SMBS (sodium metabisulfite) solution by using RO permeate and start flushing RO unit till the SMBS solution completely replaces the permeate water which is present inside the unit and then start recirculation of SMBS solution to ensure that all air pockets in pressure tube and distribution pipes are removed.
4) Once the complete RO unit is flushed with 1% SMBS solution, close all the relevant valves to prevent the air from entering the RO unit.
5) Repeat Steps 1, 2 and 3 with fresh solution of SMBS every fifteen days.
6) When the RO system is ready to return to service, flush the system for approximately 30 mins using low-pressure feed water with the product dump valve open to drain. Then start the system and allow the permeate to drain for 15 mins before taking the RO system in service.

Note:
When SMBS is used for preservation of RO membrane it is strictly recommended to use RO permeate or DI water which is free from iron or iron compound because SMBS react with iron and forms oxidising agents which can oxidise the polyamide RO membrane.

Storage before installation

When RO elements are stored prior to installation, they should be protected from direct sunlight and stored in a cool, dry place with an ambient temperature range of 40° F to 95° F (4.4° C to 35° C). It is always recommended to store RO membrane in air conditioned room in their original packing.

Element Loading Guidelines

This document describes the installation procedure and care to be taken while loading HYDRAMEM membrane elements.

Preparation prior to installation

It is highly recommended to flush and clean the new system and hardware like clarifiers, filters, pumps and pipes before installation of new RO/NF membranes in the pressure tube. It ensures that debris, preservatives and solvents are flushed out so that they do not come in contact with the membranes. Make sure water used for flushing is chlorine free to avoid oxidation of membranes.

Tools and material require are:

- Permeate/fresh water
- Personal protection equipments (gloves, glasses, shoes, hard hat etc.)
- Glycerin
- Silicone lubricant
- Brush for lubrication of brine seals
- Tools recommended by pressure tube manufacturer to open and close the pressure tube
- Spare parts of pressure tube end-cap
- Shims of various sizes (1, 2 & 2.5 mm)
- PVC pipe length same as that of pressure tubes
- Cotton swab

RO Pressure Tube Preparation

- Follow the guidelines mentioned by the manufacturer to open 'end-caps' of both the sides of pressure tube.
- Remove adaptors, permeate port and 'O' rings from 'end-caps'. Clean all these parts with water.
- Clean the pressure tube with water and lubricate the inner wall of pressure tube for smooth loading of RO/NF membrane element.
- Post cleaning lubricate the inside wall of pressure tube with a solution comprising of 50% water and 50% glycerin. This will ensure that the inner walls of the pressure tube and brine seals of RO/NF elements are not damaged while loading the membrane elements.

Loading of Membrane Element

- It is very important to fix the thrust ring and end-cap assembly at the reject end of pressure tube before loading the elements, to avoid free fall of RO/NF membrane element from the reject end and damages caused due to the same.
- Before loading arrange RO/NF element as per plant array and maintain elements loading records.
- Lubricate element brine seal with glycerin solution using brush and also apply some amount of glycerin over membrane element shell.
- Start loading the element from feed end of the pressure tube as per the flow direction indicated on the membrane element sticker.
- Gently slide the first element into feed side of the pressure tube up to three-quarters of the length.
- Apply silicon lubricant on 'O' rings of inter connector and insert the inter connector in the 1st element permeate tube.
- Lubricate second element brine seal with glycerin solution using brush and also apply some amount of glycerin over membrane element shell.

- Connect the second element to the inter-connector and push both the elements into pressure vessel up to three-quarters of the length of the second element.
- Repeat step 8 for loading rest of the membrane elements.
- Once all the membrane elements are loaded, give a final thrust to ensure that the end element is connected to the permeate port of the reject side end-cap. Check the pressure tube for shimming requirement and accordingly fix the feed side end-cap of the pressure tube.
- Repeat above steps for rest of the pressure tubes.

Pressure Tube Shimming Procedure

Shimming is the process of placing pieces of material (shims) between two parts to take up free space to prevent movement. Plastic or PVC washers are used as shims in membrane systems.

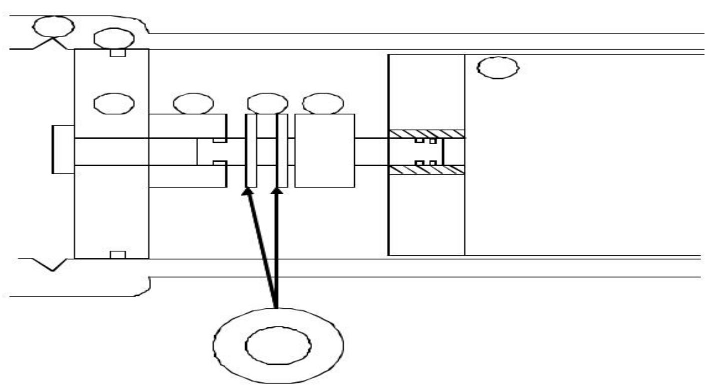
The process of shimming is performed after the membrane elements are loaded. The element stack should be pushed completely into the vessel such that the downstream element is firmly seated against the thrust ring at reject end of the pressure tube. User can also refer pressure vessel manufacturer's instructions on loading of elements.

Face-to-face end plate dimensions may vary among pressure vessel manufacturers. Hence, we strongly recommend that the element loaded within the pressure vessel be shimmed to remove excess or free space. In case of free space can result in movement of membranes. The movement can result in friction against inter connector 'O' rings, particularly during start up and shutdown. Over a period of time, it can cause them to abrade and possibly break. In case of severe pressure drop, 'O' rings can completely dislodged or blow out of their slots.

Shimming Procedure

- Remove the adapter o-ring and head seal from the feed end of the pressure tube components. This will assure that there is no interference from any of the sealing components and minimum force is required to fit the end-cap assembly and the adapter.
- Remove the end-cap assembly and slide shim over the head end of the adapter that fits into the permeate port. Initially add only two shims and check for possibility to install the retaining rings after fitting the end-cap assembly and the adapter.
- If there is a gap between the slot of the retaining ring and the end-cap assembly then add one or two more shims and recheck.
- Once the end-cap assembly and the slot of the retaining ring are face to face then further shims are not required to be added.
- After reaching the above stage, remove the end-cap assembly and adapter. Reinstall the adapter 'O'ring and head seal.
- Close the pressure tube as per manufacturer's instructions.

1) Membrane
2) Adapter
3) Shim
4) Permeate Port
5) End Cap
6) Head Seal
7) Retaining Ring Slot



Criteria for Replacement of RO Membrane Elements

This bulletin is designed to help you take replacement decision considering few key parameters. Life of a membrane element is dependent on various factors such as - basic design, pre treatment and operating practices.

Most of the time the membrane element replacement decision is taken based on deterioration in product water quality. Product water quality depends on various parameters like changing flux rate, recovery of system, feed water quality & temperature, scaling & fouling of membranes and the age of the membrane. If any one of these parameters change the product water quality will either deteriorate or improve.

Thus, the key parameters to be considered are:

- Operational practices
- Feed water quality & temperature
- Feed pressure limitation
- Scaling and fouling
- Physical condition of membrane

Operational Practice

The changes in system flux rate and recovery can deteriorate the permeate water quality. In that case operating parameters need to be restored to the original design before considering replacement of membranes.

Feed Water Quality & Temperature

The feed water quality and temperature can also cause deterioration of permeate water quality and quantity. This should be taken into consideration before considering replacement of membrane.

Feed Pressure Limitation

When RO/NF system operates continuously the membrane tends to scale or foul depending on the nature of the feed water. Due to which the feed pressure of the RO/NFs system increases. If the system is operated at increased pressure, over a period of time the high pressure pump will require elevated pressure to maintain the designed permeate flow. In that case the best solution is to clean the membrane with suitable cleaners which will bring down the feed pressure to a normal level.
But, over a period of time the effectiveness of membrane cleaning reduces with the age of the membrane and replacement of membrane becomes necessary.

Scaling and Fouling

While RO/NF system operates continuously, membrane element foul or scale depending on the impurities present in the feed water. This leads to deterioration of product water quality. Normally, the membranes are cleaned post 10% deterioration in product water quantity and quality which restores the system performance. However, if the system continues to underperform membrane replacement should be considered.

Membrane replacement is always capital intensive hence, sometime user may replace all the membranes or manage with partial replacement. It also depend on situation and product water quality requirement. Many of the large installation don't replace all the membranes in one go but replace small quantity every year.

Physical Condition of Membrane

The physical parameters responsible for deterioration of product water quality is leakage from inter connector & adaptor 'O' rings or damages to the brine seal. Profiling and probing of RO/NF module will help to locate damaged inter connector & adaptor 'O' rings or faulty membrane element. The quality of product water should restore immediately after replacing the damaged 'O' ring or brine seal. If replacement of 'O' ring or brine seal does not restore system performance than glue line damage could be the next possible reason of poor performance.

Profiling and probing of RO/NF module needs to be carried out again to locate the damaged membrane. Once a particular membrane is identified as a source of poor product water quality the same needs to be checked for glue line damage or mechanical integrity. If the glue line or mechanical integrity is damaged, then replacement of membrane is the only solution. But it is also important to identify the root cause of such damage or else, the replacement will not serve the purpose and new membrane may also get damage

Disposal of Membrane Elements

User is responsible for safe disposal of HYDRAMEM membrane element in accordance with local and federal regulations in the applicable jurisdiction.

We also recommend user to ensure the following:

- Membrane element do not contain preservative solution or hazardous liquid
- No hazardous substance is deposited on the membrane surface while disposal

Membrane Selection Chart

Product	Brackish Water	Low Pressure	Fouling Resistance	Sea Water	Nano
8040* 4040*	HM 8040 BWE 400 HM 8040 BWE 365 HM 4040 BWE	HM 8040 LPE 400 -- HM 4040 LPE	HM 8040 FRE 400 -- --	HM 8040 SWE 400 -- HM 4040 SWE	HM 8040 NFE 400 -- --
Area Sq.ft. 8040 4040	365 / 400 85	400 85	400 --	400 85	400 --
RO System Flux Range (lmh) **	RO Permeate: 31 - 41 Well Water: 24 – 31 Surface with UF: 24 - 31 Surface W/o UF: 17 - 24	RO Permeate: 31 - 41 Well Water: 24 – 31 Surface with UF: 24 - 31 Surface W/o UF: 17 - 24	Waste water with UF: 14 - 20 Waste W/o UF: 10 - 17	Sea water with UF: 14 - 20 Sea water W/o UF: 10 - 17	18 – 39

* For any other sizes, please contact Ion Exchange India Ltd.

** To use Hydramem Ultra Filtration membranes in the pre treatment

Trouble-Shooting

Following, is a trouble-shooting guide for customers to diagnose most problems that may occur. In addition, our customer service personnel can help with specific problems or questions.

Trouble Shooting Guide

Problem	**Probable Cause**	**Corrective action**
RO unit is not making enough water	1. Water temperature is too low. 2. Low water supply pressure. 3. RO membranes are fouled. 4. Low RO pump pressure. 5. Increasing product pressure. 6. Feed water TDS level is too high.	1. Control temperature. 2. Check pre-filters & replace. 3. Clean membranes and replace if necessary. 4. Increase pressure by adjusting reject valve. 5. Check piping and valves. 6. Common occurrence since production is based on feed water conditions.
RO unit is making too much water	1. O-ring by-pass in membrane vessel. 2. Chlorine damage to membrane. 3. Water temperature has increased. 4. Reverse flow, causing rupture in membrane.	1. Remove membranes and inspect o-rings to be sure they are sealed properly; replace if necessary. 2. Replace membrane. 3. Control temperature. 4. Replace membrane and check valve on product water line.
TDS in product water is too high	1. O-ring by-pass in membrane vessel. 2. Chlorine damage to membrane 3. Membrane is fouled. 4. Reverse flow, casing rupture. 5. Feed water TDS has increased.	1. See above. 2. Replace membrane. 3. Clean or replace . 4. See above. 5. Cannot be adjusted.
RO pump will not stay on	1. Low supply water pressure to unit. 2. RO reject valve is open too far. 3. High pressure light is on.	1. Check pre-filters; replace Check supply pressure 2. Adjust. reject valve. 3. Adjust reject valve.
RO pump runs but no product water	1. Instruments are not reading correctly. 2. Blockage in product water lines. 3. Reject flush solenoid is not closed.	1. Calibrate or replace. 2. Check and correct. 3. Check flow through valve.

HYDRAMEM Membrane Element Warranty.

Ion Exchange (India) Ltd guarantees the proposed product to be free from defects in material or workmanship when operated in accordance with written instructions for a period of one year from start-up or fifteen months from receipt, whichever is earlier. Parts not manufactured by Ion Exchange (India) Ltd are covered by their manufacturers warranties that are which is generally for one year.

Ion Exchange (India) Ltd spiral-wound membrane element are guaranteed to operate within specifications as mentioned in product data sheet, when used for general water treatment for a period of 12 months from receipt provided the membrane element have not been expose to high operating temperatures, high or low pH, on disinfected water, or on solution which tend to precipitate.

1 Ion Exchange (India) Ltd Warranty applies for 3 years from whichever of the following event occurs first.

a) Pretreated water is fed into RO unit for the first time.

b) Three (3) months following shipment from a manufacturing facility in India to the destinations in Asia, Middle East, African countries or Six (6) months from the date of shipment in other cases.

2 Ion Exchange (India) Ltd warrants storage of membrane element as follows.

a) All dry membrane elements for six (6) months should be stored at ambient temperature less than 100° F (38 ° C).
b) At temperatures between 100° F (38 °C) and 122° F (50° C) for three months, provided that elements are stored in the original box with the polyethylene bag intact under dry conditions.
c) At temperatures over 122 ° F (50° C) there is no warranty.
d) All wet membrane elements shipped from any Ion Exchange (India) Ltd facility must be stored in a cool dry location away from direct sunlight or artificial light at temperatures under 86° F (30° C) in their original box with the polyethylene bag intact. For a period of 3 months or expiration date whichever occurs is early.
e) Store in a cool dry location out of direct sunlight or artificial light at ambient temperature less than 86° F (30° C) for six (6) months.

3 Prerequisite condition of Performance warranty

a) The performance Warranty set forth above shall be void if the element(s) shall not be operated within the operating conditions and recommendations described in the HYDRAMEM Technical Hub. Operating conditions of the element(s) must not exceed the operating limits as specified in the specification sheets.
b) The element(s) must not be fouled by any kind of precipitates, suspended solids, organic matters, inorganic scale, chemicals, or biological growth influencing the element performance negatively. The feed water entering the element(s) must not contain oil, grease or other foreign organic or inorganic material detrimental to the elements. The feed water to the element(s) must not contain strong oxidising agents such as active chlorine or ozone proven to be harmful to the element(s) performance and operating lifetime.
c) Neither nonionic nor cationic surfactants, as well as coagulant, should be used for the membrane cleaning or come into contact with the element(s).

d) The element(s) shall be protected against any shocks such as load shocks, vibrations, pulsation, air or water hammers at all times during start-up, normal operation, and cleaning. Back pressure, where permeate side pressure exceeds feed and brine side pressure, shall not exceed 0.7 kg/cm2 (10 psi) at all times.
e) In case of a system performance decline (permeate flow, salt rejection or pressure drop), appropriate countermeasures must be performed in a reasonable time.

f) Buyer is responsible for providing the end-user with adequate manuals for system operation and maintenance, as well as training of the operators and supervisors, ensuring user's ability to perform cleaning, performance restoration, diagnostic and troubleshooting procedures.

g) Buyer shall ensure that frequent and adequate system normalized performance data are routinely recorded, reviewed, filed and documented in a systematic form from initial plant start-up. Operation data such as troubleshooting, maintenance, operation time and chemical dosage shall also be recorded. These data must be made available to Ion Exchange (India) Ltd upon request in case of a warranty claim.

h) Limitations on pH and temperature can vary with membrane type and the application of the equipment. For general water treatment, pH should be kept between 5.0 and 7.0 with a temperature below 85º F (29° C) unless specifically designed for higher temperatures. For special applications or for pH or temperature ranges outside the stated limits Ion Exchange (India) Ltd may reduce the warranty period.

i) Only Ion Exchange India approved cleaners, biocides, dispersants, or other chemicals may be used with the membrane element. Use of other chemicals may void the warranty.

4 Other General Condition

a) The User is responsible for knowing the membrane element material and for ensuring that chemicals harmful to the membrane or material are never in contact with the membrane element.

b) The customer shall be responsible for acceptance testing for the membrane element received to ensure that they meet the published performance specifications. Ion Exchange (India) Ltd shall be notified within thirty (30) days for first use of any membrane element not meeting specifications. Should Ion Exchange (India) Ltd not receive notification of non compliance with performance specifications within said thirty (30) day period, Ion Exchange (India) Ltd will consider that all membrane elements are accepted.

c) It is the obligation of the User to maintain frequent operating data records. Ion Exchange (India) Ltd may request these records in the warranty evaluation. User must notify Ion Exchange (India) Ltd at the very first sign of changes in operation of the membrane element. Such notification should be in writing and should include all data requested on the operating log sheets.

5 Site Return Goods authorization Note

If the membrane element is to be returned for warranty inspection, the User must obtain a Site Return Goods Authorisation Note (SRGAN) number from Ion Exchange (India) Ltd before returning the membrane element. Membrane element are to be returned on freight prepaid basis to Ion Exchange India and Ion Exchange India will return any warranty replacement membrane element to the customer on prepaid basis. Membrane element must be kept damp at all times and must be clean and bagged in a watertight bag before returning.

6 Site Visit

Ion Exchange (India) Ltd at its discretion, (i) dispatch its expert and/or outside expert for on-site examination, or (ii) request Buyer return of the alleged defective elements to Ion Exchange (India) Ltd freight prepaid for examination. In case the result of such examination shows that (1) the failure of the element(s) performance is due to a cause other than breach of the Performance Warranty, or (2) the performance of the alleged defective elements meets the Performance Warranty, Buyer shall pay to Ion Exchange (India) Ltd a fee of USD 1000 per day per person in case of oversea location & Rs 2500 per day per person (In India Only), plus all direct expenses incurred by Ion Exchange (India) Ltd personnel in connection with any inspection and testing of such elements and Ion Exchange (India) Ltd may return such alleged defective elements to Buyer on freight collect basis.

7 Disclaimer:

No warranties, expressed or implied, are given except as expressly provided above. The implied warranties of merchantability and fitness for particular purpose are not provided and are expressly disclaimed and excluded. Ion Exchange (India) Ltd is not liable for consequential, incidental, special exemplary and punitive damages, loss of profits, plant shut down time or suits by third parties against buyer, due to a performance failure or defect of the element(s). All limitations on liability shall survive the expiration, termination or cancellation of this limited warranty. Failure or refusal to fully disclose the use and operating parameters of Ion Exchange (India) Ltd membrane elements to Ion Exchange (India) Ltd shall render all warranties, other than materials and workmanship, null and void.

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