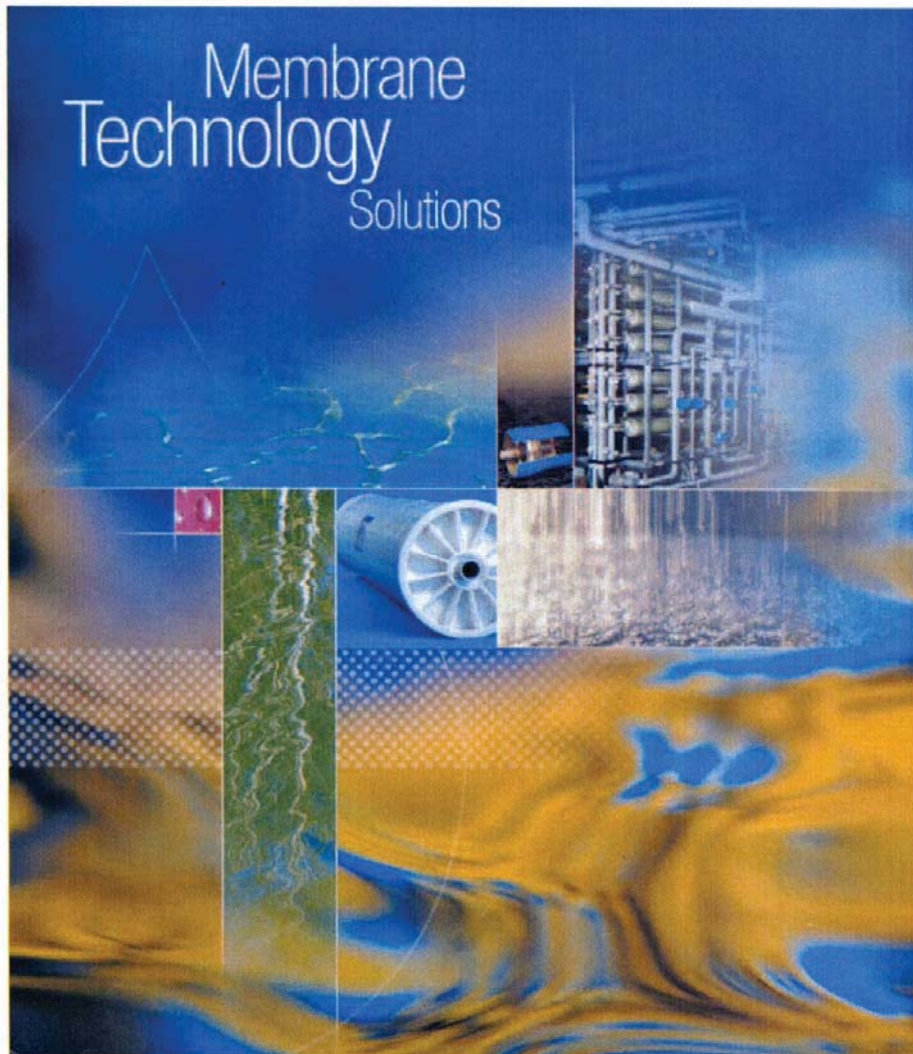


Operation, Maintenance and Handling Manual for membrane elements



Version: Jan. 2019

TORAY REVERSE OSMOSIS ELEMENTS

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Introduction

General

Proper operation and maintenance of Reverse Osmosis (RO) system is key factors in maximizing long-term plant availability and efficiency, and minimizing fault-related down time.

This manual contains check-lists and procedures for commissioning elements at start-up as well as providing useful information relating to normal operation and maintenance procedures. Separate sections cover membrane element performance data recording and normalization.

Conventions and symbols



Danger

This symbol indicates an imminent hazardous situation which will result in serious injury or death when the instruction is not observed.



Warning

This symbol indicates a potentially hazardous situation which will result in serious injury or death when the instruction is not observed.



Caution

This symbol indicates a potentially hazardous situation which might result in injury or property damage when the instruction is not observed.



Prohibited

“Prohibited”

This symbol indicates a prohibited action or procedure.



Instruction

“Instruction”

This symbol indicates an important action or procedure which has to be taken without fail.

Installation of RO Elements

Prior to installation - preparations

- 1) Before directing any pre-treated feed water to elements, make sure piping system and pressure vessels are free of dust, oil, metal residues, organic deposits etc. This check should also be made when elements are reloaded or replaced.
- 2) Verify feed water quality matches system design values.
- 3) Flush system (without elements loaded) with pre-treated feed water for approx. 30 minutes.
- 4) Remove end plates from both ends of pressure vessel, check inside of the vessel and if necessary clean mechanically.



If the inside of the pressure vessels are dirty, they should be cleaned. A soft mop or swab should be used, occasionally flushing with pre-treated water. Care must be taken not to scratch the inside surface of the vessels.

- 5) Install permeate adapter with O-rings into the permeate port of brine side end plate. Lubricate both parts using glycerin. Thrust ring should be used according to following note.

Note:	with "thrust ring"	without "thrust ring"
	TM-series 8 inch	others

Make sure "thrust ring" for absorption of axial thrust (this is a part of the pressure vessel) is installed for TM-series 8 inch such that it will transmit axial forces from brine side element (this is the first element to be installed).

- 6) Optionally, permeate adapter with O-rings is inserted into the permeate port of brine side end plate at this stage. The risk of seal damage can, however, be minimized if this installation is done as last step, before re-fitting piping connections.
- 7) Attach brine side end plate onto the brine side of the vessel and install retaining ring set according to instruction manual of the pressure vessels.

TORAY REVERSE OSMOSIS ELEMENTS



To facilitate final control of element installation, it is useful to remove the head seal prior to insertion. Verification of full element insertion is easier this way, since the installed head seal usually provides for additional resistance upon removal of the end plate.



Instruction

All required parts (except the vessel permeate adaptors) are shipped with each element package from Toray.

Permeate adaptors and thrust devices are typically supplied by the pressure vessel manufacturer.

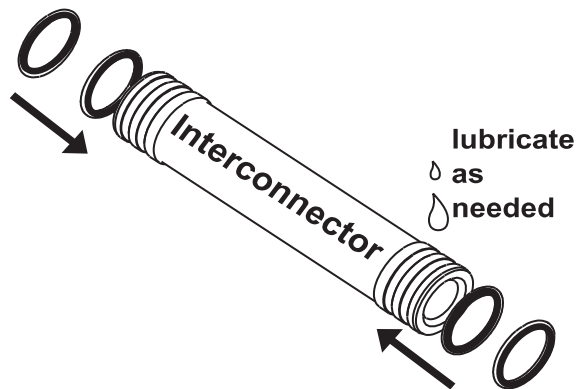
When ordering pressure vessels, please specify type of RO element to be installed to ensure correct parts are provided by the vessel manufacturer.

Unpack the elements.

- 1) Open element boxes, and remove RO elements and accessories. The accessories are separately packaged in small plastic bags inside the element box. Put empty boxes aside.
- 2) Prepare necessary parts as shown in the following table:

Parts	Required quantity
Brine seals	One per element
O-Rings	4 pcs. per element
Permeate port adaptor (open)	One per pressure vessel
Permeate plug adaptor (solid)	One per pressure vessel
Interconnectors	(qty. of elements) – (qty. of pressure vessels)

- 3) Assemble interconnectors with supplied O-rings carefully to avoid any scratches. Use glycerine as lubricant. Keep assembled interconnectors in a clean place until insertion into permeate tubes.



- 4) Safety considerations prior to opening of element packing bags:



Danger

As shipped from Toray, new elements are packaged in approx. 0.5-1.0% sodium bisulfite solution, or sodium chloride solution with deoxidizer. Do not ingest these solutions. Solutions may be irritating to eyes and skin. Protection equipment is required. For details, see SDS of sodium bisulfite solution.

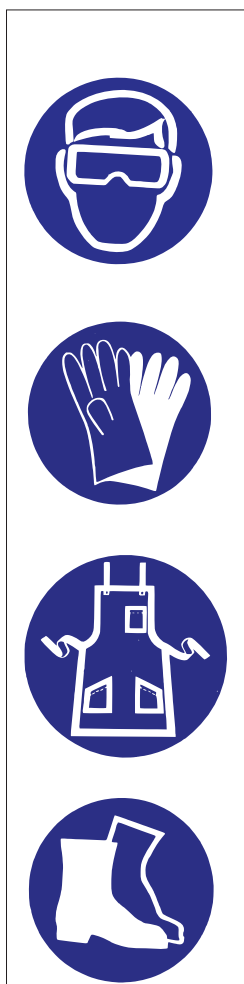
The element shell is FRP (Fiber Reinforced Plastic). Beware of glass fiber strands and use correct safety equipment.

- 5) Cut open the element's shipping bag and prepare for insertion, following illustrations provided below.



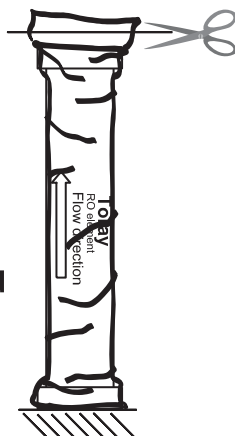
Toray elements come with a “flow direction arrow” laminated into the element shell. The arrow is simply provided to help ensure the brine seal is oriented in the right direction during installation. The arrow does not indicate a mandatory installation direction – the element can in fact be installed either way. The important point is the correct installation of the brine seal relative to direction of brine flow (see illustrations below).

Sample procedure A: In case of element with styrofoam caps



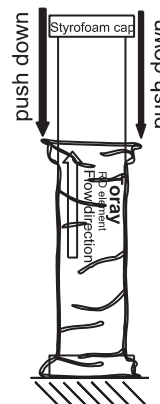
1.

Cut open
the element's
shipping bag
at the top end

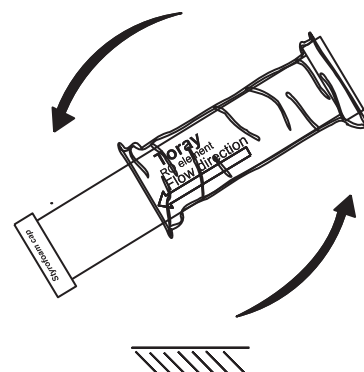


2.

Push down
shipping bag.
Leave upper
styrofoam cap
in place.



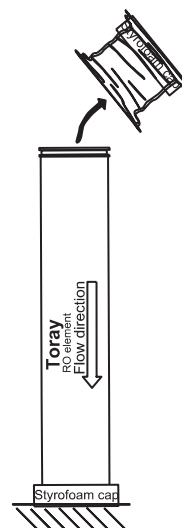
3.



Turn the element over.
Element will stand on
styrofoam cap now.

4.

Remove top styrofoam cap,
together with shipping bag.



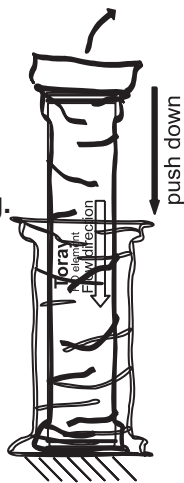
The shipping bags are made of a special material which is a barrier to oxygen. This improves the useful lifetime of the preservation solution in the bag. If the bags are carefully and cleanly cut open at one end, some can be kept and re-used in case any RO elements need to be conserved or shipped.

TORAY REVERSE OSMOSIS ELEMENTS

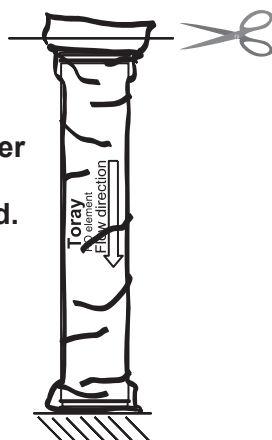
Sample procedure B: In case of element packed without styrofoam cap

1.

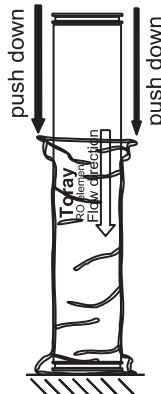
Push down outer shipping bag. Take out element with inner bag.


2.

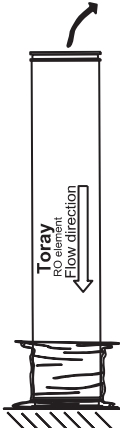
Cut open inner shipping bag at the top end.


3.

Push down inner shipping bag.


4.

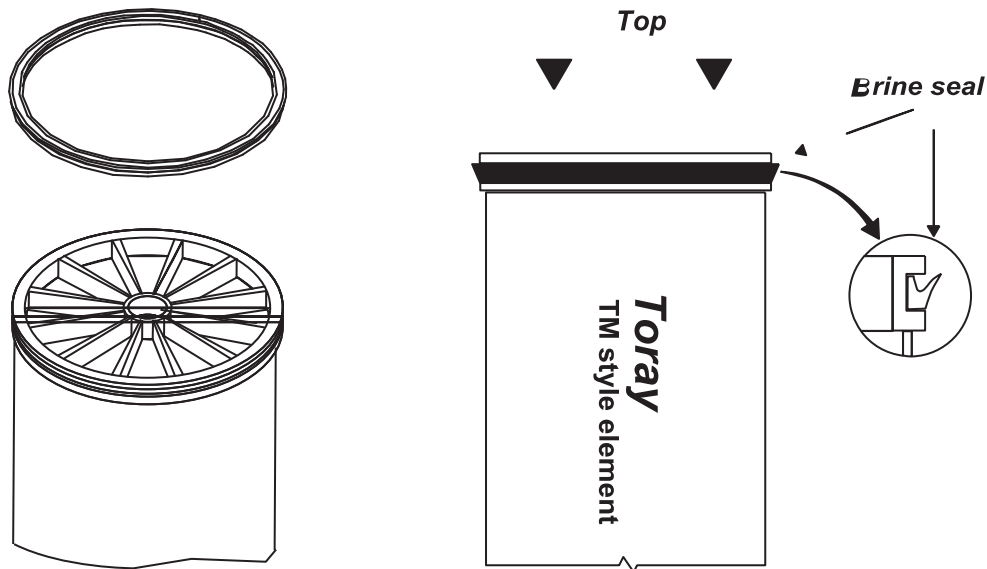
Put out element from inner shipping bag.



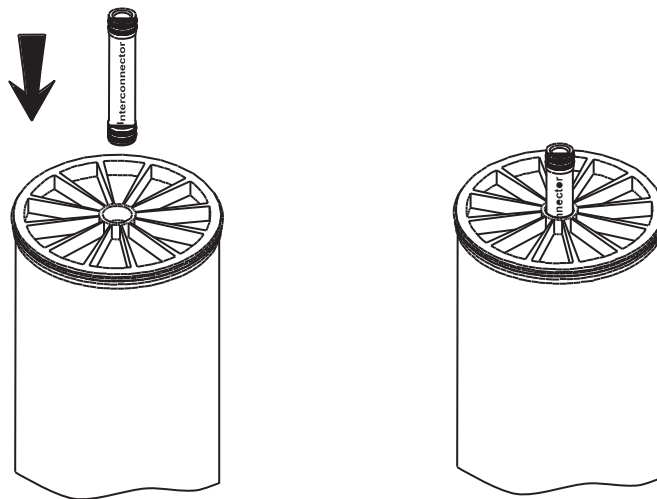
Assembly of element and accessories

1) Install brine seal:

Toray elements shipped from Toray Membrane USA and TMME will come with brine seal pre-installed, so this step can be omitted. Just check correct position of seal in this case. For other regions, follow subject illustration.



2) Install interconnector. Lubricate using glycerine as necessary.



TORAY REVERSE OSMOSIS ELEMENTS
Insertion of elements



Instruction

This is best done by a team of two persons.

Verify position and direction of the V-shaped brine seal as in illustration TMM-200.1.

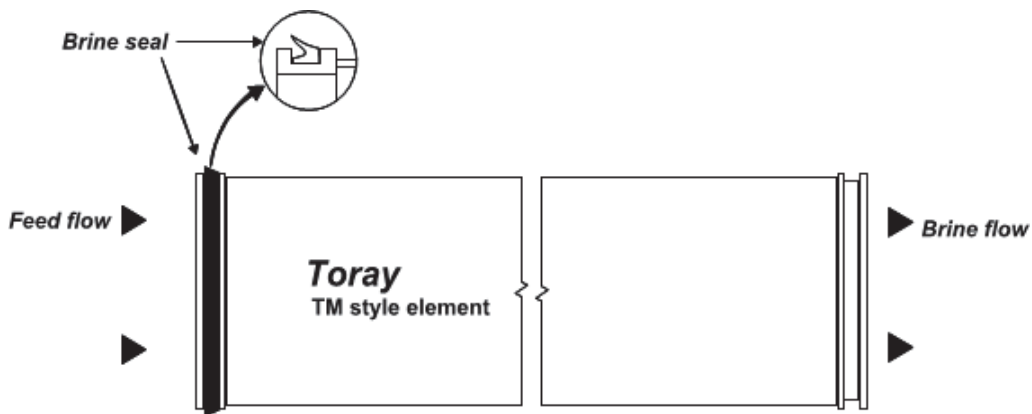


Illustration TMM-200.1: Orientation of brine seal



Caution

Only one brine seal per element is required. Do NOT install two. The brine seal is typically fitted at the feed end of the element.

If not already performed, open the RO pressure vessel's feed side.

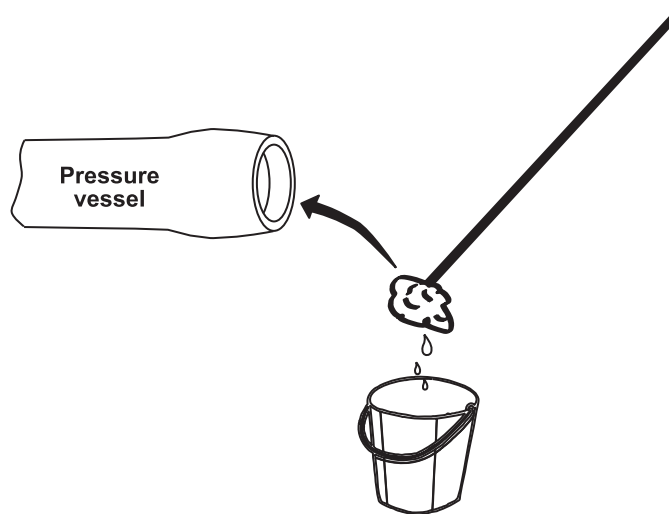
This procedure can be prepared by removing any head locking devices, prior to starting unpacking of elements, if site conditions allow this.

TORAY REVERSE OSMOSIS ELEMENTS

Lubricate the inside of RO pressure vessel with water and glycerine. This will facilitate installation of elements (especially with longer pressure vessels containing multiple elements). Consider using approximately 100 ml of glycerine for each pressure vessel. If the viscosity of the glycerine is too high, dilute it with clean water as needed for better lubrication.

Limit ingress of foreign matter, dust and dirt to vessels to a minimum by only opening/ closing one vessel at a time.

Use of a clean, soft mop or swab or similar tool will enable lubrication of the full length of the vessel. Take care not to scratch the inner surface of the pressure vessel.



After lubricating brine seals and vessel's inner surface with glycerine, insert element from feed side end into the pressure vessel. Approximately 2/3 of its length should be in the vessel, and 1/3 outside the vessel (see Illustration TMM-200.2), Insert element carefully and smoothly, especially the first element.



Illustration TMM-200.2: Insertion of first element

Attach brine seal to the second element as described for first element. Connect the two elements at the inter-connector, see Illustration TMM-200.3. The partly inserted element is best held in place by a helper. Now push both elements smoothly and firmly into vessel, keeping them in line to avoid damages to inter-connector or brine seal.

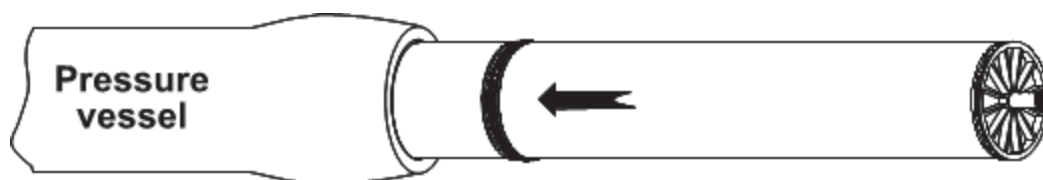


Illustration TMM-200.3: Insertion of following elements

Repeat procedure (see Illustration TMM-200.3). Insert elements one by one into the pressure vessel.

Insert the last element until only 1/3 of the element is outside the vessel

Locate and install correct brine end permeate adaptor (with O-rings) into the internal permeate port of the brine side end plate.

Note: if permeate is to be collected from the brine end of the vessel install the permeate port adaptor. If permeate is not to be collected at the brine end install the solid permeate plug adaptor.

Lubricate all O-rings with glycerine. (Note: this step can wait until just prior to end plate installation into the pressure vessel to minimize any risk of O-ring damage).

Locate and install Thrust ring into the brine side end of the pressure vessel (if provided).



Instruction

A Thrust Ring is typically necessary for 8 inch (and larger) diameter elements. Its purpose is to help absorb axial loads transmitted through the elements in the vessel during operation. It should not be omitted. Omission may result in the possibility of mechanical damage to the downstream elements.

Insert brine side end cap into the brine side of the vessel and install retaining ring set according to pressure vessel manufacturer's instructions.

TORAY REVERSE OSMOSIS ELEMENTS



It can be useful to check for complete adaptor insertion into the downstream element and correct position of the brine side end plate relative to the retaining ring groove by first removing the end plate seal (located on the circumference of the end plate). This reduces the resistance to movement of the end plate. The end plate seal **MUST** be replaced prior to final installation of the end plate.

Push the last element until the downstream element permeate adaptor tube is firmly connected, and brine side end plate is securely located against the retaining ring set

To prevent premature wear of permeate seal rings, the elements cannot be allowed to move in the axial direction. The permeate ports are typically supplied by the pressure vessel manufacturer. Shim rings are also typically available from the pressure vessel manufacturer to fill remaining gaps or tolerances (see Illustration TMM-200.4).

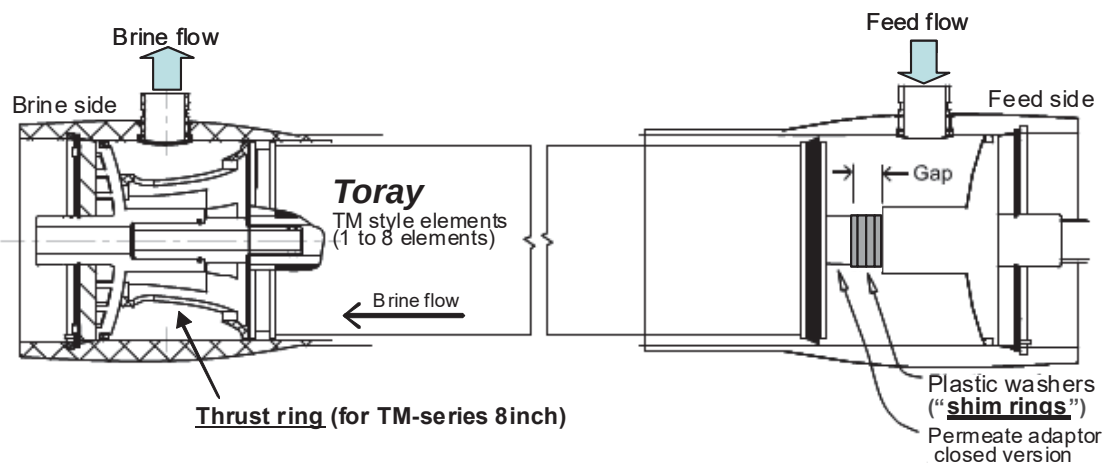


Illustration TMM-200.4: Applying shim rings

After installing all membranes, check distance “A” (see Illustration TMM-200.5). If distance “A” is bigger than the thickness of shim provided by the pressure vessel manufacturer, use the shim to fill the excess distance. Remained distance should be smaller than the thickness of shim. Shims must be positioned on the upstream end of the vessel.

The risk of mechanical disconnection of permeate adapters is especially high if the permeate header is connected to feed side of pressure vessel. The pressure vessel brine side is preferable over the feed side for installation of the permeate output connection to pipework.

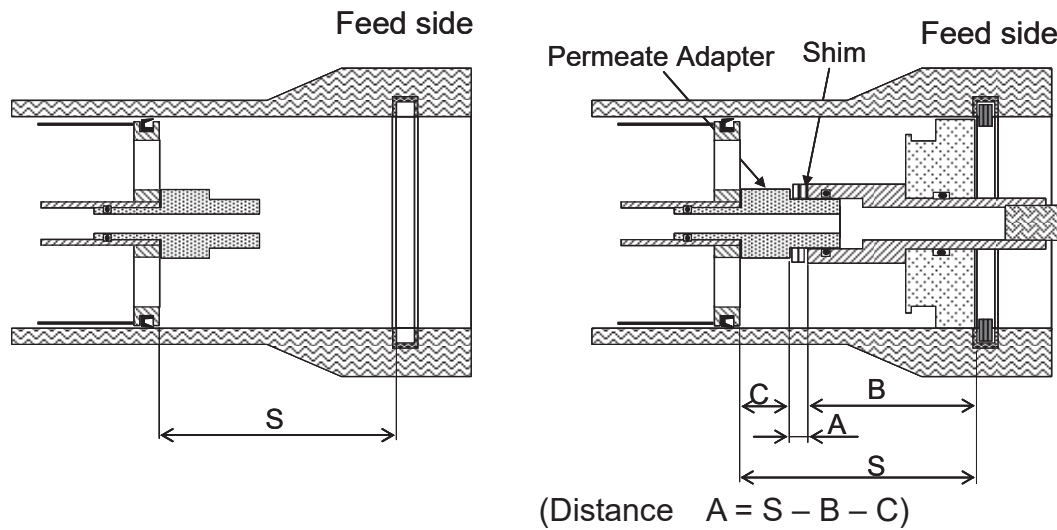


Illustration TMM-200.5: Shimming procedure

Permeate ports not used are best plugged with “closed” or “solid” type permeate adaptors (Permeate plugs) supplied by pressure vessel manufacturer. This provides the best protection against brine entering the permeate stream.

Attach the feed side end plate of pressure vessel, and fit piping system to end plates. **IMPORTANT:** Make sure head seals for all pressure vessel end plates are installed at this time.

Documentation of loading process

Toray membrane elements bear individual serial numbers, which can be used to trace element origin and factory test results. It is recommended to record the numbers of RO elements installed during the loading process, indicating their exact installed location. A successful way to do so is to create a “membrane map” or “loading Diagram” similar to the sample below. Identification of the pressure vessel and elements are such facilitated for performance monitoring and troubleshooting:

Pressure vessel no. (or row/column position)	Brine	Element # 12345677	Other Element #'s	Element # 1234556	Feed
---	-------	-----------------------	----------------------------	----------------------	------

Pressure vessel no. (or row/column position)	Brine	Element # 12345687	Other Element #'s	Element # 1234546	Feed
---	-------	-----------------------	----------------------------	----------------------	------

(continue for further pressure vessels).

This can most easily and successfully be done using spreadsheet software (such as Microsoft Excel).

Initial start-up checks

After completely connecting piping works, carry out sequence of initial start-up checks as described in TMM-220 of Toray's Operation, Maintenance and Handling Manual for RO elements.

Element Removal

Elements may have to be removed from the pressure vessels. Some possible reasons are:

- Inspection
- Long term storage
- Shipment
- Replacement

The procedure to remove elements is as follows:



Caution

Before removing connection from the feed, brine and permeate piping ports on the pressure vessel, the remaining water in pressure vessel should be drained out to release the pressure inside.

- 1) Remove connection fittings from the feed, brine and permeate piping ports on the pressure vessel.



For side port and multiport pressure vessel configurations, removal of the permeate piping connections from the end plates is all that is required.

- 2) Remove the pressure vessel end plates from both the feed and concentrate ends of the pressure vessel.
- 3) Push the element stack into the vessel from the feed end of the pressure vessel. Push the element stack forward so the brine end element sticks out of the pressure vessel far enough for the operator to be able to grip the element and pull the remainder of the element out of the pressure vessel.
- 4) When removing the downstream element from the brine end of the pressure vessel, pull the element straight out. Do not apply any load up, down, or side to side on the interconnector that connects the element being removed to the upstream element(s) still remaining in the pressure vessel. Excessive load can damage the interconnector, product tube, brine seal, or interconnector O-rings.
- 5) Repeat procedures 3) and 4) to remove the remaining element(s) in the pressure vessel. A section of PVC pipe can be used to push the elements forward towards the brine end of the vessel for removal.

- 6) As elements are removed, take care to remove and retain all interconnectors and permeate end plate adapters. These parts may be reused. It is good engineering practice to replace all O-ring seals and brine seals with new ones prior to replacement.

If re-installation of elements is expected in the near future, it is recommended the elements are packed immediately into clean plastic bags, (see TMM-500: Storage).

For reloading elements, proceed according to TMM-200: Installation of RO elements.

For proper disposal of removed elements as industrial waste, please check local regulations and dispose accordingly.

Start-up Checks for RO

Checks before commissioning

- 1) Prior to loading membrane elements and allowing water to enter the RO system, check the following:
 - Feed water quality matches design values for selected RO elements.
 - Verify all dust, grease, oil, metal residues etc. have been removed from pipework installation.
 - Ensure cleanliness of system; if necessary, clean according to TMM-200: Installation of RO elements.
 - Fouling Index (SDI15)
 - Turbidity (NTU)
 - Chlorine and/or any other oxidants are absent from the RO feed.
 - Sufficient bisulfite surplus can be dosed (if used for chlorine removal).
 - Verify all instruments and components are operating properly.



Caution

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

- Pretreatment is working correctly. Ensure dosing of any flocculants used in the pretreatment (in particular cationic compounds and some nonionic compounds), are optimized so such compounds are not present in the RO feed water.



Caution

Filter Cartridges must be free of surfactants, lubricants and textile aides. Either ensure the filters are supplied without such additives, or, if unsure if they are present, flush the cartridges according to published guidelines of cartridge manufacturer.

Install RO elements. Refer to Section TMM200: Installation. Make sure all fittings are tight (in particular Victaulic® couplings and pressure vessel end plate retaining rings).

- 2) Following element installation, purge air from piping system, including all headers and RO vessels, for minimum one hour. Use pre-treated feed water at low feed pressure, with brine valve fully opened. Pay attention not to exceed allowed ranges for flow and differential pressure!

To avoid a "water hammer" condition resulting from a mixture of air and water being present in the piping, it is recommended that the piping be vented to atmosphere to purge any entrained air while filling the piping. The initial flow rate should be kept low to avoid unsafe conditions.

Once brine flow is observed from the brine piping, increase the flushing flow rate to expel any remaining air that may be present in the piping through the vent ports.

Some pockets of air can be difficult to remove. It is recommended that the flush procedure be started and stopped several times to help move any remaining pockets of air to the venting port(s). Continuous flushing may only pressurize the air while allowing it to remain trapped in the piping.

Suggested flush flow rates when venting air from piping depend on the pressure vessel diameter.

- For 8" vessels regulate the flush flow rate to 40 l/min (11.0 gpm) per vessel.
- For 4" regulate the flush flow rate to 10 l/min (3.0 gpm) per vessel.

While flushing to remove air in the piping, keep the line pressure < 0.1 MPa (15 psi).

It is important to open any permeate side isolating valves, and minimize permeate side back pressure during flushing procedure. Brine pressure should be always higher than permeate side pressure to avoid permeate back pressure problems.

For detailed instructions for flushing procedure, see TMM-250: Flushing procedure.

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

Element types TM	Per vessel	Per single element
8"	0.34 MPa (50 psi)	0.10 MPa (15 psi)
4"	0.34 MPa (50 psi)	0.10 MPa (15 psi)

- 3) After bleeding all air from the system, the initial trial run for the RO can commence according to design operating parameters.

In particular, adjust the following parameters to design values:

- Permeate flow rate
- Recovery ratio

And check the Operating pressure.

Operate for at least 1 hour, and check permeate quality.

During the initial trial run, dump permeate and brine to drain. Do not operate any internal concentrate recirculation during trial run, (if the system has recirculation capability).

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

Check the permeate conductivity for each vessel. If conductivity of permeate is much higher than expected, check O-rings, brine seals etc. of the vessel affected, and change parts if necessary. Log all data and record corrective measures taken.

Data should be taken as a minimum requirement 1, 24, and 48 hours after start-up. These data points should be used for normalization standard data. It is therefore very important all the instrumentation is correctly calibrated before start up.

The following data should be considered the minimum to be recorded during initial operation:

- Feed conditions:
 - RO feed pressure
 - Water temperature
 - TDS (conductivity)
 - pH
 - Silt Density fouling index (SDI15)
 - Turbidity (NTU)
 - Chlorine (must be not detectable*),

- Brine:
 - Flow
 - TDS (conductivity),
 - pH
- Permeate:
 - Permeate flow of each stage (and total system)
 - TDS (conductivity) from each vessel and total system.
 - Permeate pressure (for each bank)
- differential pressure across each RO bank,

It is recommended to take feed water, brine water and permeate water samples for analysis of individual ions.

A typical data log sheet is shown in section TMM-230 Operation Monitoring.

*) If NaHSO_3 is dosed for chlorine removal, a minimum of 0.5 mg/l HSO_3 must be detectable in brine at any time to ensure full removal of chlorine.

Regular start-up checks for daily operation

- 1) Check feed water quality is meeting recommendations for membrane elements loaded in the system.
- 2) Flush RO system with pre-treated feed water at low feed pressure prior to start of high pressure pump to remove air from the system.

NOTE: Following instructions are for a “generic” start procedure for a system using a

centrifugal pump with feed and brine flow control valves. For other options, see later section "General Start-up procedures for different High pressure pump (HPP) configurations".

Regulating valve between high-pressure pump discharge and membranes should be nearly closed at high pressure pump start-up to avoid excessive flows and possibility of water hammer.

- 3) 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!



Caution

At any time, maximum pressure drop across any vessel is 0.34 MPa (50 psi) for TM-element types. Details are given on specification sheets published for each element type.

- 4) Adjust RO operating parameters to design permeate and brine flow rates. Do not exceed design recovery ratio (defined as permeate flow/feed water flow) during any stage of operation.
- 5) Dump permeate water to drain until required water quality is obtained.

Parameters for start-up procedures

The following parameters are important, and must be maintained during start up of RO systems. The design and control of the RO system must be suitable to ensure the following can be maintained.

1. Pressure increase < 0.07 MPa (10 psi) / sec at any time during start-up sequence of SWRO
2. Pressure increase < 0.034 MPa (5 psi) / sec at any time during start-up sequence of BWRO
3. Feed flow increase < 5% / sec of final flow
4. Permeate pressure lower than brine pressure at all times, **especially during flushing phase, and transient conditions during start up sequence.**



Caution

The installation of check valves alone on the permeate header may be insufficient to ensure requirement #4, especially with ultra-low pressure element types. During flushing, ensure that the permeate line is truly at atmospheric pressure and permeate pressure is always lower than brine pressure. Alternatively, direct the brine and permeate flows to one common discharge line during flushing sequence, ensuring equal static water column for both streams.

General Start-up procedures for different High pressure pump (HPP) configurations

NOTE: The information provided here is for general reference only. Pumps, energy recovery devices (ERD's) and associated control equipment are not supplied by, or operated by Toray, and Toray accepts no liability which may result from incorrect usage or installation of such devices. Consult your OEM equipment manual or the pump supplier for information regarding safe operation of specific pump models on your system. For detailed instructions regarding safe operation of energy recovery devices (ERD's), please consult your OEM equipment manual, or contact your ERD supplier.

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

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

1) Plunger (displacement) pump system with constant speed motor
(Illustration TMM-220.1)

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.

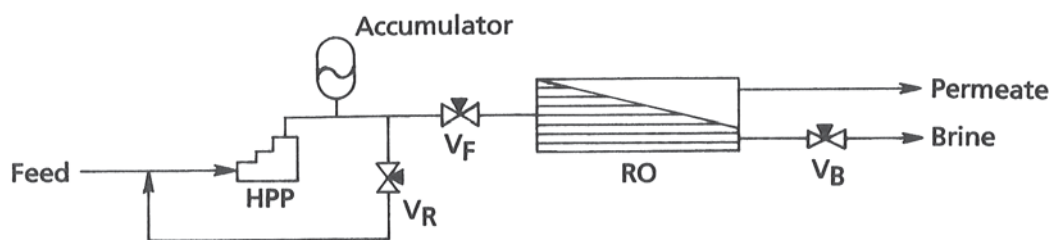


Illustration TMM-220.1: Plunger (displacement) pump system with constant speed motor

2) Centrifugal pump system with constant speed motor
(Illustration TMM-220.2)

1. Open brine flow 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 V_B 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.

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

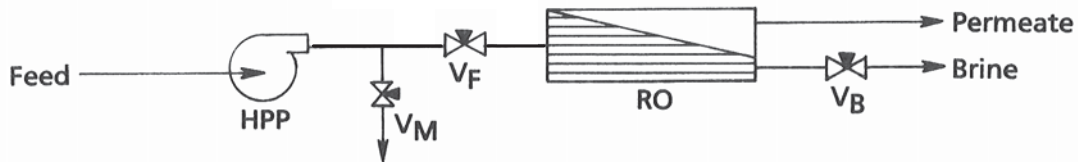


Illustration TMM-220.2: Centrifugal pump system with constant speed motor

3) Centrifugal pump system with constant speed motor and soft start (Illustration TMM-220.3)

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), (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 ΔP), 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.

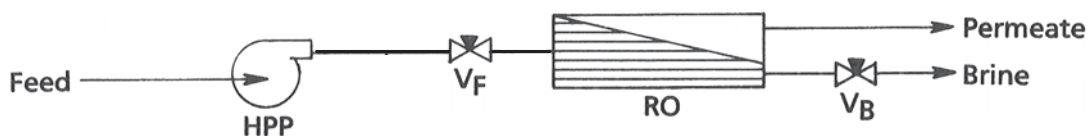


Illustration TMM-220.3:

Centrifugal pump system with constant speed motor and soft start

4) Centrifugal pump system with frequency controlled motor

(Illustration TMM-220.4)

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 V_B until brine flow starts decreasing. Feed pressure now starts to increase.
5. Check feed pressure, pressure drop and permeate flow.
6. Repeat procedure 3-5 step by step until permeate and brine flow match design.

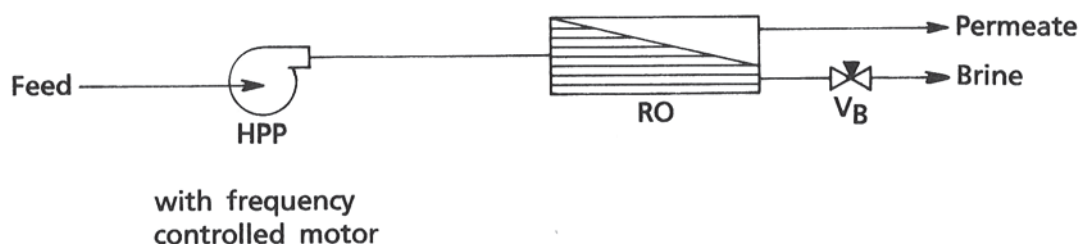


Illustration TMM-220.4: Centrifugal pump system with frequency controlled motor

Note: Above Illustrations TMM-220.1 to 220.4 are for general explanation of high-pressure pump start-up procedures only. Some of the necessary equipment and instruments are not shown.

Operation Monitoring

Monitoring of a RO system's performance is a fundamental prerequisite to ensure dependable RO system performance. Regular RO system performance records will provide a solid basis for troubleshooting and evaluating membrane element and system performance.

Monitoring

Operating data to be logged and data logging intervals are listed in Tables 1.A through Table 1.C.

Table 1.D summarizes typical water analysis items for periodic comparison to earlier (original) analytical data.

Table 1.E summarizes items for scheduled or system performance related maintenance.

Regular monitoring and check points

When feed water quality and operating parameters (such as pressure, temperature, differential pressure and recovery) are constant, permeate flow rate and permeate quality should also remain essentially constant ($\pm 5\%$).

If operating parameters change, regular performance normalizations of current data are necessary to compare normalized data to original (start-up) performance values. Confirm that the current normalized performance is in agreement with the original (Start-up) system design parameters.

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

It is also advisable to perform normalization calculations before and after any scheduled maintenance procedures. If, after such maintenance procedures, the normalized performance data indicates significant deviations from original operating parameters, system adjustments may be required to return performance to the original RO system design parameters.

Logbook

A log book should be maintained. All relevant operational events (however trivial they may seem to be at the time) and their date of occurrence should be recorded for future reference. Some key operational parameters to record are as follows:

Parameters

Key factors affecting performance

Permeate quality

- Feed water chemical composition (total concentration of ions)
- Feed pH
- Feed water Temperature
- Pressure of Feed, Brine and permeate for each stage
- Feed Water quality (total ions, colloids and suspended solids; fouling tendency (SDI15 by Millipore Type HA)
- Recovery (conversion) ratio

Permeate flow rate

- Recovery (conversion) ratio
- Pressure at Feed, Brine and permeate of each stage
- Feed Water Temperature
- Feed Water quality (total ions, colloids and suspended solids; fouling tendency (SDI15 by Millipore Type HA)

Normalization of system performance

In order to effectively evaluate current system membrane element performance, it is necessary to compare currently recorded membrane performance data to initial membrane performance data recorded at the time the membranes were first placed in service.

As the current conditions of operation may be different (different salinity of the feed, different water temperature etc.) the current data must be “normalized” to the original start up operating conditions to allow direct and meaningful comparison. “Normalization” therefore refers to the manipulation of current data to reflect what the flows, and quality parameters would be if the plant was actually operating at the original (start-up) conditions.

By comparing initial membrane performance data (new elements) with current “normalized” membrane performance data, we can determine if any membrane element maintenance (such as a chemical cleaning or system adjustments) is required.

Toray normalization software (TorayTrak) performs these calculations. It is available to download on the Toray web site at no charge:

Download site: <http://www.toraywater.com>

For general information on TorayTrak, see this section “Normalization program TorayTrak”, page 42.

Precautions and useful information for monitoring operating data

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

Quick recognition of undesirable trends in normalized operating data allows timely application of appropriate countermeasures, and avoids irreversible damage to membrane elements or other system components.

Guidelines for maintenance (considerations for cleaning) are described in TMM-310: Guidelines for RO cleaning.

Troubleshooting guides are described in the Troubleshooting Sections TMM-600 and 610.

Typical signs of system performance change are shown in section TMM-610: Typical Performance Changes and Countermeasures

In order to evaluate actual system status and to detect trends early, a graph of normalized performance data is highly recommended. (see Illustration TMM-230.1)

For specific projects and special membrane element applications, please consult the Toray warranty for special conditions and requirements regarding the extent and frequency of plant monitoring.

RO system operation parameters and logging intervals

**Table1. A: Softened drinking or well water,
SDI < 2, peak 3; NTU < 0.3, peak 0.5**

Parameters	Online Monitoring (Continuously)	Daily (datasheet)	Periodically ⁽¹⁾	Alarm & safety system
1. Date and time of data logging		X		
2. Total operating hours		X		
3. Number of vessels in operation			X	
4. Feed water conductivity	X ⁽²⁾	X		
5. Total hardness		X		X
6. Feed water pH	X	X	X	
7. Feed water FI (SDI ₁₅)		X		
8. Feed water temperature	X ⁽³⁾	X		X ⁽³⁾
9. Feed water pressure	X	X		X
10. Feed water chlorine concentration	X ⁽⁴⁾	X ⁽⁴⁾		X ⁽⁴⁾
11. Feed water ORP *)	X ⁽⁸⁾	X		
12. Brine surplus of HSO ₃ (> 0.5 mg/l) **)		X		X
13. Feed water individual ion concentration			X ⁽⁶⁾	
14. Brine conductivity		X		
15. Brine pH	X ⁽²⁾		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 ⁽⁵⁾	X		X ⁽⁵⁾
21. Total permeate flow rate	X	X		X
22. Permeate flow rate for each bank		X		
23. Permeate individual ion concentration			X ⁽⁶⁾	
24. Total recovery ratio		X		
25. Recovery ratio for each bank			X	
26. Normalized salt passage			X	
27. Normalized permeate flow rate			X	
28. Brine pressure	X	X		
29. Brine pressure - Permeate pressure	X	X		X

*) The ORP meter reading should always be less than the value of the line shown in the figure 230-1.

**) HSO₃⁻ surplus in brine >= 0.5 mg/l 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

TORAY REVERSE OSMOSIS ELEMENTS

- water.
- (5) In case of fluctuating pressure > 0.5 MPa, 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 1D.
 - (7) In case of high fluctuations or acid dosing
 - (8) In case of prechlorination / dechlorination only

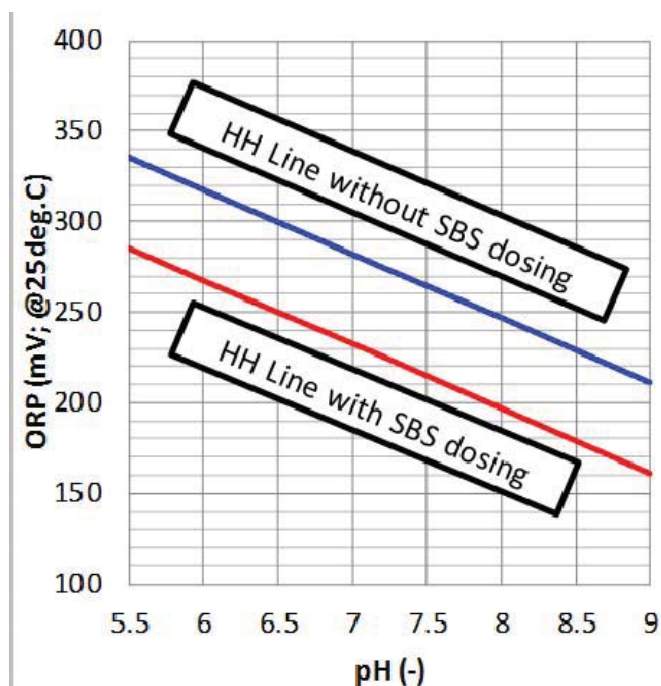


Figure 230-1: HH lines for controlling ORP value in feed water

Table1B: Drinking or well water, SDI < 3, peak 4; NTU < 0.3, peak 0.5

Parameters	Online Monitoring (Continuously)	Daily (datasheet)	Periodically ⁽¹⁾	Alarm & safety system
1. Date and time of data logging		X		
2. Total operating hours		X		
3. Number of vessels in operation		X	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		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. Feed water ORP *)	X ⁽⁹⁾	X		
12. Brine surplus of HSO ₃ (> 0.5 mg/l) **)		X ⁽⁸⁾		X
13. Antiscalant concentration in feed water		X		X ⁽⁵⁾
14. Feed water individual ion concentration			X ⁽⁶⁾	
15. Brine conductivity		X		
16. Brine pH	X ⁽³⁾	X		
17. Pressure drop of each bank	X	X		X
18. Brine flow rate	X	X		X
19. Total permeate conductivity	X	X		X
20. Permeate conductivity of each vessel			X	
21. Permeate pressure	X ⁽⁷⁾	X		X ⁽⁷⁾
22. Total permeate flow rate	X	X		X
23. Permeate flow rate for each bank		X		
24. Permeate individual ion concentration			X ⁽⁶⁾	
25. Total recovery ratio		X		X
26. Recovery ratio for each bank			X	
27. Normalized salt passage			X	
28. Normalized permeate flow rate			X	
29. Brine pressure	X	X		
30. Brine pressure - Permeate pressure	X	X		X

*) The ORP meter reading should always be less than the value of the line shown in the figure 230-1.

**) HSO₃⁻ surplus in brine >= 0.5 mg/l 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 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 procedure is water analysis of individual ions, comparing results with projected data. Required typical ions are listed in Table 1D.

TORAY REVERSE OSMOSIS ELEMENTS

- (7) In case of fluctuating pressure > 0.5 MPa, closed permeate loop or (automatic) valve → risk of water hammer.
- (8) Volumetric recording of daily consumption, divided by total daily feed flow.
- (9) In case of prechlorination / dechlorination only

**Table1C: Surface water/tertiary effluent,
 SDI < 4, peak 5; NTU < 0.3, peak 1.0**

Parameters	Online Monitoring (Continuously)	Daily (datasheet)	Periodically ⁽¹⁾	Alarm & safety system
1. Date and time of 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		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 water chlorine concentration	X	X		X
11. Feed water ORP *)	X	X		
12. Brine surplus of HSO ₃ (> 0.5 mg/l) **)		X		X
13. Antiscalant concentration in feed water		X		X
14. Feed water individual ion concentration			X ⁽²⁾	
15. Brine conductivity		X		
16. Brine pH	X	X		
17. Pressure drop of each bank	X	X		X
18. Brine flow rate	X	X		X
19. Total permeate conductivity	X	X		X
20. Permeate conductivity of each vessel			X	
21. Permeate pressure	X	X		X
22. Total permeate flow rate	X	X		X
23. Permeate flow rate for each bank		X		
24. Permeate individual ion concentration			X ⁽²⁾	
25. Total recovery ratio		X		X
26. Recovery ratio for each bank			X	
27. Normalized salt passage			X	
28. Normalized permeate flow rate			X	
29. Brine pressure	X	X		
30. Brine pressure - Permeate pressure	X	X		X

*) The ORP meter reading should always be less than the value of the line shown in the figure 230-1.

**) HSO₃⁻ surplus in brine >= 0.5 mg/l if raw water is chlorinated

Notes:

- (1) Log these parameters monthly from initial start-up operation. For trouble shooting or 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 1D.

TORAY REVERSE OSMOSIS ELEMENTS

Table 1D: Typical Water Analysis Items

Items		Feed Water	Permeate
1. Conductivity (25 °C)	($\mu\text{S/cm}$)	X ⁽¹⁾	X
2. Total dissolved solids	(TDS)	X	X
3. pH	(-)	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 ²⁻)	X	X
8. Phosphate	(PO ₄ ³⁻)	X	
9. Fluoride	(F ⁻)	X	
10. Sodium	(Na ⁺)	X	X
11. Potassium	(K ⁺)	X	X
12. Ammonium	(NH ₄ ⁺)	X	
13. Calcium	(Ca ²⁺)	X ⁽¹⁾	X
14. Magnesium	(Mg ²⁺)	X ⁽¹⁾	X
15. Strontium	(Sr ²⁺)	X	
16. Barium	(Ba ²⁺)	X	
17. Iron as ion	(Fe ³⁺)	X	
18. Manganese	(Mn ²⁺)	X	
19. Silicate	(SiO ₂)	X	X
20. Silicic acid	(SiO ₃ ⁻)	X	X
21. Boron	(B)	X ⁽²⁾	X ⁽²⁾
22. Chemical oxygen demand	COD	X	
23. Biological oxygen demand	BOD	X	
24. Total organic carbon	TOC	X	X
25. Carbon Dioxide	(CO ₂)	X	
26. Microorganism	(unit/cc)	X	
27. Hydrogen Sulfide	(H ₂ S)	X	
28. Temperature	(°C)	X	

Note:

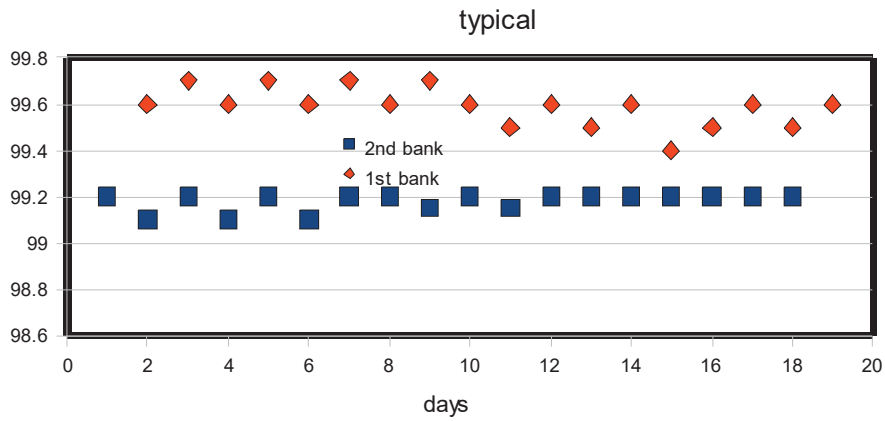
Above table is for reference only. Selection of required ions for analysis will also depend on feed water quality and required permeate quality.

- (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.
- (2) In case of specified data for permeate quality.

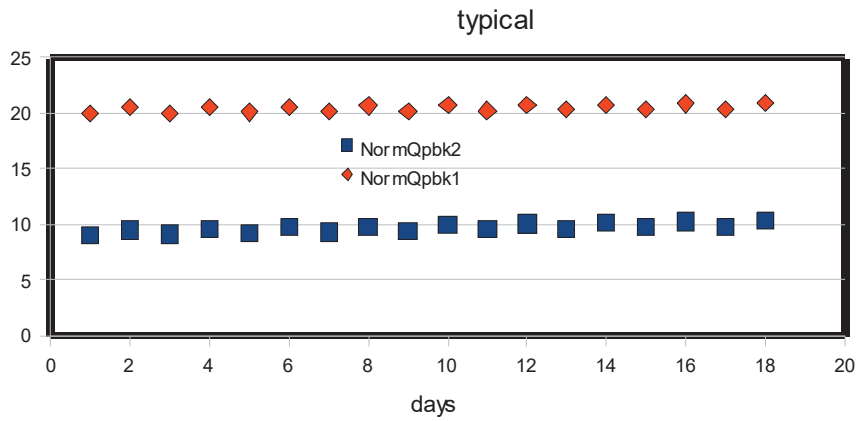
Table 1.E: RO system maintenance items (to be noted in system log)

Items	Frequency & procedure
<u>1. Instruments</u> 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 manufacturer.
<u>2. Cartridge filter change</u> Use only new pre-washed filter cartridges free of surfactants and chemical additives introduced during cartridge filter manufacture.	Record cartridge filter housing differential pressures before and after installation of cartridge filters It is also beneficial to record the date of installation and filter model #.
<u>3. RO system cleaning</u> As a minimum, record the following: Type of cleaning solution, solution concentration and conditions during the cleaning (pressure, temperature, flows, pH, conductivity)	Perform according to maintenance manual supplied by system manufacturer. TORAY membrane element cleaning guidelines and instructions are referenced in TMM Sections 310 and 320.
<u>4. Membrane treatment upon shut-down</u> Record preservation method, concentration of preservative solution, operating conditions before shut down and duration of shutdown.	Perform according to system manufacturer's operating manual. TORAY guidelines & instructions for long and short term membrane element preservation can be found in TMM sections 240 and 260.
<u>5. Pretreatment operating data</u> RO system performance depends largely on proper operation of the pretreatment systems.	Residual chlorine conc., Discharge press. of booster pump, consumption of all chemicals, calibration of gauges and meters.
<u>6. Maintenance Log</u>	Record any routine system maintenance procedures, mechanical failure events and change of position or replacement of any membrane elements.

TORAY REVERSE OSMOSIS ELEMENTS
Normalized Salt Rejection



Normalized Permeate Flow Rate



Differential pressure

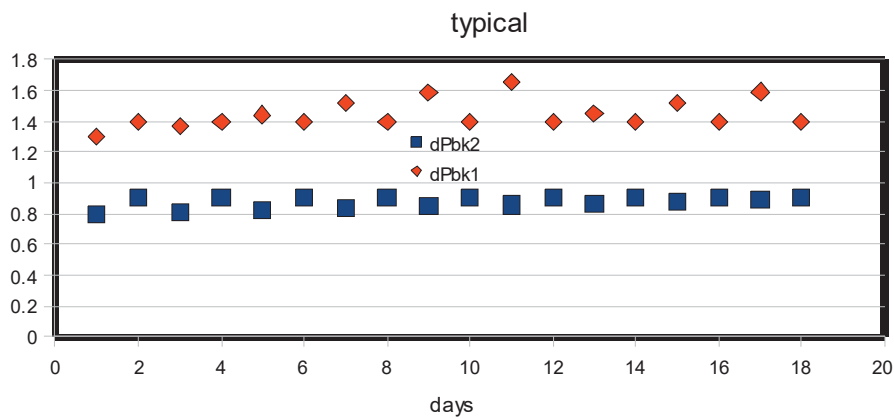


Illustration TMM-230.1: Typical monitoring chart for RO system

--Daily monitoring and data normalization are recommended. Watch out for performance change trends. As the current conditions of operation may be different (different salinity of the feed, different water temperature etc.) the current data must be “normalized” to the original start up operating conditions to allow direct and meaningful comparison. “Normalization” therefore refers to the manipulation of current data to reflect what the flows, and quality parameters would be if the plant was actually operating at the original (start-up) conditions.

In the above example, Illustration TMM-230.1, no performance changes are indicated, which is typical for reasonable system operation.

By comparing initial membrane performance data (new elements) with current “normalized” membrane performance data, it can be determined if any membrane element maintenance (such as a chemical cleaning or system adjustments) is required.

Normalization program TorayTrak

To assist in RO system performance data normalization TORAY developed a RO performance data normalization program called TorayTrak. TorayTrak is available as a free download at the Toray web site www.toraywater.com.

TorayTrak is provided as Macro-Free Microsoft Excel programs with 5 versions to deal with different process system designs and varied operational data collection points. The process schemes available are:

A. One-stage system

[TorayTrak_OneStage_PTotal.xlsx](#)

B. Split permeate one-stage system

[TorayTrak_OneStage_Split.xlsx](#)

C. Two-stage system with 1st and 2nd stage permeate flow rate monitoring

[TorayTrak_TwoStage_PF1_PF2.xlsx](#)

D. Two-stage system with 1st stage and overall permeate flow rate monitoring

[TorayTrak_TwoStage_PTotal_PF1.xlsx](#)

E. Two-stage system with 2nd stage and overall permeate flow rate monitoring

[TorayTrak_TwoStage_PTotal_PF2.xlsx](#)

Procedures for normalization are given in ASTM D 4516.

The following is a general introduction to TorayTrak for one-stage system as an example.

TORAY REVERSE OSMOSIS ELEMENTS

1) Configuration

	A	B	C	D	E	F	G	H	I	J										
1																				
2																				
3																				
4																				
5																				
6																				
7	Measured Permeate Flow Values				Toray Trak Excel Single (1) Stage System, Total Perm Flow 3.0.2 Version - NO MACROS 2018/1/12 Date Released															
8	Overall / Total Perm Flow																			
9																				
10																				
11	ENTER SITE SPECIFIC INFORMATION BELOW				System Configuration Information - Select Elements / Units															
12	Select Element Model ==>				TM720L-400	STAGE 2 - not used		STAGE 3 - not used												
13	Select Number of vessels/stage ==>				2	not used		not used												
14	Select Number of elements/vessel ==>				6	not used		not used												
15	Number of elements/stage and total				12.00	not used		not used		12.00	TOTAL ELEMENTS									
16	Membrane area/stage and total				447.60	not used		not used		447.60	TOTAL AREA M^2									
17	Flux/stage and total				5.68	not used		not used		5.68	Average Reference Flux (GFD)									
18	Baseline permeate flow/stage and total				19.00	not used		not used		19.00	Baseline Permeate Flow Rate									
19					DO NOT CHANGE THIS AREA!!!															
20	Select Temperature Units ==>				☐ Deg F ☒ Deg C	C		TempUnits		<== Select Temperature Units										
21																				
22	Select Pressure Units ==>				☐ psi ☒ bar ☐ kpa	bar		PressUnits		<== Select Pressure Units										
23																				
24																				
25																				
26	Select Flow Units ==>				☒ gpm ☐ m^3/hr ☐ l/min ☐ l/sec	gpm		FlowUnits		<== Select Flow Units										
27																				
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33	NOTE: If you change anything here, recalculate the whole sheet Ctrl+Alt+F9																			
34																				

INTRODUCTION
1 Configuration
Scada
Data
NormPerm
NormSP
NormDP
SpFlux and KW
TorayTrak Help

1. Left click your mouse on the "Configuration" Tab. All required system information is in green fill.
2. From the drop down lists enter Toray membrane model #(s), enter # of pressure vessels (PV) and # of elements / PV.
3. Next select the desired engineering units. These units must remain consistent for all data entries in the workbook.

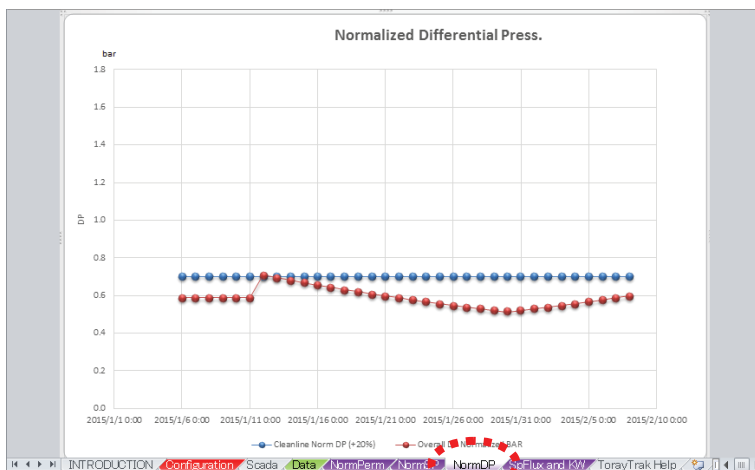
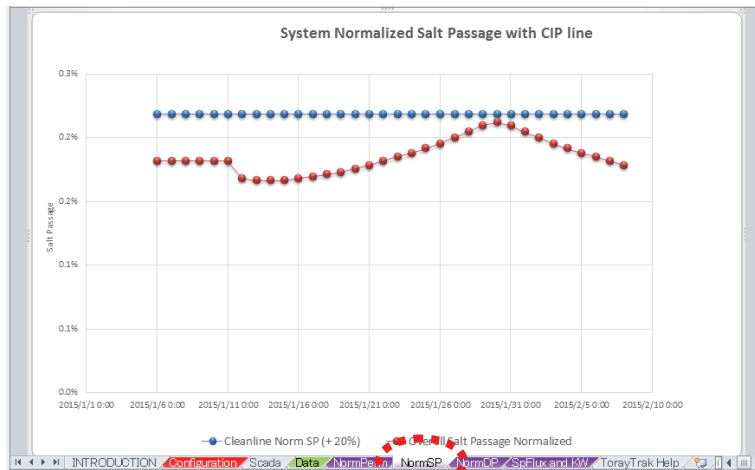
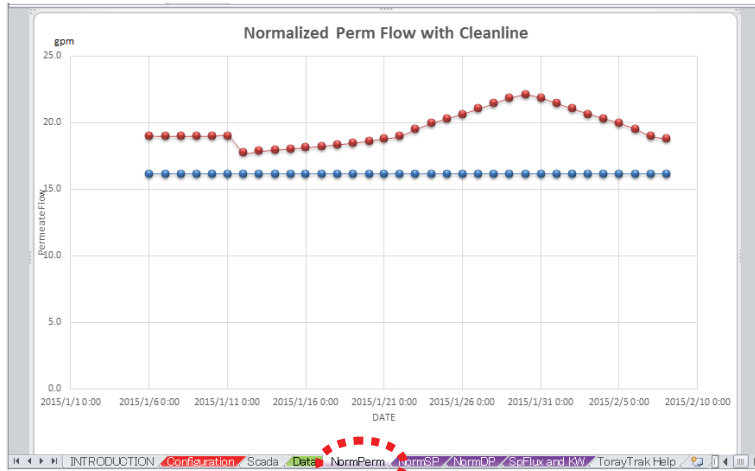
2) Input data

	A	B	C	D	E	F	G	H	I	J	K
1	C		< Temperature Units Selected. Use Sheet CONFIGURATION to change								
2	bar		< Pressure Units Selected. Use Sheet CONFIGURATION to change								
3	Data Entry Cells are YELLOW with Black Text										
4	USE CONFIGURATION SHEET FOR UNITS ==>			C	uS	uS	gpm	gpm	bar	bar	bar
			2.								
5	DATE & TIME	Elapsed Time day	Comments	Temp	Feed uS	Overall Perm uS	Overall Perm Flow	Conc Flow	Feed Press	Final Conc Press	Perm Press
6	2015/1/6 0:00		<First Data goes here>	25.0	7283	27	19.0	9.5	12.3	11.7	0.1
7	2015/1/7 0:00	1	Tip for cleaner graphs -	25.0	7283.1	27.4	19.00	9.50	12.29	11.70	0.09
8	2015/1/8 0:00	2	Only add a date when you have data	25.0	7283.1	27.4	19.00	9.50	12.29	11.70	0.09
9	2015/1/9 0:00	3	Formulas exist to row ~200. Below	25.0	7283.1	27.4	19.00	9.50	12.29	11.70	0.09
10	2015/1/10 0:00	4	R200, copy row to add more data	25.0	7283.1	27.4	19.00	9.50	12.29	11.70	0.09
11	2015/1/11 0:00	5		25.0	7283.1	27.4	19.00	9.50	12.29	11.70	0.09
12	2015/1/12 0:00	6		5.0	7283.1	13.4	19.00	9.50	22.26	21.31	0.09
13	2015/1/13 0:00	7		7.0	7283.1	14.3	19.00	9.50	20.76	19.85	0.09
14	2015/1/14 0:00	8		9.0	7283.1	15.2	19.00	9.50	19.40	18.54	0.09
15	2015/1/15 0:00	9		11.0	7283.1	16.3	19.00	9.50	18.18	17.36	0.09
16	2015/1/16 0:00	10		13.0	7283.1	17.5	19.00	9.50	17.07	16.29	0.09
17	2015/1/17 0:00	11		15.0	7283.1	18.8	19.00	9.50	16.07	15.33	0.09
18	2015/1/18 0:00	12		17.0	7283.1	20.2	19.00	9.50	15.16	14.46	0.09
19	2015/1/19 0:00	13		19.0	7283.1	21.8	19.00	9.50	14.34	13.66	0.09
20	2015/1/20 0:00	14		21.0	7283.1	23.5	19.00	9.50	13.59	12.95	0.09
21	2015/1/21 0:00	15		23.0	7283.1	25.3	19.00	9.50	12.91	12.30	0.09
22	2015/1/22 0:00	16		25.0	7283.1	27.4	19.00	9.50	12.29	11.70	0.09
23	2015/1/23 0:00	17		27.0	7283.1	29.9	19.00	9.50	11.78	11.22	0.09
24	2015/1/24 0:00	18		29.0	7283.1	32.6	19.00	9.50	11.36	10.83	0.09
1.											
INTRODUCTION Configuration Scada Data NormPerm NormSP NormDP SpFlux and KW TorayTrak											

1. Left click your mouse on the "Data" tab where membrane performance data is to be entered.
2. Starting on row 7, enter membrane performance data in columns A through K. All columns titled in yellow coloured field after the Date entry must contain data out to column K.
3. Baseline data to establish recommended cleaning lines are generated by averaging the data entered in rows 7 - 10.

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3) Trend graph



The trend graphs of the normalized membrane performance data by overall system is automatically displayed in the following three tabs “NormPerm”, “NormSP” and “NormDP”.

Shutdown Considerations for RO Systems

- 1) When shutting down a RO system the system should be thoroughly flushed at low pressure with sufficient quality flushing water to displace all the brine from the pressure vessels. (see TMM-250 Flushing procedures).

Acceptable water for flushing are: Pre-treated feed water (refer to table 240-1), or RO product water.

Water used for flushing should not contain any oxidants. Maintain the flush water solution pH between 3-8.5 at all times.

Table 240-1: Suggested flushing water for various RO feed water treatment system

RO feed water type	Flushing water
Sea water	Pre-treated feed water
Brackish water	Pre-treated feed water
Waste water	RO product water
High pH Feed water, (such as 2nd pass high pH feed water)	• Pre-treated feed water without NaOH • 1st pass product water without NaOH

- 2) Ensure membrane elements are kept wet, properly sanitized, and protected from freezing at all times during the shut-down period.
- 3) Ensure guidelines for temperature and pH of the preservative solution are observed during shut-down period.

Take care that product back pressure never exceeds 0.03 MPa at any time. Product back pressure should be assessed on an individual stage basis. Product backpressure is defined as product pressure minus feed resp. brine pressure.

**Caution**

If multiple RO trains are running in parallel, and one train is to be shut down, care should be taken to assure the train to be shut down is properly isolated from the common header piping using check valves or isolation valves. It is most important that pressure relief valves be present and installed on each individual train permeate line.

- 4) Membrane elements should not, under any circumstances, be exposed to chlorine or other chemical oxidants. Any such exposure may result in damage to the membrane, possibly resulting in irreversible increase in salt passage.
- 5) Extra care must be taken to avoid chlorine exposure
 - When disinfecting piping or pre-treatment equipment upstream of the membrane
 - When preparing cleaning or storage solutions
 - Care must be taken to ensure that no trace of chlorine is present in the feed water to the RO membrane elements.
 - If residual chlorine is known to be present in the RO feed, it must be removed with sodium bisulfite (SBS) solution in stoichiometric excess, allowing sufficient contact time to accomplish complete dechlorination.

Short-term shut-down**Definition:**

Short-term shut-down is for periods where an RO plant must remain out of operation for more than one day, but fewer than four days, with the RO elements remaining loaded in the vessels.

Prepare each RO train as follows:

Flush the RO section with flushing water, while simultaneously venting any air from the system feed piping.

- 1) When the pressure vessels are filled with flushing water, isolate the train by closing all isolation valves.
- 2) Repeat 1) and 2) above every 24 hours.

For detailed instructions of flushing procedures, see TMM-250: Flushing procedure.

Long-term shut-down

Definition:

Long-term shut-down is for periods where an RO plant must remain out of operation for more than four days with the RO elements remaining in the pressure vessels.

Prepare each RO train as follows:

Case.1) Flushing the RO system when sufficient flushing water is available.

Flush with flushing water for 0.5-1.0 hour at least every 2 days, while simultaneously venting any air from the system. When the pressure tubes are filled, close the valves.

For detailed instructions, see TMM-250 Flushing procedure

Case.2) Flushing the RO system when no flushing water source is available.

- a) Circulate permeate through the system. While circulating permeate through the system inject the RO system flush line with a 500 to 1000 mg/l (maximum) SBS solution. This solution will serve to inhibit biological growth during the shut down period. Circulate for 30–60 minutes.
- b) Make sure the RO system is completely filled with the SBS solution. To prevent the solution from draining from the system take care to close all system isolation valves.
- c) The pH of the preservative solution should never be allowed to drop below 3.0. The pH should be checked regularly. If the pH drops below 3.2, the preservative solution should be drained and replaced as soon as possible.

- d) If pH measurement of preservation solution is not possible, repeat Steps a) and b) with fresh solution.
- Every 30 days if the temperature is less than 80°F (27°C)
 - Every 15 days if the temperature is equal to or greater than 80°F (27°C)

Notes: Any contact of the SBS solution with air (atmospheric oxygen) will oxidize SBS to sulfate, and the preservative solution pH will begin to drop. Care should be taken to keep the SBS preservative solution isolated from atmospheric oxygen. If the SBS is allowed to revert to sulfate the potential for biological activity will increase.

Flushing Procedures

One simple procedure for removal of foulants is to flush the system with flushing water. Flushing scours the membrane surface by taking advantage of high velocity at low pressure. A large volume of flush water is required. This procedure can be an effective method for the removal of light organic fouling provided it is applied before significant performance decline has been observed.

General operating conditions for flushing are as follows:

Flushing water: Use pre-treated feed water (refer to table 250-1), or RO product water.

Flushing water should not contain any oxidants

Flushing water pH range should be maintained between 3-8.5.

Table 250-1: Flushing water to use for various RO feed water treatment systems

RO feed water type	Flushing water
Sea water	Pre-treated feed water
Brackish water	Pre-treated feed water
Waste water	RO product water
High pH Feed water, (such as 2nd pass high pH feed water)	• Pre-treated feed water without NaOH • 1st pass product water without NaOH

Pressure: Low pressure (0.1-0.2 MPa [15-30 psi])

Water flow rate: High flush water flow rate is best but do not exceed recommended vessel pressure drop.
 Limit pressure drop to max 0.2 MPa [30 psi] per stage.

Maximum feed flow
rate per vessel

- 8 inch element: • 200 l/min (53 gpm)
- 4 inch element: • 50 l/min (13 gpm)

Temperature: < 40°C (104°F)

Period: 0.5-1.0 hour

It is important to keep the permeate side isolation valve(s) open to keep the permeate back pressure to a minimum during the flushing procedure.
Feed/brine pressure should always be higher than permeate pressure to avoid any membrane damage.



Instruction

Flush each stage (bank) separately.
Do not re-circulate flushing water.

Preservation Procedures for RO Elements

The objective is to store elements under clean conditions to maintain performance and to prevent bacteria growth.



Instruction

After system shut-down, displace brine in the system with flushing water.

General conditions for preservation:

Flushing water: Use Pre-treated feed water (see Table 260-1), or RO product water.

Water for the flushing should not contain any oxidants.

Flushing water pH range should be maintained between 3-8.5.

Table 260-1: Flushing water of various RO feed water treatment system

RO feed water type	Flushing water
Sea water	Pre-treated feed water
Brackish water	Pre-treated feed water
Waste water	RO product water
High pH Feed water (such as 2nd pass high pH feed water)	● Pre-treated Pass 1 feed water without NaOH ● 1st pass product water without NaOH



Caution

If potential for scaling and fouling exists, membranes must be flushed on shutdown according to TMM-250 Flushing procedures.

- 1) To maintain performance, elements must be wet at all times.
- 2) To prevent bacterial growth in the pressure vessels, sanitization procedures may be required. - see TMM-400: Sanitization Methods

3) If elements are contaminated/fouled and extended shutdown is scheduled, it is recommended to perform chemical cleaning prior to preservation. This removes foulant from membranes and minimizes bacterial growth. Please review:

- TMM-300: General instructions and conditions for RO cleaning
- TMM-310: Guidelines for RO cleaning
- TMM-320: Instructions for chemical cleaning.

4) Allowable temperature range for preservation solutions 5-35°C (41-95°F)

5) Allowable pH range during preservation in the pressure vessel is 3-8.5.

6) Make-up water for preservation solution must be free from residual chlorine or other oxidizing agents.

For preservation of elements, use sodium bisulfite solution. For details see section TMM-400: Sanitization Methods

General Instructions and Conditions for RO Cleaning

The surface of an RO membrane is subject to fouling by suspended solids, colloids and precipitation. Pre-treatment of feed water prior to the RO process should be designed to avoid contamination/fouling of membrane surface as much as possible.

Operation at optimum conditions (permeate flow rate, pressure, recovery and pH-value) will result in less fouling of the membranes.

SDI15 is a measurement of particulates present in the feed water. With high SDI15 values (even in allowable range), membrane fouling due to particulates can cause performance decline in long-term operation.

Fouling can also be a consequence of large variations in raw water quality, or of errors in RO operation mode.

Fouling of the membrane surface will result in a performance decline, i.e. lower permeate flow rate and/or higher solute passage and/or increased differential pressure loss from feed side of a stage to the brine side.

Illustration 1 illustrates the effect of flux decrease due to fouling, and restoration of flux through cleaning. If the source of the foulant is not addressed and corrected, foulant removal will only bring temporary relief, as illustrated by the “saw tooth” pattern of the permeate flow in Illustration TMM-300.1.

Normalized Permeate Flow Rate

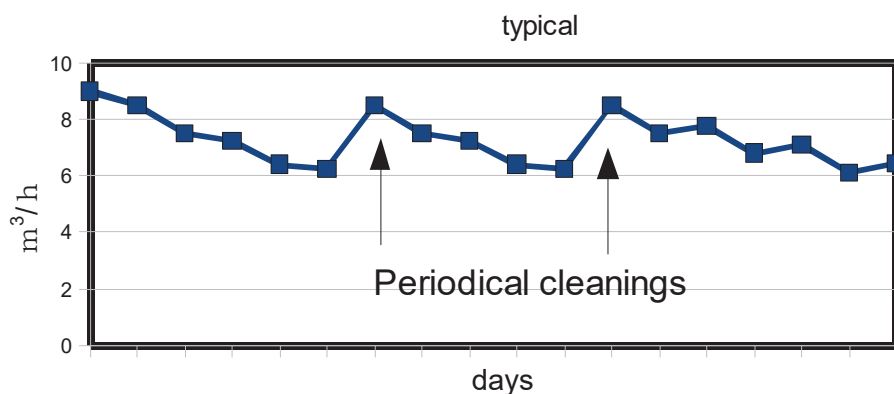


Illustration TMM-300.1: Effect of fouling on permeate flow rate

It should be noted that the best solution is typically to remove the foulant through improved pretreatment rather than subject the membranes to repeated cleanings.

Guidelines for RO Cleaning

When to clean:

For best efficiency of cleaning procedure, elements must be cleaned before fouling has fully developed. If cleaning is postponed for too long, it will be difficult or impossible to completely remove foulants from the membrane surface and re-establish full performance.

Commence cleaning when



Instruction

1. Normalized differential pressure increases more than 20%
OR
2. Normalized permeate flow rate decreases by more than 10%
OR
3. Normalized salt passage increases by more than 20%.

Weighing an element is an easy check for the occurrence of fouling. If the weight of the element is much higher than that of new element, fouling has occurred. Before weighing the element, stand it vertically on a perforated plate or drain for 60 minutes to allow drainage of fluids.

The approximate weights of new elements (drained condition) are:

- 4 inch diameter x 40 inch long: 4 kg,
- 8 inch diameter x 40 inch long (400 ft² membrane area): 15 kg
- 8 inch diameter x 40 inch long (440 ft² membrane area): 16 kg

Determination of foulant type

It is important to determine the type of foulants on the membrane surface before cleaning. The best approach for this is a chemical analysis of residues collected with a membrane filter during an SDI15 value determination for pre-treated water.



In situations where chemical analysis is not available, it is often possible to classify foulants by color and consistency of residue on the membrane filter. A brownish color residue will typically indicate iron fouling. White or beige color typically indicates silica, loam, calcium scale, or biological fouling. Crystalline constitution is a feature of calcium scale or inorganic colloids. Bio-fouling or organic material will - besides the smell - often show slimy/sticky consistency.

Selection of cleaning procedure

Once contamination of the membrane surface has been identified, the correct cleaning procedure must be selected.



Instruction

- If foulants are believed to be metal hydroxides, such as ferric hydroxide, or calcium scale, acidic cleaning procedures are promising, (see TMM-320: Instructions for chemical cleaning, TMM-330: Citric acid cleaning procedure).

- If foulant is believed to be organic or biological fouling, a cleaning procedure with detergents is recommended. (see TMM-320 Instructions for chemical cleaning, and TMM-340. Dodecyl Sodium Sulfate (DSS) Detergent Cleaning Procedure)

Evaluation of the effectiveness of cleaning

Descriptions of various cleaning procedures are given in TMM-320: Instructions for chemical cleaning. If the recommendations are followed, good results are generally obtained in many cases. Pressure drop across the modules should be reduced to initial value while permeate flow rate and solute rejection will be restored.

If performance is not sufficiently improved after cleaning, a different cleaning procedure may lead to a better result. Foulants will frequently adhere to membrane surface or remain in spacer material. Final removal may take several successive cleaning procedures. As foulants may be present as layers on the membrane surface, alternating citric acid and detergent (acid/ alkaline) cleans are frequently more effective than repeated cleans with only one type of cleaner.

Instructions for Chemical Cleaning

General guidelines

Chemical maintenance cleanings are performed to remove contaminants from membrane surfaces by dissolving and/or separating through physical and chemical interaction with cleaning chemicals.



Instruction

It is a good practice to perform a system flushing prior to initiating a chemical maintenance cleaning. If the RO system is to be shut down for an extended time, it is recommended that a chemical cleaning be performed prior to the introduction of any chemical preservatives.

After any chemical cleaning, it is recommended that the system be thoroughly flushed with either pre-treated raw water or permeate to insure removal of any residual cleaning chemicals dissolved or suspended solids from the RO system. See TMM Section 250 for flushing procedures.

CIP agents: Generic cleaning chemicals are listed in Table 320-1

Make-up water: Softened water or permeate, free of heavy metals, residual chlorine or other oxidizing agents.

Required quantity of CIP solution:

- 40-80 liters (11-22 gallons) per 8-inch element (depending on the severity of the fouling)
- 10-20 liters (3-6 gallons) per 4-inch element (depending on the severity of the fouling)

CIP pressure: Low pressure (0.1-0.2 MPa [15-30 psi])

CIP flow rate

Recommended flow rate: 100-150 L/min. ([25-40 gpm], [6-9 m³/h]) per 8-inch vessel;
 25-36 L/min. ([6.5-10 gpm], [1.5-2.2 m³/h]) per 4-inch vessel;
 The goal is to try and achieve the recommended cleaning flow rates above while keeping the cleaning solution pressure within the CIP pressure range of 15-30 psi.

Min. feed flow rate: 50 l/min (13.2 gallons/min.) for each 8-inch vessel
 10 l/min (2.7 gallons/min.) for each 4-inch vessel

TMM-320
Instructions for Chemical Cleaning

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Temperature:	The Maximum temperature of cleaning solution is depended on the pH of cleaning solution as below: Temperature $\leq 35^{\circ}\text{C}$, (pH2-11) Temperature $> 35^{\circ}\text{C}$ and $\leq 45^{\circ}\text{C}$, (pH2-10) For other pH, please contact Toray representative.
Cleaning technique	Clean each bank separately. It is also helpful to recirculate the cleaning solution then allow the membranes to soak in the solution. This procedure can be repeated several times to assist in the membrane cleaning process. See below suggested recirculation time intervals.
Recirculation intervals	0.5-1 hour (repeat 2-3 times) monitor solution temperature (see maximum temperatures above)
Soaking period:	2-24 hours incl. recirculation time (times depend on type and degree of fouling)
Method of cleaning:	Recirculation followed by soaking of each bank
Final flushing period:	Minimum. 1-2 hours, depending on application

It is important to keep any permeate side valves open to keep permeate back pressure to a minimum during the flushing procedure.
Feed/brine pressure should always be higher than permeate pressure to avoid any membrane damage. See TMM Section 250 for more details on flushing RO System.

Table 320-1: CIP chemicals

Contamination	CIP chemical	Cleaning Conditions	 Ref. description Instruction
Calcium scale Metal hydroxides Inorganic colloids	Citric acid 1-2%, adjust with ammonia (NH ₃)	pH value: 2-4	10.TMM-330 Citric acid cleaning procedure
Organic matter, bacterial matter ^{*)}	Dodecyl Sodium Sulfate (DSS, Sodium Lauryl Sulfate), 0.03-0.2% with alkaline solution or Polyoxyethylene Sodium Lauryl Sulfate(PSLS), 0.1-0.5% with alkaline solution	pH value : 7-11, adjust with sodium hydroxide, or sodium tripolyphosphate or trisodium phosphate	11.TMM-340 Dodecyl Sodium Sulfate (DSS) Detergent Cleaning Procedure
Acid insoluble Scaling ^{**)} CaF ₂ ; BaSO ₄ ; SrSO ₄ ;CaSO ₄	SHMP 1% Sodium hexametaphosphate	pH value: 2 adjust with hydrochloric acid	12.TMM-350 Sodium Hexa Meta Phosphate + hydrochloric acid Cleaning Procedure

1) Alkaline solution with 1% EDTA is more effective in some cases.

*) Combining sterilization and detergent cleaning is effective for bacterial contamination. First, perform sanitization, and then detergent cleaning, (see TMM-400 Sanitization methods for RO/NF - elements)

**) It is recommended to start with an acid cleaning to remove any other (combined) acid soluble fouling materials (such as e.g. CaCO₃). Acid insoluble scaling is difficult or impossible to remove if fouling layer is aged. Cleaning should be done within one week after such scaling is recognized.

Membrane cleaning system design considerations

For a typical flow diagram of a cleaning system, see Illustration TMM-320.1, typical arrangement of a CIP system.

Required useful volume of the membrane cleaning tank can be calculated as follows:

- Consider system volume (piping, pressure vessels, etc.) for preparation of cleaning solution.



Instruction

- Useful volume $V_n = A - B - C$, where

A =	Quantity of cleaning solution per element, times number of elements: ● 40-80 liters (11-22 gallons) for each 8" element, ● 10-20 liters (3-6 gallons) for each 4" element, Depending on the extent of fouling suggested volumes 8"/4" are: 1. = slightly fouled: 40/10 liters (11/3 gallons), 2. = medium fouled: 50/12 liters (13.2/3.2 gallons), 3. = heavily fouled: 60/15 liters (16/4 gallons),
B =	System volume (cleaning system piping and pipe headers.)
C =	Water volume of elements in pressure vessel subject to simultaneous cleaning. (20 liters [6 gallons] for 8", 5 liters [1.3 gallons] for 4")

Table 320-2: CIP volumes and flowrates for dimensioning the CIP Tank

The required useful volume V_n represents the volume of cleaning solution remaining in the tank after the elements and the CIP pipework are filled with cleaning solution. Note that the depth of solution remaining in the tank (V_n divided by tank cross sectional area) must be sufficient to meet any Net Positive Suction Head (NPSH) requirements for the selected cleaning pump.

Cleaning flow rate measured as the discharge flow rate of the cleaning pump should be as follows:

100-150 L/min. ([25-40 gpm], [6-9 m³/h]) per 8-inch vessel;

25-36 L/min. ([6.5-10 gpm], [1.5-2.2 m³/h]) per 4-inch vessel;

The goal is to achieve the recommended maximum flow rate while maintaining CIP pressure range between 0.1-0.2 MPa (15-30 psi).

Table 320-3A: Examples of CIP calculations: Metric units

Example		1	2	3	3
Degree of contamination		Slightly fouled	Moderately fouled	Heavily fouled	Heavily fouled
Element size	mm (inch)	200 (8)	200 (8)	200 (8)	100 (4)
# vessels being cleaned in parallel	pc.vessels	30	10	6	3
Total CIP flow	Liter/min. (m ³ /h)	3000 (180)	1000 (60)	600 (36)	75 (4.5)
# Elements / vessel	pcs.	6	6	4	3
Total elements	pcs.	180	60	24	9
CIP Solution required per element	Liter	40	50	60	15
Total CIP volume (A)	Liter	7200	3000	1440	135
ID of CIP piping	mm	150	100	60	25
Length of CIP piping	m	130	100	60	20
ID of header	mm	200	200	100	20
Length of header	m	10	0	4	3
Volume of CIP piping +headers (B)	Liter	2611	785	231	11
CIP solution contained / element	liter	20	20	20	5
Total CIP solution contained in elements (C)	liter	3600	1200	480	45
Useful volume of cleaning tank Vn required:	liter	989	1015	729	70

Note: See Table 320-2 “CIP volumes and flow rates for dimensioning CIP tank” for values used in the examples

Table 320-3B: Examples of CIP calculations: US typical units

Example		1	2	3	3
Degree of contamination		Slightly fouled	Moderately fouled	Heavily fouled	Heavily fouled
Element size	inch	8	8	8	4
# vessels being cleaned in parallel	pc.vessels	30	10	6	3
CIP flow/ vessel	USGPM	25	25	25	6.5
Total CIP flow	USGPM	750	250	150	19.5
Elements per vessel	pcs.	6	6	4	3
Total elements	pcs.	180	60	24	9
Volume CIP Solution required per element	US gallons	10.6	13.2	15.9	4.0
Total CIP volume (A)	US gallons	1908	792	382	36
ID of CIP piping	inch	6	4	2.5	1
Length of CIP piping	feet	430	330	195	65
ID of header	inch	8	8	4	1
Length of header	feet	33	0	12	9
Volume of CIP piping +headers (B)	USgallons	717	215	58	3
CIP solution contained / element	US gallons	5.3	5.3	5.3	1.3
Total CIP solution contained in elements (C)	US gallons	954	318	127	12
Useful volume of cleaning tank Vn	US gallons	237	259	194	21

Note: See Table 320-2 “CIP volumes and flow rates for dimensioning CIP tank” for values used in the examples



Pump head is calculated from:

- Max. differential pressure across RO elements (approx. 0.2 MPa) [30 psi]

- Pressure loss of piping system and pressure vessel connections
- Max. differential pressure across cleaning cartridge filter (approx. 0.2 MPa) [30 psi]

IMPORTANT NOTES:



Instruction

1. Provide a separate return line for permeate. It is important to keep any permeate side valves open to keep permeate back pressure to a minimum during the flushing procedure. Feed/brine pressure should always be higher than permeate pressure to avoid any membrane damage.



Caution

2. Design of cleaning tank must allow for complete draining.



Instruction

3. To avoid excess foaming of cleaning solutions the cleaning solution and permeate return lines should be of sufficient length to extend below the level of the solution in the CIP cleaning tank.

4. Spent cleaning solutions must be neutralized before discharge. Consider local regulations for discharge.



Warning

5. When working with chemicals, follow safety regulations indicated in material safety sheets. Wear suitable protection, such as eye protection, protective gloves and rubber apron!

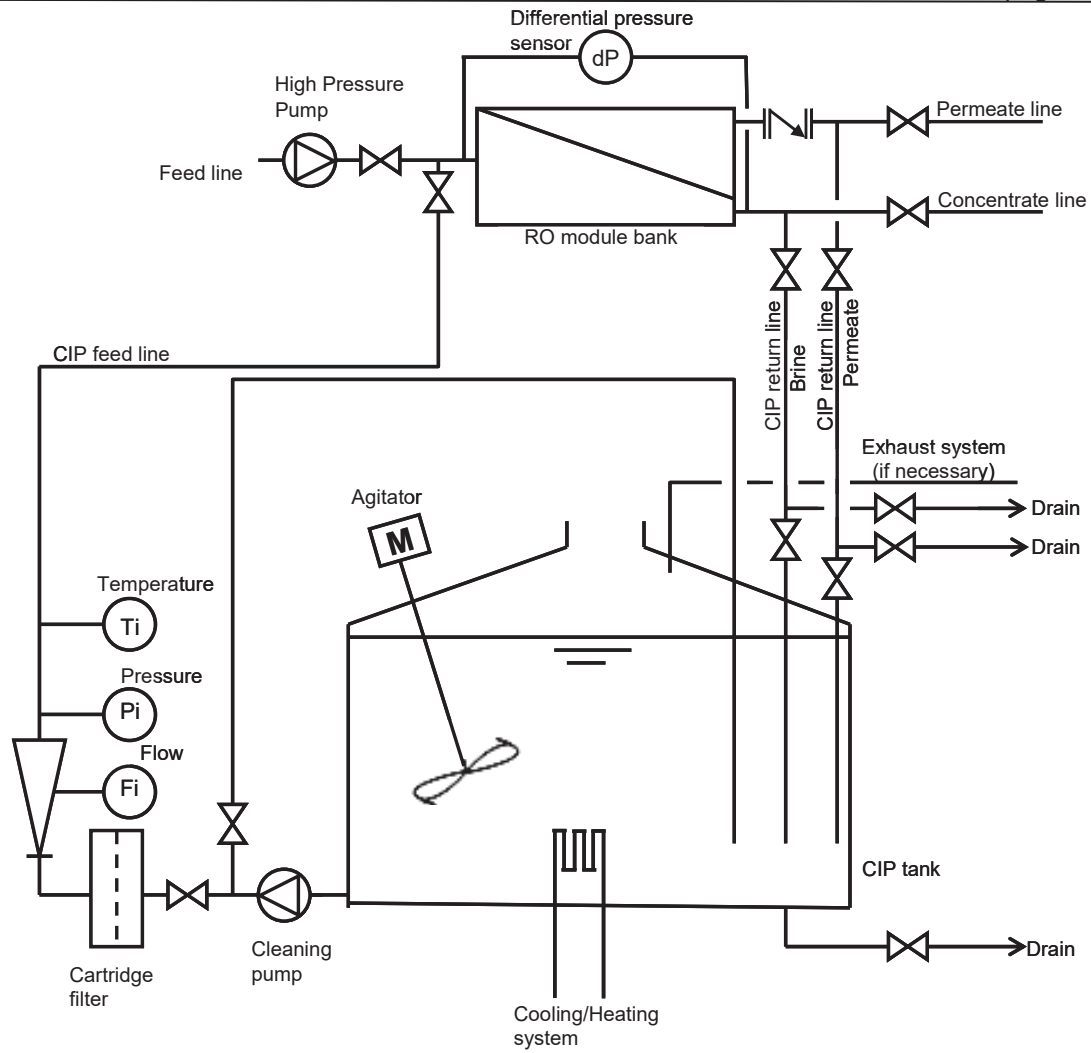


Illustration TMM-320.1: Typical CIP system arrangement

Citric Acid Cleaning Procedure

Flushing of elements

Prior to cleaning with citric acid solution, it is advisable (although not mandatory) to flush elements with softened water or RO permeate (see TMM-250. Flushing procedures).

Preparation of a 2% citric acid solution



- 1) Fill cleaning tank with water

Cleaning tank should be filled with RO permeate or softened water, free of oxidizing agents. The amount of cleaning water is determined by the size of the RO system and the extent of fouling, (see TMM-320 Instructions for chemical cleaning).

- 2) Dissolve citric acid

Add citric acid (white powder), in small increments to the cleaning water to obtain a 2% (by weight) - solution. Continuous agitation (or recirculation of the cleaning solution directly from the cleaning pump into the cleaning tank) will help to dissolve the citric acid quickly and completely. Break up any large chunks or lumps of citric acid prior to adding to the tank to avoid damaging the agitator or circulation pump parts.

Example: To prepare 1000 liters (264.2 gallons) of 2% (by weight) solution, 20 kg (44 lbs) of citric acid are required.

The solution pH should be adjusted with either ammonia (NH₃) or sodium hydroxide (NaOH) to the specified value (see TMM-320 Instructions for chemical cleaning).

- 3) Adjusting the pH of the solution with ammonium hydroxide should be performed with the agitator or recirculation pump in operation. Use an exhaust system if necessary to draw off released ammonia gas. Use of an electric drum transfer pump or manual drum transfer pump helps to minimize the release of ammonia gas.

The amount of ammonium hydroxide (NH₄OH), required to adjust the pH to 3.5 can be calculated approximately in proportion to the amount of citric acid by following formula

Amount of NH₄OH (100%) = 0.1 x Amount of citric acid (100%) in kg

For example, if the calculated amount of citric acid is 20.4 kg, the required amount of ammonium hydroxide (30% by weight) is 6.8 kg = $(0.1 \times 20.4) / 0.3$.

Circulation of cleaning solution

Circulate the cleaning solution at low pressure - less than 0.2 MPa (30 psi) is recommended. Elevated solution temperature will improve cleaning results.



Caution

Note: Cleaning efficiency can be improved by recirculating the cleaning solution for longer periods of time. It is necessary to monitor the cleaning solution temperature to make sure not to exceed recommended maximum allowable cleaning solution temperature (refer to TMM-320 Instructions for chemical cleaning).



Instruction

Soaking elements in the cleaning solution can be an effective procedure to dissolve metal foulants. Alternating soaking intervals with recirculation of the cleaning solution can also be beneficial.

Citric acid cleanings are used when the suspected foulant(s) are metal compounds. If the elements are severely fouled, the citric acid cleaning solution may become less effective as the cleaner reacts with the metal foulant(s). The initial cleaning solution will have a greenish yellow color. As the metals react with the cleaning solution during the recirculation phase the color may begin to turn a dark yellow progressing to a darker red brown color. This color shift indicates the cleaning solution effectiveness has been impaired due to chemical interaction with the foulant(s). When the solution color approaches the darker color it is recommended that the solution be discarded. A fresh citric acid solution should be prepared and the cleaning procedure repeated to assure a complete and effective cleaning.

Flush elements

Once the chemical cleaning circulation is finished completely drain and rinse the cleaning solution tank. Next fill the cleaning solution tank with permeate or oxidant free feed water. Fill the tank with sufficient flush water to displace all cleaning solution remaining in the cleaning system piping, RO system headers, and pressure vessels. All flush water should be directed to drain for proper disposal. Refer to TMM section 250.



Instruction

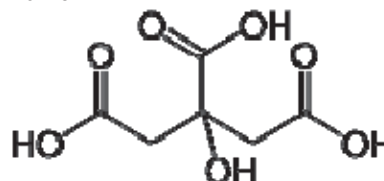
Flush each bank separately. Do not recirculate flushing water.

General description of citric acid



Danger

Appearance: white crystalline powder
 pH: ~ 1.7 (100 g/l water, 20°C)
 Density: 1665 g/cm³ (18°C)
 CAS Number: 77-92-9
 IUPAC name: 2-hydroxypropane-1,2,3-tricarboxylic acid
 Molecular Formula: C₆H₈O₇
 Molecule Shape



Safety precautions: low hazard potential, irritant



Instruction

NOTE: Please consult the Safety Data Sheet available from the chemical supplier for full safety details BEFORE handling this chemical. Use all recommended safety equipment.

General description of ammonia solution



Danger

Appearance: Colourless solution
 pH: ~ 11
 Density: 0.9 g/cm³
 CAS Number: 1336-21-6
 Molecular Formula: NH₃
 Safety precautions: Corrosive



Instruction

NOTE: Please consult the Safety Data Sheet available from the chemical supplier for full safety details BEFORE handling this chemical. Use all recommended safety equipment.

DSS (Dodecyl Sodium Sulfate) Detergent Cleaning Procedure

Flushing of elements

Prior to cleaning with DSS solution, it is advisable (although not mandatory) to flush elements with softened water or RO permeate, (see TMM-250.Flushing procedures).

Preparation of a 0.03% DSS solution

1) Fill cleaning tank with water

Fill the cleaning tank with RO permeate or softened water, free of any oxidizing agents. The amount of cleaning solution required is determined by size of RO system and extent of the fouling (see TMM-320 Instructions for chemical cleaning).

2) Dissolve DSS

Add sufficient DSS to the cleaning water to obtain a 0.03% (by weight) - solution. CAUTION - this chemical can form a film on the surface of the cleaning water capable of trapping gases resulting in the formation of foam. Precautions should be taken to minimize the potential mixing of air with the DSS when making up the cleaning solution to avoid excessive foam formation. It is recommended that the DSS be dissolved in a small volume of cleaning water then added to the bulk solution in the cleaning tank, continuous, slow agitation of the solution is required to evenly disperse the DSS. To minimize the potential for foam production, use the lowest speed setting on the mixer.

Example: To prepare 1000 liters (264.2 gallons) of the solution 0.3 kg (0.66 lbs) of DSS are required.

3) Monitor pH value

The pH of the detergent solution should be maintained within the recommended pH range. (see TMM-320: Instructions for chemical cleaning) If the pH falls outside the recommended range, solution pH adjustment will be required. The expected pH of the DSS solution is 7.

Circulate cleaning solution



Instruction

The initial flow of cleaning solution within the cleaning return line may contain a high concentration of contaminants. Discard the initial 10-15% of the cleaning solution volume to drain prior to circulating the cleaning solution to the cleaning tank.

Increasing the cleaning solution temperature will improve the efficiency of the cleaning. Do not exceed recommended temperature guidelines. In addition it is beneficial to perform the cleaning at low pressures. Do not exceed (approx.0.2 MPa [30 psi]) during circulation of the cleaning solution.



Caution

Note: Extending the circulation time is beneficial to maximize the efficiency of the cleaning. The cleaning solution temperature should be monitored closely during the circulation of the cleaning solution, Take care not to exceed recommended maximum temperature value. (refer to TMM-320 Instructions for chemical cleaning)

To minimize the potential for foam formation within the CIP solution tank make sure the cleaning solution return line and permeate lines extend below the level of the cleaning solution.



Instruction

Efficiency of chemical cleanings can be improved if the elements are allowed to soak in the cleaning solution for an extended length of time. Repeated intervals of soaking followed by circulation of the cleaning solution can also improve cleaning results.

Flush elements

Once the chemical cleaning circulation is finished completely drain and rinse the cleaning solution tank. Next fill the cleaning solution tank with permeate or oxidant free feed water. Fill the tank with sufficient flush water to displace all cleaning solution remaining in the cleaning system piping, RO system headers, and pressure vessels. All flush water should be directed to drain for proper disposal. Refer to TMM section 250.



**Flush each bank separately.
Do not recirculate flushing water.**

General description of DSS

Appearance:	Powder or aqueous solution
pH:	7-8 as 1% solution (based on powder)
Charge in solution	Anionic
Solubility in water:	10 g/100 ml
Main component:	$\text{CH}_3(\text{CH}_2)_{11}\text{SO}_3\text{Na}$ Dodecyl Sodium Sulfate (Sodium Lauryl Sulfate)
CAS No.:	151-21-3

General description of TSP (Trisodium phosphate)

Appearance:	White crystalline powder, without chunks
pH:	Strong alkalinity in solution
Density:	1.630 g/cm ³ (18°C)
Solubility in water:	28.3 g/100 ml
Main component:	Na_3PO_4
CAS No.:	7601-54-9

General description of NaOH (Sodium hydroxide)

Appearance:	White crystalline powder or granular or chunks
pH:	Strong alkalinity in solution
Density:	2.130 g/cm ³ (18°C)
Solubility in water:	Soluble in random ratio
Main component:	NaOH
CAS no.:	1310-73-2

Safety precautions

- Consult safety data sheet (SDS) of supplier of detergent before use.



Danger

Inhalation: Causes irritation to the respiratory tract. Symptoms may include coughing, shortness of breath. May cause allergic reaction in sensitive individuals. Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.

- Ingestion: Large doses may cause gastrointestinal distress, nausea and diarrhoea. Remove to fresh air. If not breathing, give artificial resuscitation. If breathing is difficult, give oxygen. Get medical attention. If conscious, induce vomiting.
- Skin Contact: Mildly irritating to skin, causes dryness and a rash with continued exposure. May cause allergic skin reactions. Immediately flush skin with plenty of soap and water. Remove contaminated clothing and shoes. Get medical attention. Wash clothing before reuse. Thoroughly clean shoes before reuse.
- Eye Contact: Causes irritation, redness, and pain. Immediately flush eyes with plenty of water for at least 15 minutes, lifting lower and upper eyelids occasionally. Get medical attention immediately.

Acidic SHMP CIP Procedure

Flushing of elements

Prior to this cleaning procedure it is advisable, especially if operating on raw water having a high total hardness concentration, to flush elements using softened water or RO permeate, (see TMM-250.Flushing procedures).

Preparation of a 1% SHMP solution

1) Fill cleaning tank

Cleaning tank should be filled with RO permeate or softened water, free of oxidizing agents. The amount of cleaning water required is determined by size of RO system and the perceived extent of fouling, (see TMM Section 320. Instructions for chemical cleaning).

2) Dissolve SHMP

Add SHMP (white powder) to water to obtain a 1% (by weight) - solution. Continuous agitation of the solution by motorized mixer or recirculation pump will be needed to completely dissolve the chemical. SHMP should be added to the cleaning tank in small batches to avoid clogging.

For example: To prepare 1000 liters (264.2 gallons) of cleaning solution, 10 kg (22 lbs) of SHMP is needed.

3) Add hydrochloric acid

Slowly add HCl to the SHMP solution until you reach a pH value of 2.



Warning

HCl is an aggressive inorganic acid, pay attention to safety precautions when handling HCl

4) Check pH value

The pH of the cleaning solution should remain just above 2. If the pH increases above 3.5 during circulation of the cleaning solution, add HCl until the pH is again just above pH 2. Should the pH go below 2 adjust the pH to slightly above pH 2 by adding caustic soda (NaOH).



Warning

Caustic soda is an aggressive inorganic base; pay attention to applicable safety rules when handling it. The expected pH of a 1% SHMP solution is neutral.

Circulate cleaning solution

The first 10-15% of the original cleaning solution volume returned from the RO system may contain high concentrations of contaminants. It is therefore recommended to dispose of this portion of the cleaning solution to drain and not recycle it back into the solution tank. Once this initial volume has been discarded, direct all the returned cleaning solution back to the solution tank for re-circulation.

Low feed water pressure should be applied during re-circulation.

(approx. 0.2 MPa [30 psi])

Higher cleaning solution temperature can improve the cleaning efficiency.



Caution

Note: Longer periods of circulation are beneficial for chemical cleanings. However, prolonged circulation will result in an increase in cleaning solution temperature. Monitor the solution temperature to make sure it does not exceed recommended maximum allowable temperature. (refer to TMM-320 Instructions for chemical cleaning).

When mixing the SHMP there is a potential for excessive foaming. To reduce this foaming potential make sure the permeate return line and cleaning solution return line are extended below the liquid level in the cleaning solution tank.



Soaking the elements in the cleaning solution can help to break up and remove contaminants. Alternating periods of soaking and circulation of the cleaning solution can improve the chemical cleaning efficiency. Stopping the re-circulation process for a total of two 15 min soaking periods during a typical one hour cleaning schedule is recommended.

If the pH value during circulation increases above pH 3.5, add



more HCl until pH value drops to just above pH 2. If pH of the returned cleaning solution increases rapidly the effectiveness of the solution has been reduced due to reaction with contaminants. Should a rapid rise in pH be noted discard the spent cleaning solution and mix up a fresh batch and proceed as before with the cleaning process.

Flush elements

At the end of the chemical cleaning process it will be necessary to flush all the spent cleaning solution from the cleaning piping, RO headers, and pressure vessels. Begin by draining the solution tank and rinse the tank thoroughly. Next it will be necessary to displace all residual cleaning solution from elements, pressure vessels and pipe lines with feed water or RO permeate.

Flush each bank separately.

Do not re-circulate flushing water.



Fill the rinsed cleaning tank with softened water or permeate. Use the cleaning system pump and piping to direct flush water through the RO system. To prevent spent cleaning solution from mixing with the clean flush water in the cleaning tank direct all return lines to drain just prior to the cleaning tank. Repeat as needed to assure complete displacement of the residual cleaning solution.(see TMM-250.Flushing procedures).

General Description of of SHMP (NaPO_3)_n

Appearance:	White powder, odorless
pH:	Approx. pH7 (1% solution)
Solubility:	Almost unlimited
Concentration:	Approx. 67%
Density:	0.95-1.05 g/cm ³ (20°C)
CAS No.:	10124-56-8

Safety precautions:

- Consult safety data sheet (SDS) of supplier of SHMP before use.



Danger

Normal safety-equipment like gloves and eye protection should be worn during handling of SHMP.

- In case of eye contact flush eye immediately with a large amount of water and consult a physician.
- Prolonged contact with skin should be avoided. Avoid breathing dust.

Sanitization Methods for RO/NF - Elements

Sanitizing solutions

Formaldehyde

One effective method to prevent propagation of bacteria is to soak the membrane elements in a sanitizing solution of 0.2-0.3 weight% formaldehyde (HCHO) at pH 6-8, the sanitizing solution pH can be adjusted by the addition sodium bicarbonate (NaHCO₃).

This sanitization method is a satisfactory and effective method to control biological activity for short or long term shut downs.

Immersion of membrane elements in a formaldehyde sanitization solution is not applicable for new elements. Elements must have been in full operation at design conditions for at least 72 hours prior to any formaldehyde sanitization procedures. Exposure of elements to formaldehyde prior to 72 hours of operation may result in irreversible flux loss.

Alternate Sanitizing solutions

If the use of formaldehyde sanitization is not permitted the following alternative solutions can be employed (see chart below). Membrane elements can be soaked in these alternate solutions during system shut downs. Please note that membrane exposure time to these alternate solutions is limited. Refer to the chart below for recommended soak intervals.

Sanitizing solution	Concentration [ppm]	Duration of treatment ^{*)} [hr]	Applicable to membrane type:
Hydrogen Peroxide H ₂ O ₂ ^{**)}	2000-10000	1 ^{***)}	Other than 800 series
Sodium bisulfite	500-1000	No limit ^{***)}	All types



Caution

1. The water used to prepare all sanitizing solutions must be free of residual chlorine or other equivalent oxidizing agents.
2. Be sure that the selected chemicals are appropriate and chemically compatible with the membrane type to be sanitized. Refer to the chart above.

-
- *) Contact time with sterilizing solutions must not exceed recommended durations to avoid membrane performance decline.
 - **) Use of hydrogen peroxide in presence of heavy metal residues will lead to fast and irreversible damage of composite membranes as well.

Hydrogen peroxide for this application must be prepared with de-ionized feed water with less than 0.2 ppb iron. If the concentration of iron is above 0.2 ppb in the solution make up water the membrane elements can be irreversibly damaged resulting in an increase in salt passage.

If heavy metal precipitates of any type (iron, manganese, etc.) are suspected to be present on the membrane surface, it is mandatory to clean the membranes with an acid solution prior to exposure to hydrogen peroxide. For details of citric acid cleaning procedure see TMM-330. Failure to do so may result in catalysed oxidation of the membrane surface by the hydrogen peroxide resulting in irreversible salt passage increase.
 - ***) After sterilization completely flushes the system with permeate or pre-treated raw water prior to placing the system back online. If the membranes are to be preserved during an extended shut down it is necessary to completely flush the system prior to introduction of any preservative solutions into the system.

Biocide

DBNPA (2,2-dibromo-3-nitrilopropionamide) is a highly effective non-oxidizing broad-spectrum biocide used for the control of bacteria, algae and fungus in reverse-osmosis systems as well as other industrial water applications.

This product is normally applied as a shock treatment to control biological activity within membrane elements. Dosing frequency depends on the microbiological activity of the RO feed water and the condition of the membranes.

There are several DBNPA-based products available. For more information about DBNPA, refer to DBNPA supplier technical data and Safety Data Sheet or contact your chemical supplier for recommendations.

Heat Sanitization of RO Elements (TS types)

Occasional or periodic hot water sanitization (pasteurization) is a preventive measure to reduce bacteria and fungus growth. The following recommendations are applicable for TORAY hot water resistant elements (TS types).



Caution

- Temperature slope during heating & cool down period: maximum 2.0°C / minute.
- It is preferable to use permeate water, or at least softened water, for this procedure.
- Heat sanitization cannot be applied to standard RO products - it will cause irreversible damage.



Instruction

- For effective sanitization water temperature can be increased up to 85°C. (Temperature required depends on bacteria strains present). Above 85°C, modules can be irreversibly damaged. Feed water pressure should be less than 0.1 MPa.



Caution

- Feed pressure during hot water treatment must be always < 0.15 MPa (22 psi).
- Differential pressure max. 0.1 MPa (15 psi) / element.

Frequency of hot water treatment depends on feed water quality and use of product water. Average frequency of treatment should, however, not exceed 1 treatment / week.



Instruction

- The necessity and effectiveness of high temperature sanitization treatment must be determined by microbiological testing of feed, brine and permeate streams.

It is important to open permeate side valve and to maintain no permeate side back pressure condition during high temperature treatment. Feed and/or brine pressure should be higher than permeate side pressure at all times to avoid permeate back pressure problems.

Storage

General

To prevent biological growth on membrane surfaces during storage and performance loss in subsequent operation, TORAY RO elements must be preserved in a solution.

Element preservation is necessary for:

- Long term storage of new and used elements
- RO system shutdown > 24 hours

If the RO elements have been in service, see TMM-240 Shutdown considerations for RO systems.

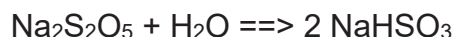
Storage of new elements

It is recommended that new elements be stored in their original packaging until such time the membrane elements are to be loaded into the pressure vessels for system start up. Recommended storage conditions are listed below:

- 1) Store elements in cool, dry place inside a closed building. Keep elements away from exposure to direct sunlight.
- 2) Avoid freezing temperatures and temperatures above 35°C (95°F).
- 3) New elements are shipped in preservation solution of 0.5-1.0% sodium bisulfite solution or sodium chloride solution with deoxidizer packets.
- 4) New elements are packed in special oxygen impermeable plastic bags under a slight vacuum. The elements are shipped in durable carton boxes. It is recommended that the elements be stored and remain in the original shipping cartons until the time they are to be installed in the system pressure vessels. Used bags and deoxidizers can be disposed as normal municipal solid waste.

Storage of used elements

- 1) For storing elements that have been in service refer to TMM Section 240: Shutdown consideration for RO systems. Using RO permeate or softened water, prepare a 500 - 1000 ppm sodium bisulfite solution. To prepare the solution, use food grade sodium metabisulfite (SMBS). SMBS reacts with water to form sodium bisulfite (SBS) according to this reaction:



- 2) After soaking the elements for about 1 hour in the bisulfite solution, remove the elements and place them in a plastic oxygen barrier bag. Oxygen barrier bags can be obtained from Toray. Seal and label the bag(s), indicating packaging date.
- 3) Storage conditions for used/repackaged elements are the same as for new RO elements. See page 1 of this section.
- 4) When used elements are sent back to Toray, please contact Toray or its representative before unloading elements.

Handling of New Elements

In order to maintain good element performance, observe the following:

Precautions during storage

- 1) The elements are shipped from TORAY in sealed oxygen impermeable plastic bags and sturdy carton boxes. Only open the element boxes just prior to element installation.
- 2) Elements can be stored within a temperature range of 5°C to 35°C (41°F to 95°F). Avoid storage in direct sunlight.
- 3) If the element storage area ambient temperature is expected to drop below freezing point (0°C), measures should be taken to keep the elements at a temperature above freezing. Do not allow elements to freeze.
- 4) Don't stack more than 5 layers of carton boxes when re-stacking from originally delivered packing (export packing).
- 5) Keep the original element packaging dry at all times to preserve their structural integrity.

General notes for installation into pressure vessels.

- 1) Carefully open plastic bags at one end. Be careful when opening the plastic bags. It is recommended some of these bags are retained for possible future use.
- 2) It is also a good idea to retain some of the packaging boxes in case an element needs to be removed and placed in storage.
- 3) When loading membrane elements, record the position of each membrane element by serial number within the system. It will be necessary to make note of the system train # (where multiple trains exist), pressure vessel number or position within the pressure vessel array, and finally the position of the membrane element within each of the pressure vessel(s). This procedure should be followed when loading every membrane element in the RO system. If an element is moved or replaced, element positions may change. Changes in position should be appropriately recorded.

-
- 4) To avoid damage handle each element with care. Avoid dropping the membrane element. To minimize the potential for contamination handle the elements with clean hands or gloves. Take precautions to keep the exterior of element clean.

 - 5) See detailed procedures in TMM-200 Installation of RO elements.

Introduction to Troubleshooting

Potential problems in RO system can be recognized early by monitoring the changes of permeate flow rate*, salt passage (salt rejection)* and differential pressure * of the RO pressure vessels. It is, therefore, recommended that the system operator(s) record and review operational data frequently. Early detection of system performance decline will alert the operators to potential operational problems and allow them to initiate appropriate countermeasures to restore membrane element performance.

Typical performance changes and their countermeasures are shown in the following Section TMM-610.

Basic steps of troubleshooting are summarized below:

Action	Item concerned
Check:	Calibration of Instruments - Pressure, Temperature, Conductivity, pH, flow etc.
Review:	Daily operational data, normalized data, maintenance logs, and comparison of current performance to design specifications.
Investigate:	Reasons for performance changes and their possible causes. Refer to TMM-610 Typical Performance Changes and Countermeasures.
Troubleshoot:	Initiate corrective measures; perform countermeasures in a timely fashion e.g. chemical cleaning, sterilization, replacement of defective parts, system adjustments.

Permeate Center pipe probing method

If the permeate conductivity measured from a specific pressure vessel indicates a sudden and significant increase in permeate conductivity it is helpful to know if this increased salt passage is due to a faulty O-ring seal (mechanical leak) or due to membrane loss of rejection. Probing the elements will help determine the cause of the increase in salt passage. Probing apparatus is shown in Illustrations TMM-600.1-2. Water quality (conductivity) can be easily measured at different positions within the pressure vessel by sampling the water using the center pipe probing technique.

*) Normalization of values marked with * is required in order to properly understand the operation data. Procedures for normalization are described in section TMM-230: Operation monitoring.

Illustration TMM-600.1: Center pipe probing method (1)

Recommended Piping Arrangement and Permeate Sampling Probe for Each Element in One Module

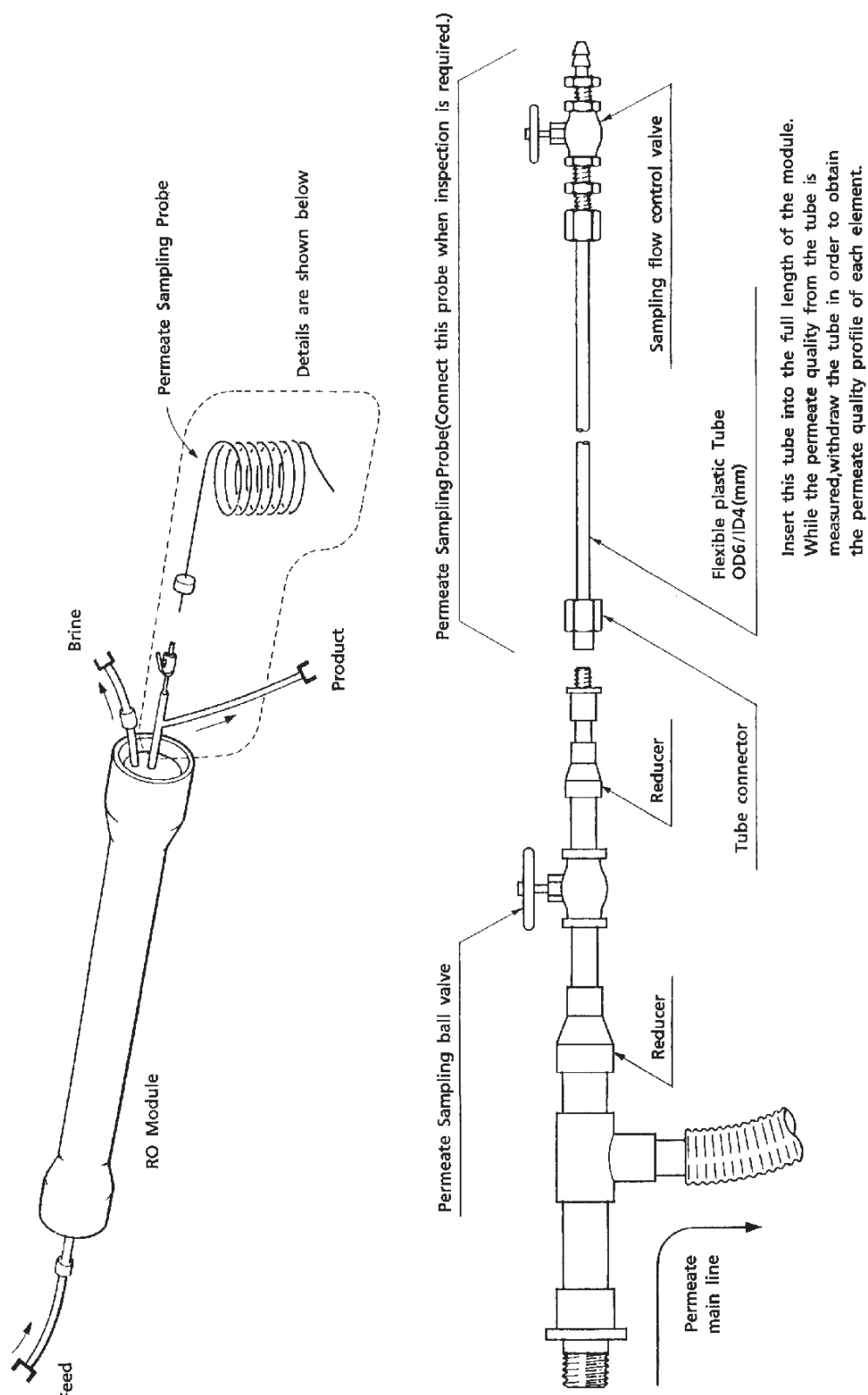
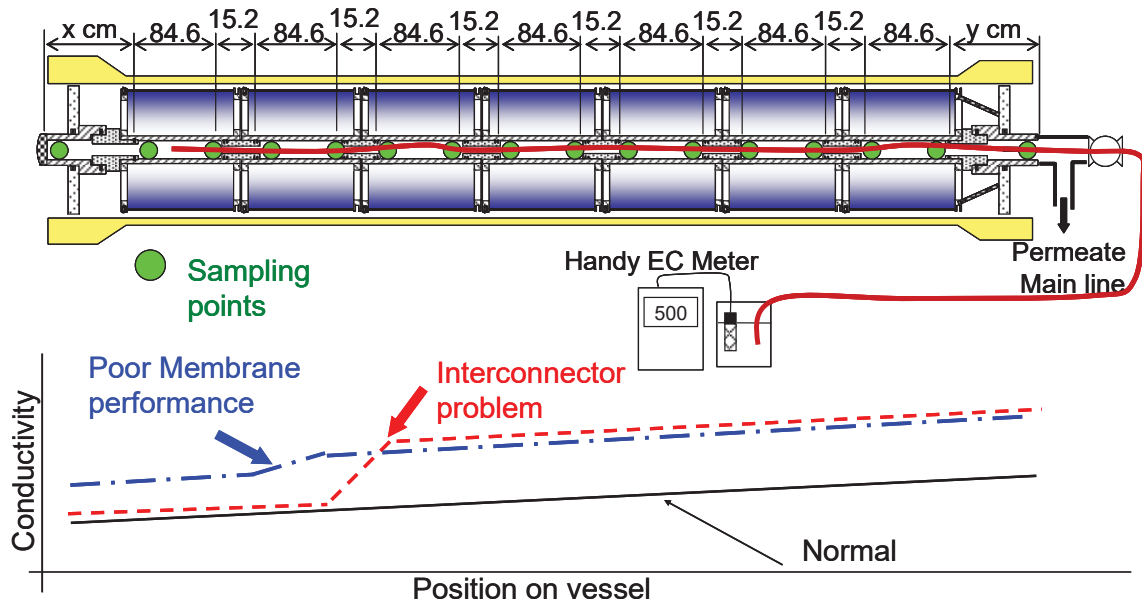
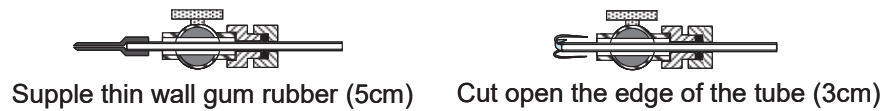


Illustration TMM-600.2 : Center pipe probing method (2)

- Pressure Vessel Probing -



Sampling tube apparatus



Typical Performance Changes and Countermeasures

To properly evaluate the performance of a RO system it is essential that reliable operational data be recorded on a daily basis. To assure the collected performance data is accurate, a regular instrument calibration schedule should be adopted. Logging of collected data and all maintenance procedures are important for proper system evaluation. Analysis of the recorded historical system data will help determine what remedy is best suited to recover any lost system performance.

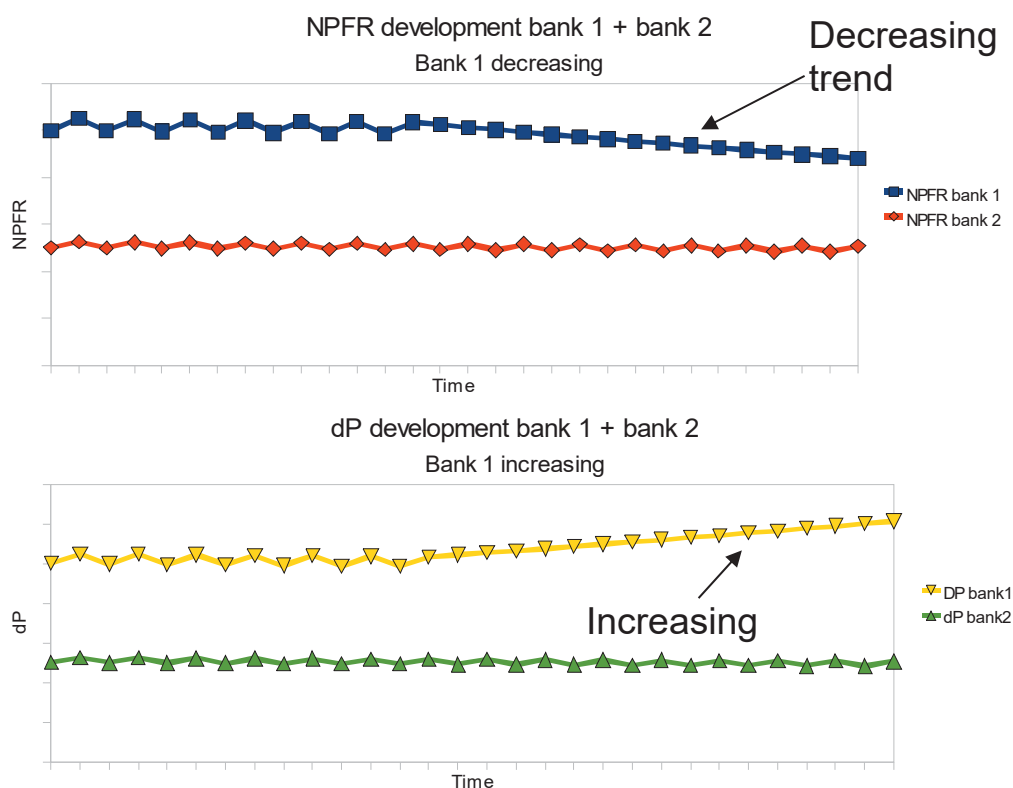
This section is about problems and countermeasures regarding salt passage and permeate flow rate. The impact of feed water conditions such as pressure, temperature, concentration, pH and recovery ratio in the system performance is discussed in section TMM-230 .Operation Monitoring.

The following abbreviations are used in this section:

NPFR = Normalized permeate flow rate

NSP = Normalized salt passage

DP = Differential pressure

Case A: Normalized permeate flow rate (NPFR) decline - first bank**Potential causes****Countermeasures**

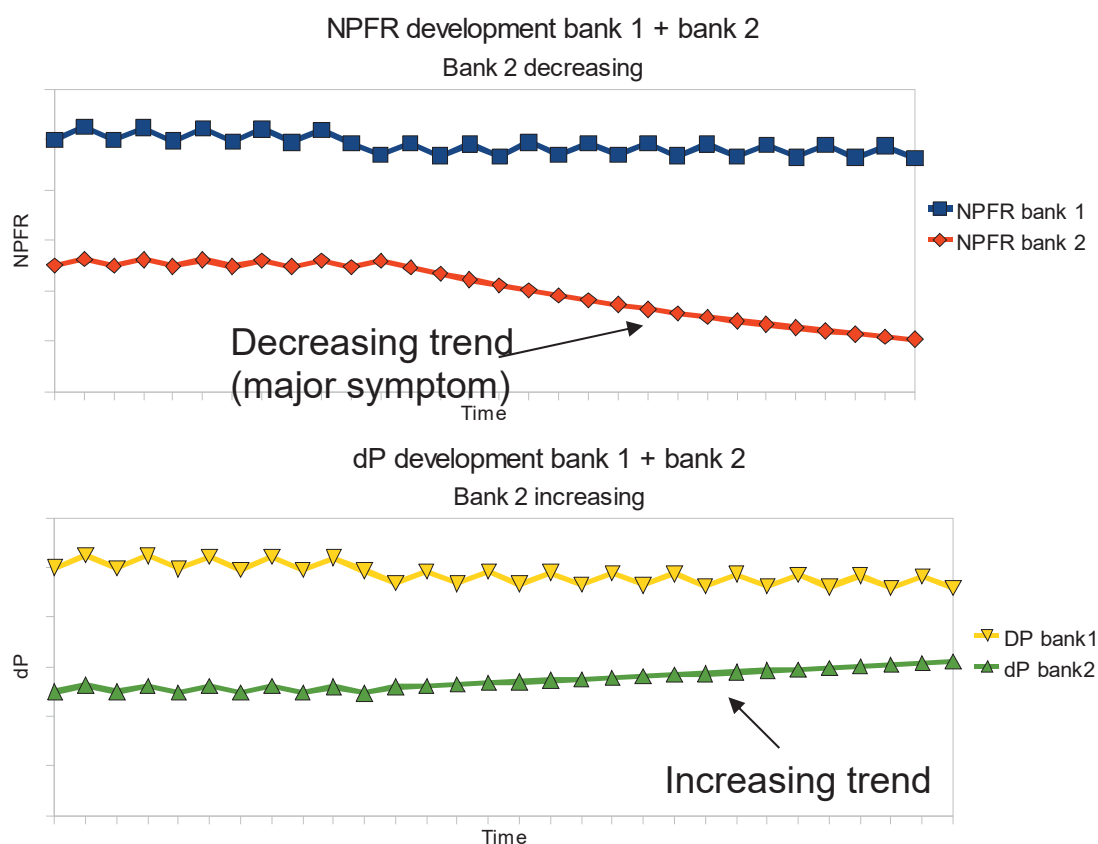
- | Potential causes | Countermeasures |
|--|--|
| ● Change in feed water quality | Check operating parameters (recovery, flux).
Optimize pre-treatment, check pre-filtration
(perform any required adjustments) |
| ● Fouling by metal hydroxides, inorganic colloids, organic or bacterial matter | Optimize pre-treatment, followed by appropriate CIP and / or sterilization |
| ● Fouling by suspended particles | Chemical cleaning.
Optimize pre-treatment, check pre-filtration equipment |

Typical Performance Changes and Countermeasures

TORAY REVERSE OSMOSIS ELEMENTS

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Case B: Normalized permeate flow rate (NPFR) decline - last bank



Potential causes

Countermeasures

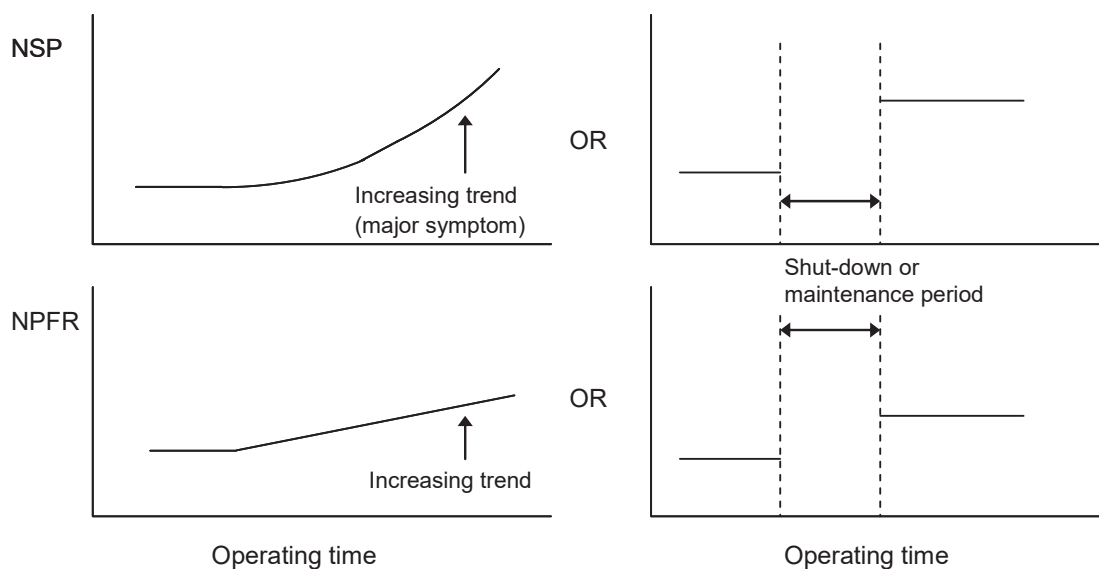
- | | |
|--|---|
| ● Change in feed water quality | Check operating parameters (recovery, flux). Optimize pre-treatment, especially the scale inhibitor injection system and dosage rate. |
| ● Scaling in bank 2
(precipitation of sparingly soluble salts) | Check feed analysis for changes. Check scale inhibitor injection system and inhibitor dosage rate. |
| ● Fouling by metal hydroxides, inorganic colloids, organic or bacterial matter | Optimize pre-treatment, analyse the foulant followed by an appropriate CIP and / or sterilization procedure. |
| ● Fouling by suspended particles | Analyze precipitate, followed by appropriate chemical cleaning |

Typical Performance Changes and Countermeasures

TORAY REVERSE OSMOSIS ELEMENTS

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Case C: Normalized salt passage (NSP) increase - all vessels



Potential causes

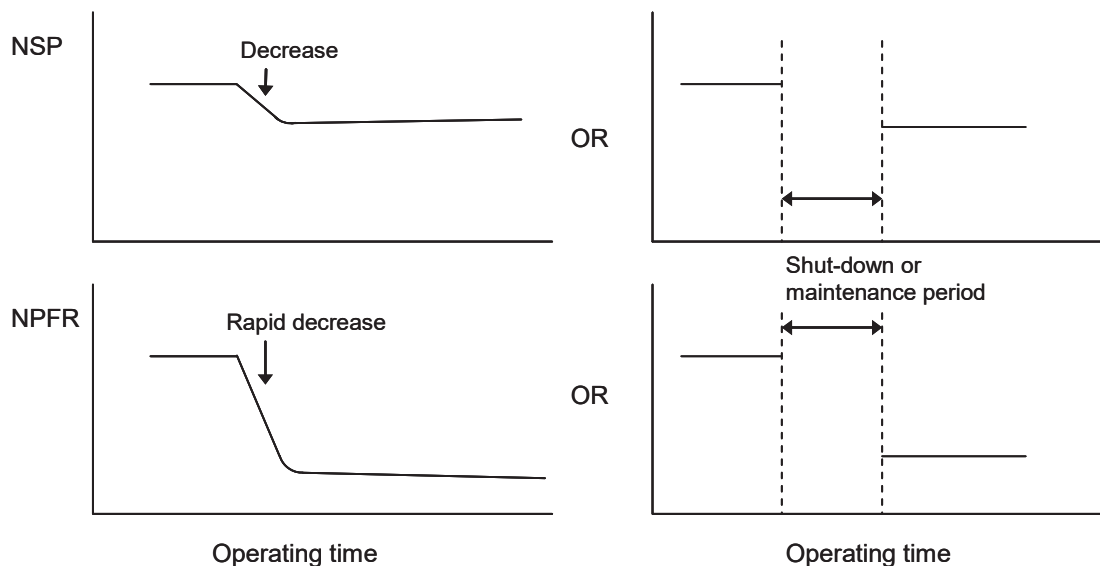
- Membrane affected by exposure to oxidants,
Use of non-compatible chemicals,
System operation outside recommended design values.
- Mechanical damage due to scratch by particles such as precipitation of sparingly soluble salts.

Countermeasures

Check, modify and/or optimize chemicals that come in contact with the membrane elements.
Check oxidant removal apparatus (if any).
Check and adjust operating conditions according to recommendations of the membrane manufacturer.

Check pre-treatment, in particular regarding pH adjustment and / or dosing rate of scale inhibitors.
Adjust system recovery with attention to limits given by feed water chemistry.

Case D: Normalized permeate flow rate (NPFR) decrease - all banks simultaneously



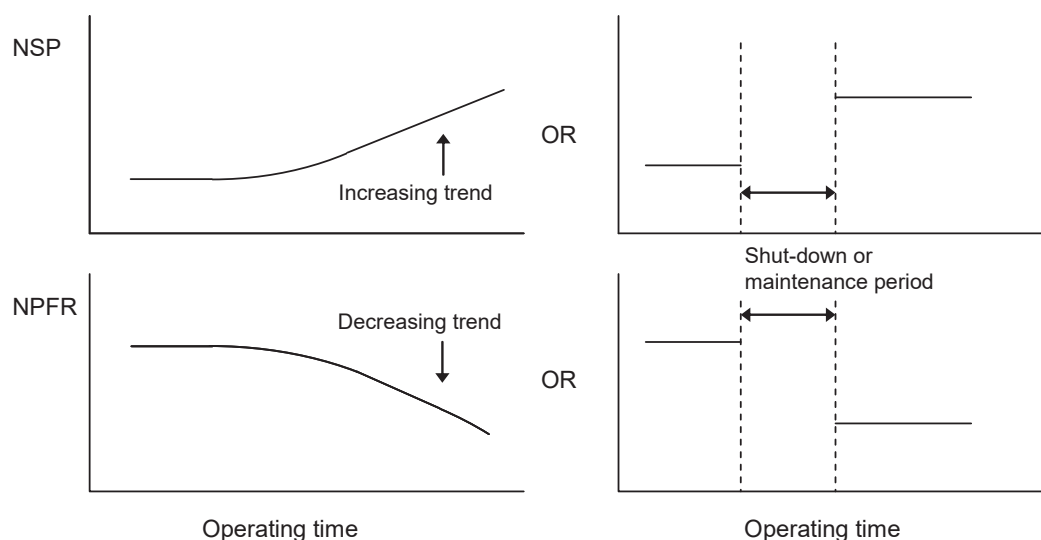
Potential causes

- Initial stages of damage caused by exposure of non-compatible chemicals.

Countermeasures

Check, modify and/or optimize chemicals coming in contact with the membranes. Check to make sure all chemicals are compatible with the installed membrane. Check and adjust operating conditions according to recommendations of the membrane manufacturer.

Case E: Normalized permeate flow rate (NPFR) decrease - all banks simultaneously, with variations for individual brine stages



Potential causes

- Excessive concentration polarization

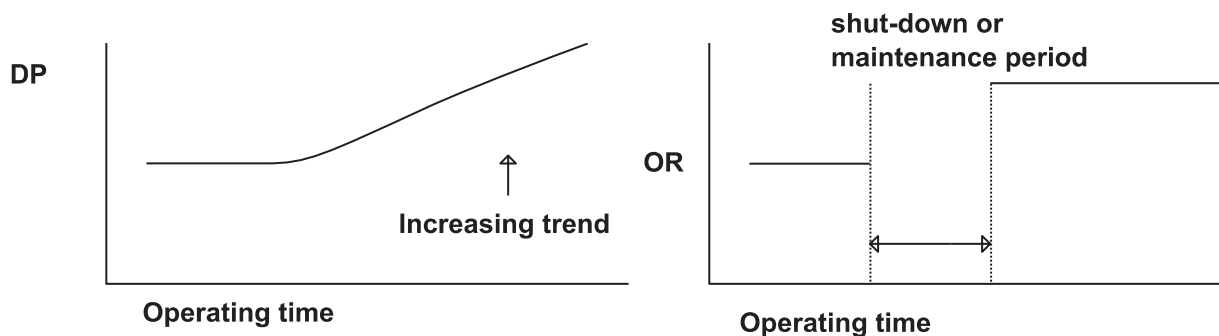
Countermeasures

Check and adjust operating conditions according to recommend guidelines. Make sure the minimum brine flow requirement has been maintained. Check the system's recovery rate to make sure it is within the system design specifications- if needed reduce the recovery.

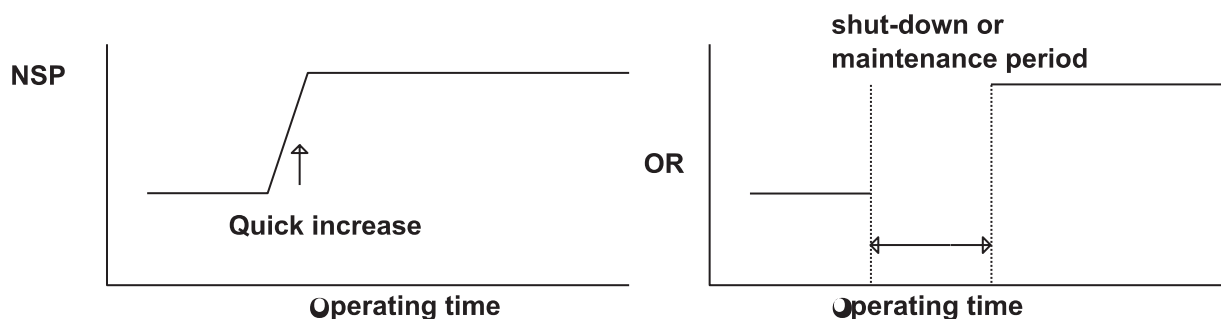
Check pre-treatment chemical dosage and addition.

Check and replace brine seals if necessary.

Case F: Differential pressure (DP) increase



Potential causes	Countermeasures
● Contamination by particulate matter or biogrowth	Refer to Case A and B. Check and improve pre-treatment, in particular for particle removal and carbon feed to system (TOC/DOC ratio)
● Excessive feed flow	Check feed flow rates for compliance with recommendations and latest trends.

Case G: Normalized salt passage (NSP) increase - individual vessels**Potential causes**

- Mechanical leakage due to O-ring seal damage
- Excessive feed flow/pressure drop
- Excessive permeate back pressure

Countermeasures

Detect location of the leak in a particular vessel by probing the pressure vessel in question.
 Make sure permeate back pressure (permeate pressure minus feed/brine pressure) is less than 0.03 MPa [5 psi] at all times especially during start-up and shut down.

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