WATER IS LIFE

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# Operation, Maintenance and Handling Manual for membrane elements

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and check for the latest available version of the Operation and Maintenance Manual.

Version: July 2005

# Contents

# Introduction

Proper operation and maintenance of a Reverse Osmosis (RO) system are key factors in maximizing long-term plant availability and efficiency with minimized fault-related down times.

These key factors must be considered starting from the design phase, and throughout manufacturing, erection and commissioning.

Section RSU-400 (this section) presents checklists and procedures for commissioning, and features useful information concerning operation monitoring methods applicable to all RO/NF systems using TORAY membrane elements.

# Start-up check lists for RO system commissioning

## 1. Checks before commissioning

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

- Cleanliness of system; clean according to RSU-620 where necessary
- Fouling Index ($SDI_{15}$)
- Turbidity (NTU)
- Absence of chlorine and other oxidants
- Sufficient bisulphite surplus (if used for chlorine removal)

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

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

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

Before installing RO elements and pumping pre-treated water to pressure vessels, verify all dust, grease, oil, metal residues etc. have been removed from pipe installation. If necessary, clean and flush piping and pressure vessels before installation of elements. Then Install RO elements. Detailed instructions for installation and pre-commissioning system cleaning, see section RSU-620

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

Feed flow rate per vessel should be in the following range:

8" vessel: 40 – 200 l/min

4" vessel: 10 – 50 l/min

2.5" vessel: 4 – 20 l/min

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“ | 0.4 MPa | 0.15 MPa |
| 4“ | 0.4 MPa | 0.15 MPa |
| **Element types SU, SUL and FR** | **Per vessel** | **Per single element** |
| 8“ | 0.3 MPa | 0.1 MPa |
| 4“ | 0.3 MPa | 0.1 MPa |
| **Element types TR** | **Per vessel** | **Per single element** |
| 4“ | 0.1 MPa | 0.05 MPa |
| 2.5“ | 0.1 MPa | 0.05 MPa |

Installation of more than 2 TR type elements per pressure vessel is not recommended.

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

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

- Permeate flow rate
- Recovery ratio
- Operation pressure

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

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

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

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

Data to be logged in particular:

- Feed: Feed pressure, temperature, TDS (conductivity), pH, fouling index ($SDI_{15}$), turbidity (NTU), chlorine (not detectable*)
- differential pressure across each RO bank
- Brine: Brine flow, TDS (conductivity), pH

- Permeate: Permeate flow of each bank and total system, TDS (conductivity) from each vessel and total system.

*) In case of $NaHSO_3$ dosing for chlorine removal, min. 0.5 mg/l $HSO_3$ must be detectable in brine at any time.

It is recommended to take water samples for analysis of individual ions.

Compare operation results with projected data.

A typical data log sheet is shown in section RSU-430.

## 2. Regular start-up checks in daily operation

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

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

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

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

⚠ At any time, maximum pressure drop across any vessel is 0.1 MPa for all TR, 0.3 MPa for SU/SUL - resp. 0.4 MPa for TM-types. Details according to specification for each type of element.

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

6) Dump permeate until required water quality is obtained.

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

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

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

### 1) Plunger (displacement) pump system with constant speed motor (fig. 410.1)

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

### 2) Centrifugal pump system with constant speed motor (fig. 410.2)

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

In case excessive brine flow is obtained at point 4 (watch $\Delta P$), brine flow control valve $V_B$ must be throttled from step (1).

### 3) Centrifugal pump system with constant speed motor and soft start (fig. 410.3)

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

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

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

### 4) Centrifugal pump system with frequency controlled motor (fig. 410.4)

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

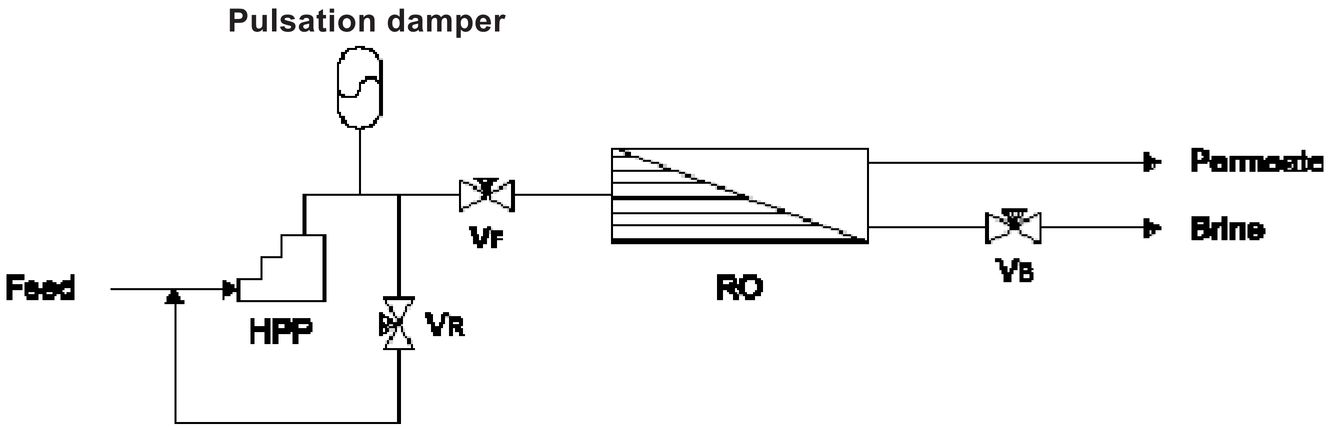


**Fig. 410.1: Plunger (displacement) pumps system with constant speed motor**

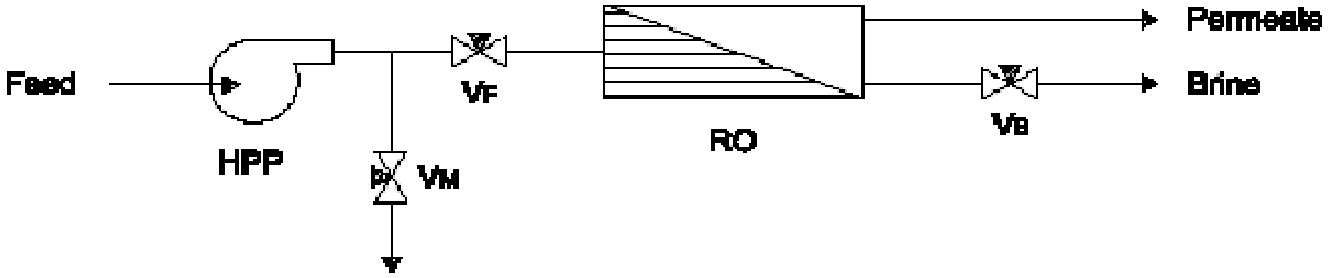


**Fig. 410.2: Centrifugal pump system with constant speed motor**

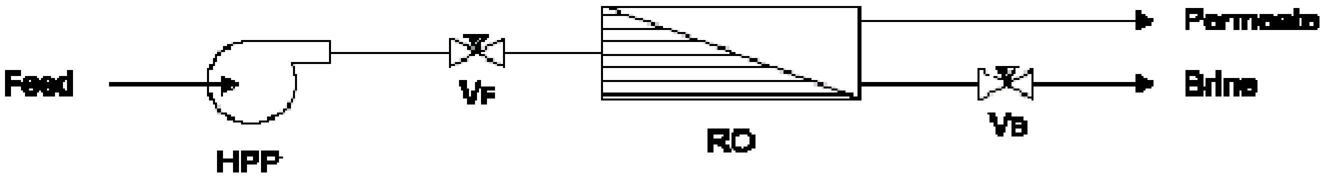


**Fig. 410.3: Centrifugal pump system with constant speed motor and soft start**

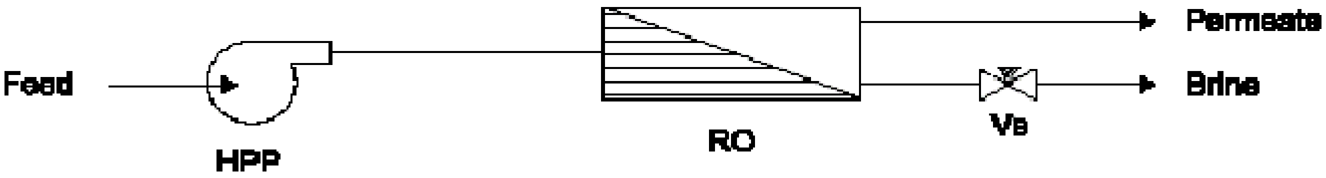


**Fig. 410.4: Centrifugal pump system with frequency controlled motor**

Note: Above fig. 410.1 – 410.4 are for general explanation of high-pressure pump start-up procedures, hence some of the necessary equipment and instruments are not shown.

## Shutdown considerations for RO systems

1. Flush brine at RO system shutdown with product water or feed water of sufficient quality at low pressure to completely displace brine from pressure vessels.

2. Ensure membrane elements are kept wet and properly sterilized and/or frost protected at all times during shut-downs.

3. Ensure guidelines for temperature and pH of the preservation water are observed during shut-downs.

4. Take care that product back pressure never exceeds 0,07 MPa after shutdowns. Product backpressure is defined as product pressure minus feed resp. brine pressure. If RO trains are running in parallel connection to a common permeate header, and with time-shifted running patterns, special attention must be paid. Suitable design elements, such as e.g. check- and relief valves must be installed in permeate lines of individual trains.

## Operation Monitoring Methods for RO System

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

### 1. Monitoring

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

Table B summarizes typical water analysis items for periodical check-up.

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

### 2. Regular Monitoring and Check Points

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

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

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

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

### 3. Logbook

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

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

## 4. Normalization of Permeate Quality

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

a) Measured values at initial operation or

b) (upon commissioning) with projection data.

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

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

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

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

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

(or - somewhat less precisely -)

$$\begin{pmatrix}\text{average feed} \\ \text{water concentration}\end{pmatrix} = \left(\frac{\text{feed water concentration} + \text{brine concentration}}{2}\right) \tag{3‘}$$

where

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

and

$$\text{concentration} = \text{TDS or conductivity}^{*2} \qquad (5)$$

[*1] Recovery results as decimal value

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

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

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

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

where

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

## 5. Normalization of Permeate Flow Rate

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

$$NPFR = \frac{NDP_S}{NDP_D} \times TCF \times QP_D \qquad (7)$$

where

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

and

**NPFR** = Normalized permeate flow rate

**NDP** = net driving pressure

**$NDP_S$** = net driving pressure at standard or design conditions

**$NDP_D$** = actual net driving pressure

**$QP_D$** = current permeate flow rate

**$ØP_{osm}$** = Average osmotic pressure

feed water osmotic pressure corresponding to average feed water concentration from eq. (3) or (3’).

**TCF** = Temperature correction factor (characteristic of membrane type used in the system)

This adjusts the current permeate flow rate to the value at 25 °C.

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

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

where

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

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

## 6. Variations of operation data from nominal value

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

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

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

(A) = data read by varying persons

(B) = Single operator precision

## 7. Precautions and useful information for monitoring operating data

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

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

1) Guidelines for maintenance (considerations for cleaning) are described in RSU-530

2) Troubleshooting guides are described in RSU-700 section

3) Typical signs of system performance change are shown in section RSU-720

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

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

## 8. RO System Operation Parameters and Check Points

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

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

*) $HSO_3$ surplus in brine if raw water is chlorinated

**Notes:**

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

(2) In case of significant fluctuations

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

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

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

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

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

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

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

## Notes:

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

(2) In case of sgnificant fluctuations

(3) In case of high fluctuations or acid dosing

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

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

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

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

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

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

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

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

**Notes:**

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

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

### Table B: Typical Water Analysis Items

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

**Note:**

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

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

## Table C: RO System Maintenance Items Recorded

| Items | Frequency & Procedure |
|---|---|
| **1. Instruments** | |
| (1) pressure sensors & indicators<br>(2) System control devices<br>(3) Safety shut-down facilities | Regular calibration and maintenance should be performed according to the maintenance manual supplied by engineering of system manufacturer. |
| **2. Cartridge Filter Change** | |
| ***Use only pre-washed filter catridges free of sufcactants and textile aides*** | Record date changed, differential pressure of old and new (clean) cartridges, and pore size, material and working of filter catridges used. |
| **3. RO system cleaning** | |
| As a minimum, record the following:<br>(1) Type of cleaning solution and its concentration<br>(2) Conditions during cleaning (pressure, temperature, flows, pH, conductivity) | Perform according to maintenance manual supplied by system manufacturer.<br>TORAY guidelines and instructions are given in RSU-530 |
| **4. Membrane Treatment upon shutdown** | |
| Record preservation method, concentration of conservation solutions, operating conditions before shut down and duration of shut-down/conservation. | Perform according to system manufacturer's operating manual.<br>TORAY guidelines & instructions are given in RSU-510 |

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

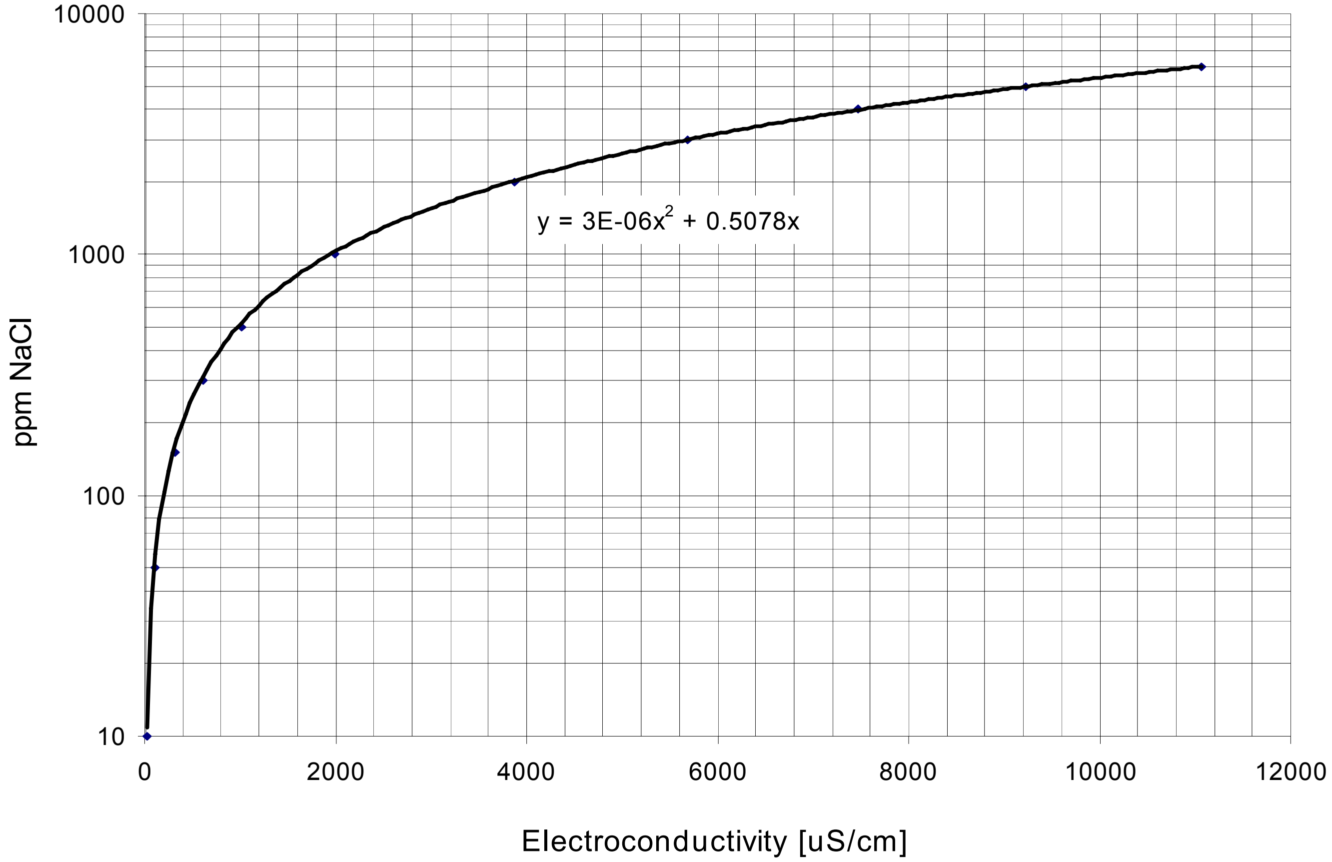


Fig. 430.1: Conductivity / NaCl concentration conversion factors at 25 °C

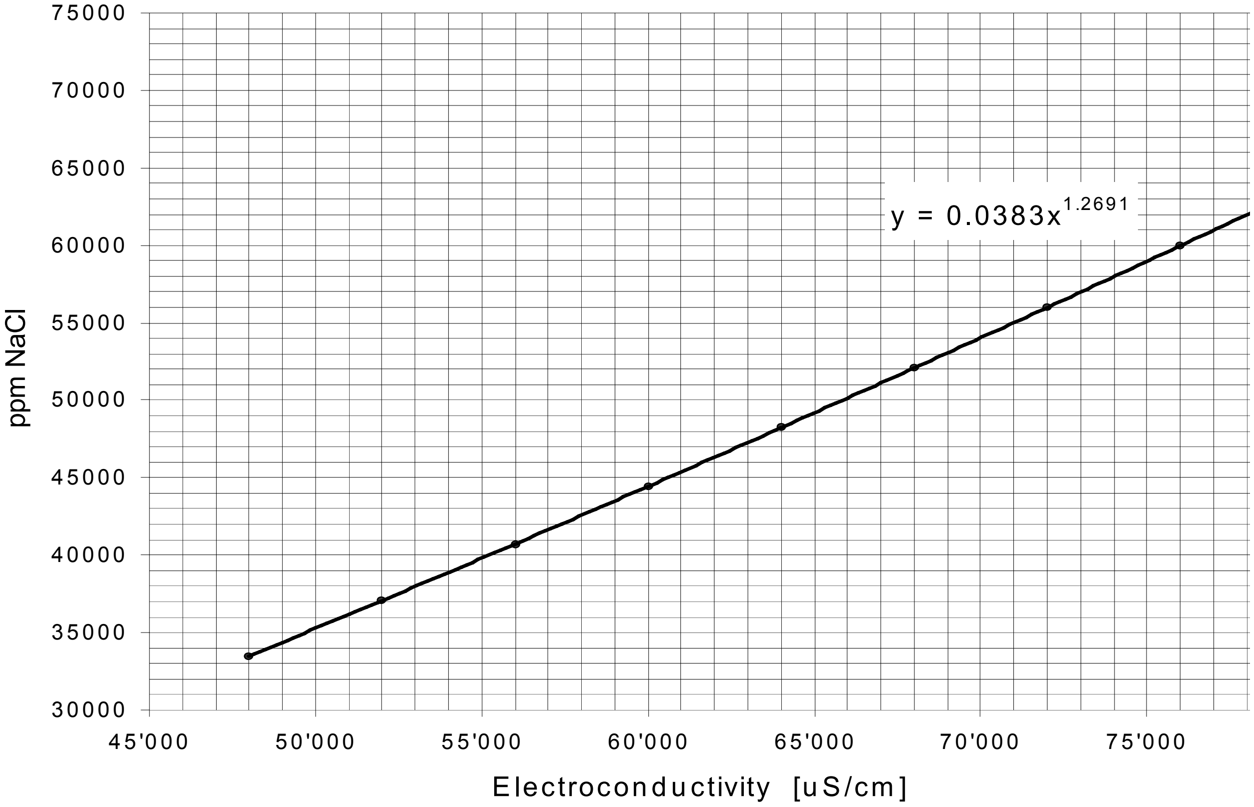


Fig. 430.2: Conductivity / NaCl concentration conversion factors at 25 °C

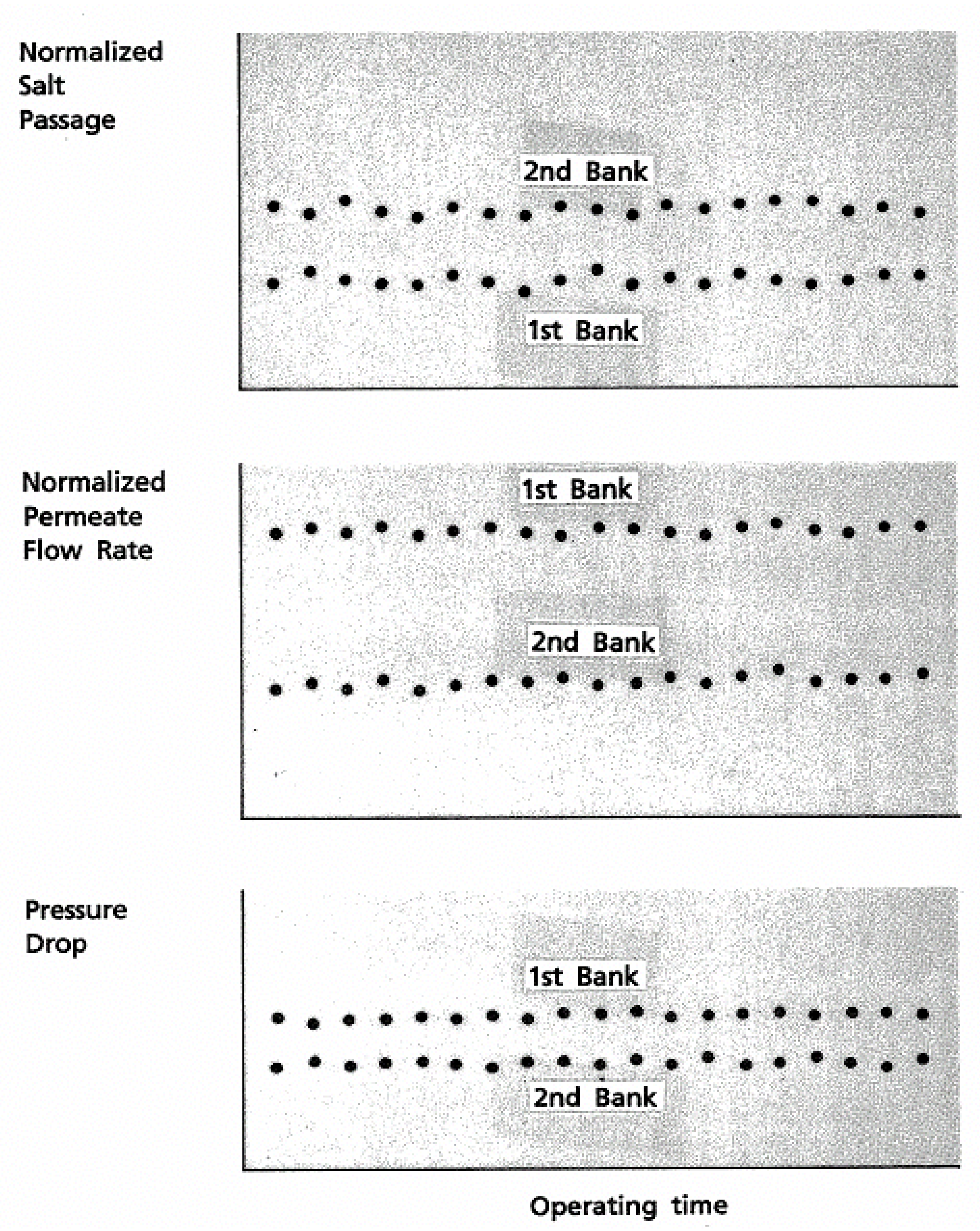


**Fig. 430.3: Typical monitoring chart for RO system**

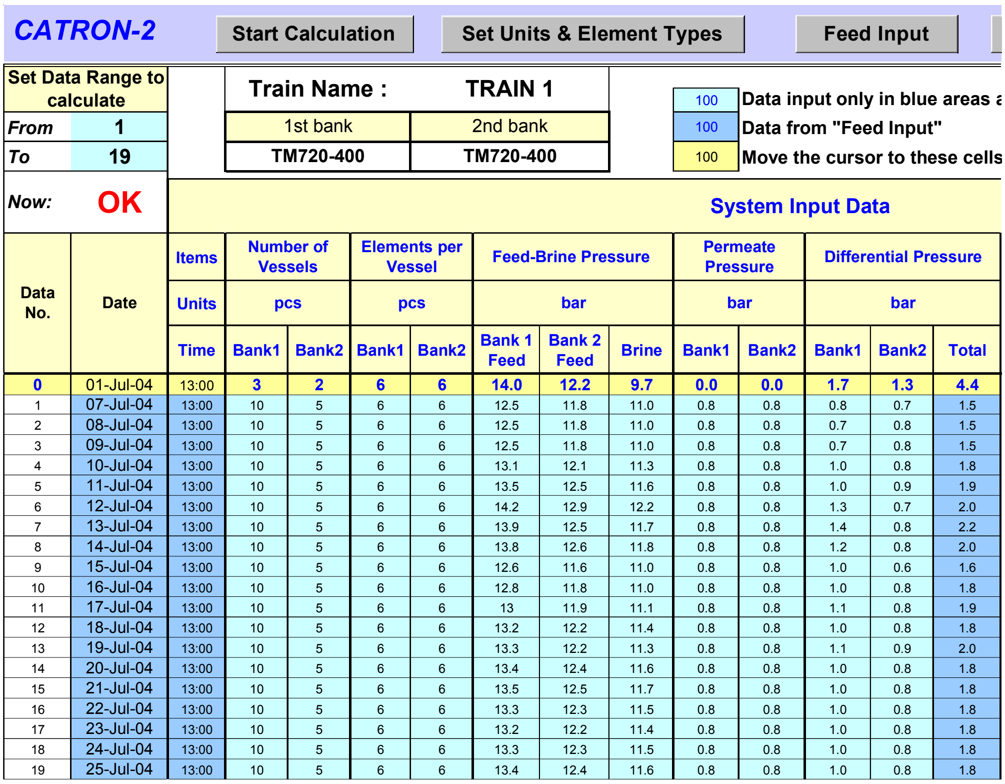
**Note:**

Daily monitoring is recommended. Watch out for performance change trends.

In this example, no performance change is observed.

## 9. Normalization program CATRON

In order to enable easy normalization, TORAY developed a special software named CATRON for his customers, see fig. 430.4 and fig. 430.5. CATRON is available under www.toraywater.com.



**Set Data Range to calculate**
*From* 1
*To* 19

**Train Name : TRAIN 1**

| 1st bank | 2nd bank |
|---|---|
| TM720-400 | TM720-400 |

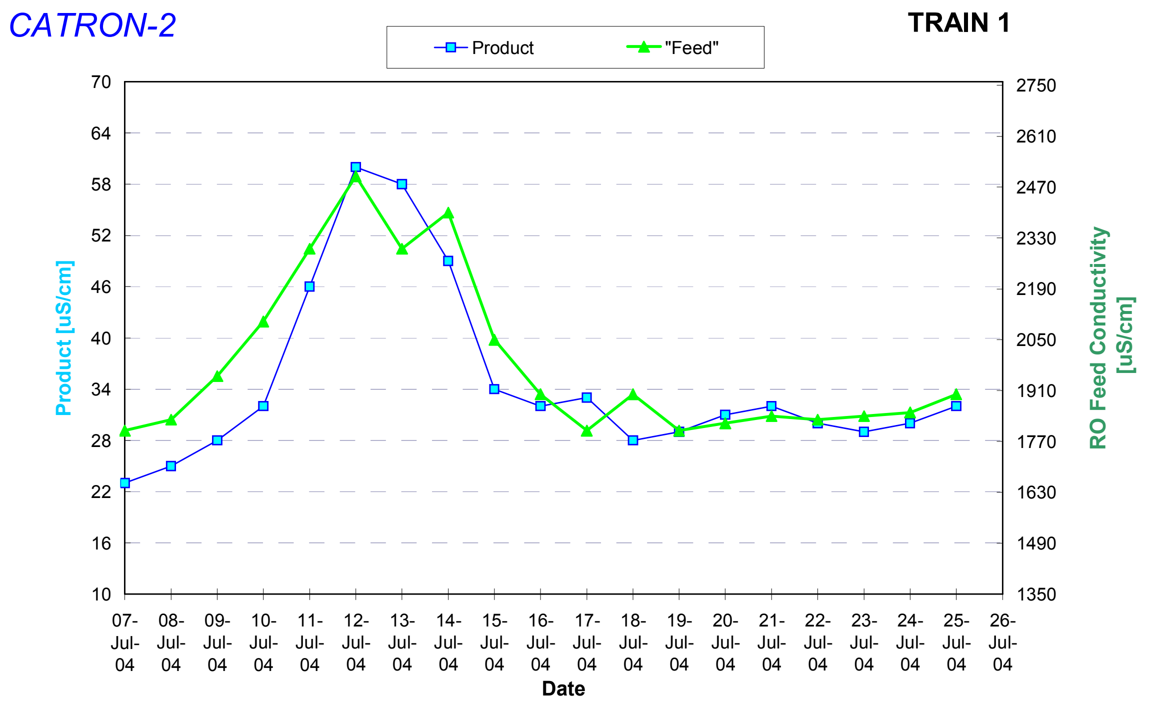
100 Data input only in blue areas a
100 Data from "Feed Input"
100 Move the cursor to these cells

*Now:* **OK**

**System Input Data**

| Data No. | Date | Items | Number of Vessels | | Elements per Vessel | | Feed-Brine Pressure | | | Permeate Pressure | | Differential Pressure | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Units | pcs | | pcs | | bar | | | bar | | bar | | |
| | | Time | Bank1 | Bank2 | Bank1 | Bank2 | Bank 1 Feed | Bank 2 Feed | Brine | Bank1 | Bank2 | Bank1 | Bank2 | Total |
| 0 | 01-Jul-04 | 13:00 | 3 | 2 | 6 | 6 | 14.0 | 12.2 | 9.7 | 0.0 | 0.0 | 1.7 | 1.3 | 4.4 |
| 1 | 07-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 12.5 | 11.8 | 11.0 | 0.8 | 0.8 | 0.8 | 0.7 | 1.5 |
| 2 | 08-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 12.5 | 11.8 | 11.0 | 0.8 | 0.8 | 0.7 | 0.8 | 1.5 |
| 3 | 09-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 12.5 | 11.8 | 11.0 | 0.8 | 0.8 | 0.7 | 0.8 | 1.5 |
| 4 | 10-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 13.1 | 12.1 | 11.3 | 0.8 | 0.8 | 1.0 | 0.8 | 1.8 |
| 5 | 11-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 13.5 | 12.5 | 11.6 | 0.8 | 0.8 | 1.0 | 0.9 | 1.9 |
| 6 | 12-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 14.2 | 12.9 | 12.2 | 0.8 | 0.8 | 1.3 | 0.7 | 2.0 |
| 7 | 13-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 13.9 | 12.5 | 11.7 | 0.8 | 0.8 | 1.4 | 0.8 | 2.2 |
| 8 | 14-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 13.8 | 12.6 | 11.8 | 0.8 | 0.8 | 1.2 | 0.8 | 2.0 |
| 9 | 15-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 12.6 | 11.6 | 11.0 | 0.8 | 0.8 | 1.0 | 0.6 | 1.6 |
| 10 | 16-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 12.8 | 11.8 | 11.0 | 0.8 | 0.8 | 1.0 | 0.8 | 1.8 |
| 11 | 17-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 13 | 11.9 | 11.1 | 0.8 | 0.8 | 1.1 | 0.8 | 1.9 |
| 12 | 18-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 13.2 | 12.2 | 11.4 | 0.8 | 0.8 | 1.0 | 0.8 | 1.8 |
| 13 | 19-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 13.3 | 12.2 | 11.3 | 0.8 | 0.8 | 1.1 | 0.9 | 2.0 |
| 14 | 20-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 13.4 | 12.4 | 11.6 | 0.8 | 0.8 | 1.0 | 0.8 | 1.8 |
| 15 | 21-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 13.5 | 12.5 | 11.7 | 0.8 | 0.8 | 1.0 | 0.8 | 1.8 |
| 16 | 22-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 13.3 | 12.3 | 11.5 | 0.8 | 0.8 | 1.0 | 0.8 | 1.8 |
| 17 | 23-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 13.2 | 12.2 | 11.4 | 0.8 | 0.8 | 1.0 | 0.8 | 1.8 |
| 18 | 24-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 13.3 | 12.3 | 11.5 | 0.8 | 0.8 | 1.0 | 0.8 | 1.8 |
| 19 | 25-Jul-04 | 13:00 | 10 | 5 | 6 | 6 | 13.4 | 12.4 | 11.6 | 0.8 | 0.8 | 1.0 | 0.8 | 1.8 |

**Fig. 430.4: Normalization program CATRON**



Product Conductivity and RO Feed Conductivity vs. Time

**Fig. 430.5: Example**

# Preservation procedures for RO elements during system shut-down periods

Store elements under clean conditions to maintain performance and to prevent bacteria growth.

Considerations for preservation:

1) After shut-down, displace brine with treated RO feed water, softened water or permeate.

   If potential for scaling and fouling necessitates, membranes must be flushed according to RSU-531 with treated RO feed water, softened water or permeate.

2) To maintain performance, elements must be wet at all times.

3) To prevent propagation of bacteria in the pressure vessel, sterilization in accordance with TORAY recommendations, see RSU-545, is recommended.

4) If elements are contaminated and extended shutdown is scheduled, perform chemical cleaning prior to conservation. This removes foulant from membranes and minimizes bacterial growth, see RSU-520, RSU-530 and RSU-532.

5) Allowable temperature and pH range of preservation water in the pressure vessel will be:

   Temperature Range : 5° – 35°C

   pH Range : 3 – 7.

6) Make-up water for preservation solution must be free from residual chlorine or other oxidizing agents. For preservation, use sodium bisulfite solution, see RSU-540.

## 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 is designed to avoid contamination of membrane surface as much as possible. Best operating conditions (permeate flow rate, pressure, recovery and pH-value) will contribute considerably to less fouling of membranes. In case of high $SDI_{15}$ value of pre-treated feed water (even in allowable range), membrane fouling can cause performance decline in long-term operation. It 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 pressure drop between feed and brine.

Fig. 520.1 illustrates the flux decrease against expected performance. Since the membrane will usually remain intact, repeated (periodical) flushing or cleaning can largely restore performance. In most cases, foulant removal will bring temporary relief, as illustrated by the „saw tooth“ pattern in Fig. 520.1.

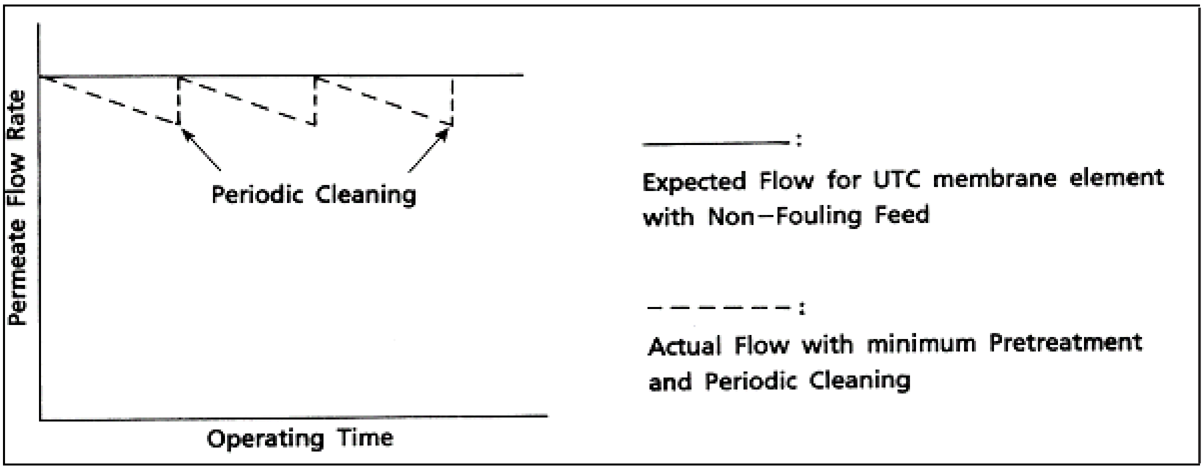


**Fig. 520.1: Effect of fouling on permeate flow rate**

# Guidelines for RO cleaning

## 1. 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 membrane surfaces and to re-establish full performance.

Commence cleaning when feed-brine differential pressure of any bank reaches 150 % of initial value, or normalized permeate flow rate decreases by more than 10 %, or normalized permeate quality decreases by more than 20 %.

## 2. Determination of foulants

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 for $SDI_{15}$ value determination.

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 will direct investigation to consider iron fouling. White or beige 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.

## 3. Selection of cleaning procedure

Once contamination of the membrane surface has been identified, the correct cleaning procedure must be selected. If foulants are believed to be metal hydroxides, such as ferric hydroxide, or calcium scale, P3-Aquaclean ACS or citric acid cleaning procedure is recommended, (see RSU-532, RSU-533 and RSU-534). In case the primary problem is believed to be organic or biological fouling, a cleaning procedure with detergents is recommended, (see RSU-532, RSU-535, RSU-536 and RSU-537).

## 4. Evaluation of the effectiveness of cleaning

Descriptions of various cleaning procedures are given in RSU-532. Observing recommended cleaning procedures will usually yield good results. 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 recommended cleaning procedure may lead to a better result. Foulants will frequently adhere to membrane surface or remain in spacer material. Final removal takes several successive cleaning procedures in many cases. Alternating chemical cleanings with detergent and citric acid (alkaline – acid) are frequently more effective than either alone.

## Flushing procedures without chemicals

The plainest dirt removal procedure is flushing. Flushing cleans the membrane surface by high flow velocity using a large quantity of feedwater at low pressure. It is effective for cleaning of light organic fouling, provided it is applied before significant performance decline has been observed. Best, perform flushing several hours after shut-down of the RO system, in order to utilize the soaking effect for separation of foulant layers from the membrane‘s surface.

General operating conditions for flushing are as follows:

| | | |
|---|---|---|
| Flushing water: | Pre-treated feed water | |
| Pressure: | Low pressure (0.1 – 0.2 MPa) | |
| Water flow rate: | High flow rate is preferable. Limit pressure drop to max 0.2 MPa per vessel. | |
| Maximum feed flow rate per vessel is as follows: | 8.0 inch element:<br>4.0 inch element: | 200 l/min<br>50 l/min |
| Temperature: | < 35°C | |
| Period: | 0.5 - 1.0 hour | |

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

# Instructions for chemical cleaning

## 1. General guidelines

Chemical cleaning is used to remove contaminations from membrane surfaces by dissolving and/or separating through physical and chemical interaction with cleaning chemicals.

It is usually applied after flushing. It is good practice to perform chemical cleaning as periodical and preventive maintenance or before extended shutdown of the system.

After chemical cleaning, use pre-treated raw water or permeate to completely flush resulting dissolved or suspended solids out of the RO system .

| | |
|---|---|
| Chemical cleaning agents: | As listed in Table 1 |
| Make-up water: | Softened water or permeate, free of heavy metals, residual chlorine or other oxidizing agents. |
| Required quantity of | 40 – 80 liters per 8 - inch element (depending upon fouling) |
| cleaning solution | 10 – 20 liters per 4 - inch element (depending upon fouling) |
| Cleaning operation pressure: | Low pressure (0.1 – 0.2 MPa) |
| Min. feed flow rate: | 50 l/min for each 8 - inch vessel |
| | 10 l/min for each 4 - inch vessel |
| Temperature: | as high as possible; however max. 45 °C.<br>In case temperature of cleaning solution exceeds 45 °C due to heat build-up (liquid friction) from circulating pump, consider installation of a cooling facility. |
| Type of cleaning | Alternation of recirculation and soaking, each bank separately |
| Circulating period: | 0.5 - 1 hour (repeat 2 - 3 times) is recommended |
| Soaking period: | 2 - 24 hours incl. circulation time (depends on type of fouling) |
| Method of cleaning: | Circulating and soaking in each bank |
| Final flushing period: | Min. 1 – 2 hours, depending upon application |

| Contamination | Chemical Reagent | Cleaning Conditions | Ref. |
|---|---|---|---|
| Calcium scale<br>Metal hydroxides<br>Inorganic colloids | P3-Aquaclean ACS 1% | pH value 2 - 3 | RSU-534 |
| | Citric acid 1 – 2 % | pH value: 2 – 4<br>adjust with ammonia ($NH_3$) | RSU-533 |
| Organic matter, bacterial matter *1) | P3-Aquaclean ACS 1 % | pH value 2 - 3 | RSU-534 |
| | P3-Aquaclean LAC 1 % | pH value 11<br>adjust with hydrochloric acid | RSU-535 |
| | P3-Aquaclean ENZ 0.5 %<br>+<br>P3-Aquaclean LAC | pH 11<br>adjusted with<br>P3-Aquaclean LAC *2) | RSU-536 |
| | Dodecyl Sodium Sulfate (DSS, Sodium Lauryl Sulfate), or<br>Polyoxyethylene Sodium Lauryl Sulfate (TSP), all 0.1 – 0.5 % | pH value : 7 – 11, adjust with<br>sodium hydroxide, or<br>sodium tripolyphosphate<br>or trisodium phosphate | RSU-537 |
| Acid insoluble scaling<br>CaF; $BaSO_4$; $SrSO_4$;$CaSO_4$ | P3-Aquaclean SAL 0,5 % | pH 11 | RSU-538 |
| | P3-Aquaclean BUF 2.5 %<br>+<br>P3-Aquaclean SAL | pH value 11<br>adjusted with<br>P3-Aquaclean SAL *3) | RSU-539 |
| | SHMP 1 %<br>Sodium hexametaphosphate | pH value 2;<br>adjust with hydrochloric acid | RSU-540 |
| Silica scaling ($SiO_2$) | P3-Aquaclean SAL 0,5 % | pH 11 | RSU-538 |
| | P3-Aquaclean BUF 2.5 %<br>+<br>P3-Aquaclean SAL | pH 11<br>adjusted with<br>P3-Aquaclean SAL *3) | RSU-539 |

**Table 1: Chemical Cleaning Reagents**

*1) Combining sterilization and detergent cleaning is effective for bacterial contamination. First, perform sterilization, and then detergent cleaning, (see RSU-545 for sterilization/preservation)

*2) Combination of enzymatic (P3-Aquaclean ENZ) and P3 Aquaclean LAC at high pH is effective for removal of large amounts of organic residues and biological contamination. If system performance decreased due to heavy organic or inorganic fouling or oil contamination, cleaning efficiency and consequently system performance can be increased using a combination of P3-Aquaclean LST and P3-Aquaclean LAC as cleaning booster. Consult TORAY for detailed cleaning instructions.

*3) Combination of complexing agent P3-Aquaclean SAL with high pH cleaner P3-Aquaclean BUF is effective to remove acid insoluble scaling and $SiO_2$ scaling. It is recommended to start with an acid cleaning to remove any other (combined) acid soluble fouling materials (such as e.g. $CaCO_3$). 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.

## 2. Dimensioning a cleaning system

For a typical flow diagram of a cleaning system, see fig. 532.1.

Required useful volume of the cleanig tank can be calculated as following:

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

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

A = Quantity of cleaning solution per element, times number of elements.

40 - 60 l for each 8“ element, 10 - 15 l for each 4“ element, according to degree of fouling:
1 = slightly fouled 10/40 l, 2 = medium fouled 12/50 l, 3 = heavily fouled 15/60 l.

B = System volume (cleaning system piping, volume of pressure vessels and pipe headers

C = Volume of water in elements subject to simultaneous cleaning. (10 l for 8“, 2,5 l for 4“)

Flow for cleaning (= discharge of pump) should be approx. 6 m³/h/8“ vessel and 1.5 m³/h/4“ vessel.

Pump head is calculated from:

- max. differential pressure across RO elements (= approx. 0,2 MPa)
- pressure loss of piping system and pressure vessel connections
- max. differential pressure across cleaning cartridge filter (approx. 0,2 MPa)

## Examples:

| **Item** | **Unit** | **Case a)** | **Case b)** | **Case c)** | **Case d)** |
|---|---|---|---|---|---|
| Element size | inch | 8 | 8 | 8 | 4 |
| Cleaning bank | pc.vessels | 30 | 10 | 6 | 3 |
| Cleaning flow | m³/h | 180 | 60 | 36 | 4.5 |
| Elements in each vessel | pcs. | 6 | 6 | 4 | 3 |
| Total elements | pcs. | 180 | 60 | 24 | 9 |
| Degree of contamination | ° | 1 | 2 | 3 | 3 |
| Solution per element | liter | 40 | 50 | 60 | 15 |
| Cleaning volume A | liter | **7200** | **3000** | **1440** | **135** |
| ND of cleaning pipe | mm | 150 | 100 | 65 | 25 |
| Length of cleaning pipe | m | 13 | 100 | 60 | 20 |
| ND of header | mm | 200 | 200 | 100 | 20 |
| Length of header | m | 10 | 0 | 4 | 3 |
| Volume of pipeworks B | liter | **2611** | **785** | **231** | **11** |
| Water volume each element | liter | 10 | 10 | 10 | 2.5 |
| Total water volume elements C | liter | **1800** | **600** | **240** | **22.5** |
| Useful volume of cleaning tank required: $V_n$ | liter | **2789** | **1615** | **969** | **102** |

**Table 2: Dimensioning a cleaning system**

**Important notes**

- Provide a separate return line for permeate. During the entire cleaning period, permeate must be returned to cleaning tank without back pressure.
- Design of cleaning tank must allow for complete draining.
- End piece of cleaning- and permeate return line should be submerged in cleaning solution inside the cleaning tank to avoid foam formation.
- Spent cleaning solutions must be neutralized before discharge. Consider local regulations for chemicals discharge.

⚠ **When working with chemicals, follow safety regulations. Wear eye protection, suitable gloves and rubber apron!**

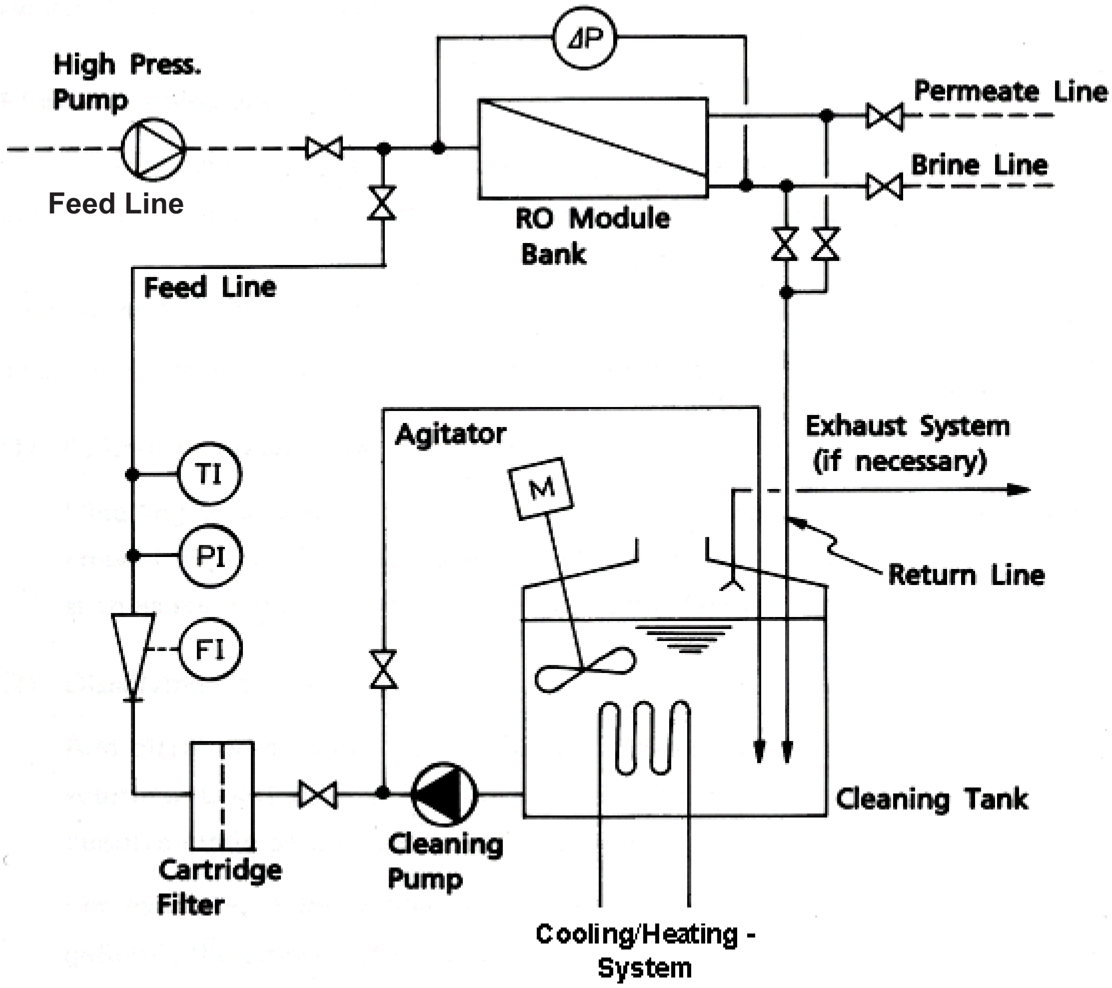


Fig. 532.1: Typical flow diagram of a cleaning system

| | |
|---|---|
| ——— | Cleaning line |
| - - - - - - | Offline during cleaning |
| FI | Feed flow rate indicator |
| PI | Pressure indicator |
| TI | Temperature indicator |
| ΔP | Differential pressure indicator for each bank |

**Note:**

Clean each bank separately.

# Citric acid cleaning procedure

## 1. Flushing of elements

Prior to cleaning with citric acid solution, it is advisable (although not conditional) to flush elements with softened water or permeate (see RSU-531).

## 2. Preparation of a 2 % citric acid solution

1) Fill cleaning tank with water

Cleaning tank is filled with permeate or tap water, free of oxidising agents. The amount of cleaning water is determined by size of RO system and degree of fouling, (see RSU-532).

2) Dissolve citric acid

Add citric acid (white powder), by and by, to the cleaning water to obtain a 2 % (by weight) - solution. Continuous agitation of the solution will be needed to dissolve citric acid quickly and completely. Break any large chunks prior to filling in, to avoid damage of agitator or pump.

For example: To prepare 1’000 l of solution 20 kg of citric acid are used.

3) pH adjustment with ammonia ($NH_3$) or sodium hydroxide (NaOH) to specified value (see RSU-532)

pH of the solution should be adjusted with ammonium hydroxide during agitation. Use exhaust system if necessary to draw off released ammonia gas. Use of a barrel pump or manual chemical pump helps to minimize release of ammonia gas.

The amount of ammonium hydroxide ($NH_4OH$), 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 $NH_4OH$ (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 x 20.4) / 0.3.

## 3. Circulation of cleaning solution

Circulate cleaning solution at low pressure; approx. 0.1 MPa. Higher temperature is favorable in order to obtain better results.

**Note**: 35 °C may not be exceeded. A longer period of circulation is preferable for cleaning, but may be limited by increasing temperature, (refer to RSU-532)

Soaking of elements in the cleaning solution is effective to dissolve the metal foulants. Repeated soaking, alternating with circulation, is recommended.

If quantity of citric acid in the cleaning solution containing iron citrate is sufficient, color will be greenish - yellow. Colour change of solution towards dark yellow or red - brown will indicate that all citric acid has been bound to metal ions. In this case, cleaning solution should be drained. Prepare a fresh batch to continue and complete cleaning procedure.

## 4. Flush elements

Discard all spent cleaning solution. The cleaning tank is completely emptied. Flush out and completely displace any residual cleaning solution from modules, pressure vessels and pipe system with feed water or permeate. This is easiest done by filling water into the cleaning tank and directing the return line to drain, directly before tank, (see RSU-531).

## 5. General description of citric acid

| | |
|---|---|
| Appearance: | white crystalline powder, without chunks |
| pH: | ~ 1.7 (100 g/l water, 20 °C) |
| Density: | 1’665 g/cm$^3$ (18 °C) |
| CAS Number: | 77-92-9 |
| Main component: | $(HOOCCH_2)_2C(OH)COOH$ |
| Safety precautions: | low hazard potential, irritant |

# P3-Aquaclean ACS cleaning procedure

## 1. Flushing of elements

Prior to cleaning with acidic P3-aquaclean ACS solution, it is advisable (although not conditional) to flush elements with softened water or permeate, (see RSU-531).

## 2. Preparation of a 1 % P3-Aquaclean ACS solution

1) Fill cleaning tank with water

Cleaning tank is filled with permeate or tap water, free of oxidizing agents. The amount of cleaning water is determined by size of RO system and degree of fouling, (see RSU-532).

2) Dissolve P3-Aquaclean ACS

Add P3-Aquaclean ACS (yellow - brownish liquid) to cleaning water to obtain a 1 % (by weight) - solution. Continuous agitation of solution will be needed to evenly dissolve P3-Aquaclean ACS. Stir and mix slowly to avoid foam formation.

For example: To prepare1’000 l of the solution 10 kg of P3-Aquaclean ACS are used.

3) Monitor pH value

The pH of the detergent solution should be in the range of 2 – 2.5. When pH is < 2, pH adjustment is required using sodium hydroxide (NaOH). Estimated pH of a 1 % P3 aquaclean ACS solution is 2.3 – 2.9.

## 3. Circulate cleaning solution

When starting circulation of the cleaning solution, discard the first 10 - 15 % of returned liquid directly before cleaning tank inlet. This part will hold high concentrations of contaminants and should not be re-used.

Low feed water pressure should be applied during circulating period. Higher temperature is preferable for better cleaning efficiency.

**Note**: 35 °C may not be exceeded. A longer period of circulation is preferable for cleaning, but may be limited by increasing temperature (refer to RSU-532).

To minimize foam formation, design return line and permeate return line such that endpiece is below surface of cleaning solution inside tank.

Soaking of the elements in cleaning solution is effective to dissolve metal foulants. Repeated and alternating soaking and recirculation of cleaning solution is recommended.

If pH value during circulation exceeds pH 3, add more P3-Aquaclean ACS until pH value is < 2.5. If pH value quickly increases > pH 3.5, discard cleaning solution, prepare fresh solution and repeat cleaning procedure to reach best cleaning efficiency.

## 4. Flush elements

Discard all spent cleaning solution. The cleaning tank is completely emptied. Flush out and completely displace the residual cleaning solution from modules, pressure vessels and pipe system using feed water or permeate. This is easiest done by filling cleaning tank with water and directing the return line to drain, directly before tank, (see RSU-531).

## 5. General description of P3-Aquaclean ACS

| | |
|---|---|
| Appearance : | clear, yellow liquid |
| pH : | 2.3 – 2.9 as 1 % solution w/w |
| Density : | 1.0 – 1.1 $g/cm^3$ (20 °C) |
| Charge in solution : | Anionic |
| Main components : | Organic acids & anionic surfactant |
| Safety precautions: | Consult the P3-Aquaclean ACS safety and product data sheet |

# P3-Aquaclean LAC Cleaning Procedure

## 1. Flushing of elements

Prior to cleaning with caustic P3-aquaclean LAC solution, it is advisable (although not conditional) to flush elements with softened water or permeate (see RSU-531).

## 2. Preparation of a 1 % P3-Aquaclean LAC solution

1) Fill cleaning tank with water

Cleaning tank is filled with permeate or tap water, free of oxidizing agents. The amount of cleaning water is determined by size of RO system and degree of fouling, (see RSU-532).

2) Dissolve P3-Aquaclean LAC

Add P3-Aquaclean LAC (yellow - brownish liquid) to cleaning water to obtain a 1 % (by weight) - solution. Continuous ,slow agitation of the solution by a mixer will be needed to evenly dissolve P3-Aquaclean LAC. Avoid foam formation by mixing at low stirrer rpm.

For example: To prepare1’000 l of the solution 10 kg of P3-Aquaclean LAC are used.

3) Monitor pH value

The pH of the detergent solution should be < 11. pH adjustment is required using hydrochloric acid (HCl) to reach pH value < 11. The expected pH of 1 % P3 Aquaclean LAC solution is 11.2 – 11.6.

## 3. Circulate cleaning solution

When starting circulation of the cleaning solution, discard the first 10 - 15 % of returned liquid (directly before cleaning tank inlet), since this part will hold high concentrations of contaminants and should not be re-used.

Low feed water pressure should be applied during circulating period. Higher temperature is preferable for better cleaning efficiency.

**Note**: 35 °C may not be exceeded. A longer period of circulation is preferable for cleaning, but may be limited by increasing temperature, (refer to RSU-532).

To avoid foam formation, design return lines such that endpiece is below surface of cleaning solution inside tank.

Soaking of the elements in cleaning solution is effective to dissolve metal foulants. Repeated and alternating soaking and recirculation of cleaning solution is recommended.

If pH value during circulation drops below pH 9, add more P3-Aquaclean LAC until pH value is close to 11. If pH value rapidly drops below pH 9, discard cleaning solution, prepare fresh solution and repeat cleaning procedure to reach best cleaning efficiency.

## 4. Flush elements

After cleaning, discard all spent cleaning solution. The cleaning tank is completely emptied. Flush out and completely displace any residual cleaning solution from modules, pressure vessels and pipe system using pre-treated feed water or permeate. This is easiest done by filling cleaning tank with water and directing the return line to drain, directly before tank, (see RSU-531).

## 5. General Description of P3-Aquaclean LAC

| | |
|---|---|
| Appearance: | clear, yellow – brownish liquid |
| pH: | 11.2 – 11.6 as 1 % solution w/w |
| Density: | 1.1 – 1.25 g/cm$^3$ (20 °C) |
| Charge in solution: | Anionic |
| Main components: | Dispersants, inorganic and organic complexation agents, anionic & non-ionic surfactants |
| Safety precautions: | Consult the P3-Aquaclean LAC safety and product data sheet |

# P3-Aquaclean ENZ Cleaning Procedure

## 1. Flushing of elements

Prior to cleaning with P3-aquaclean ENZ solution, it is advisable (especially with hard raw water) to flush elements using softened water or permeate, (see RSU-531).

## 2. Preparation of a 0.5 % P3-Aquaclean ENZ solution

1) Fill cleaning tank with water

Cleaning tank is filled with permeate or tap water, free of residual chlorine. The amount of cleaning water is determined by the volume of the RO system (number of modules, module volume, pipe lines and cleaning tank) and the level of fouling, (see RSU-532).

2) Dissolve P3-Aquaclean ENZ

Add P3-Aquaclean ENZ (yellow - brownish liquid) to cleaning water to obtain a 0.5 % (by weight) - solution. Continuous agitation of the solution by a mixer will be needed to evenly dissolve P3-Aquaclean ENZ. As P3-Aquaclean ENZ is a foaming product, we recommend slow mixing of the cleaning solution.

For example: To prepare1’000 l of the solution 5 kg of P3-Aquaclean ENZ are used.

3) Monitor pH value

The pH of the detergent solution should be in the range of 9 – 10.5. When pH is outside this range, pH adjustment is required using P3-aquaclean LAC or sodium hydroxide (NaOH). The expected pH of 0.5 % P3 Aquaclean ENZ solution is 6.7 – 7.3.

## 3. Circulate cleaning solution

When starting circulation of the cleaning solution, discard the first 10 - 15 % of returned liquid, since this part will hold high concentrations of contaminants and should not be re-used.

Low feed water pressure should be applied during circulating period. Higher temperature is preferable for better cleaning efficiency.

**Note**: 35 °C may not be exceeded. A longer period of circulation is preferable for cleaning, but may be limited by increasing temperature, (refer to RSU-532).

As P3-Aquclean ENZ is a foaming product, design return line and permeate return line such that endpiece is below surface of cleaning solution inside tank.

Soaking of the elements in cleaning solution is effective to dissolve the metal foulants. Repeated and alternating soaking and recirculation of cleaning solution is recommended.

If pH value during circulation drops below pH 9, add more P3-Aquaclean LAC or sodium hydroxide (NaOH) until pH value is between 9 and 10.5. If pH value quickly drops below pH 8.5, discard cleaning solution, prepare fresh solution and repeat cleaning procedure to reach optimal cleaning efficiency.

## 4. Flush elements

Discard all spent cleaning solution. The cleaning tank is completely emptied. Flush out and displace completely the residual cleaning solution from the modules, pressure vessels and pipe lines with feed water or permeate. This is easiest done by filling water into the cleaning tank and directing the return line to drain, directly before tank, (see RSU-531).

## 5. General Description of P3-Aquaclean ENZ

| | |
|---|---|
| Appearance: | Clear brown liquid (separates slightly) |
| pH: | 6.7 – 7.3 as 0.5 % solution w/w |
| Density: | 0.95 – 1.05 g/cm$^3$ (20 °C) |
| Charge in solution : | Anionic |
| Main components : | Blend of anionic surfactants and different enzymes |
| Safety precautions: | Consult the P3-Aquaclean ENZ safety and product data sheet |

# Dodecyl Sodium Sulfate (DSS) Detergent Cleaning Procedure

## 1. Flushing of elements

Prior to cleaning with DSS solution, it is advisable (although not conditional) to flush elements with softened water or permeate, (see RSU-531).

## 2. Preparation of a 0.2 % DSS solution

1) Fill cleaning tank with water

Cleaning tank is filled with permeate or tap water, free of oxidizing agents. The amount of cleaning water is determined by size of RO system and degree of fouling (see RSU-532).

2) Dissolve DSS

Add DSS to cleaning water to obtain a 0.2 % (by weight) - solution. Attention – this chemical creates lots and lots of foam! Pre-dissolution in a small vessel is needed prior to blending into the cleaning liquid. Continuous, slow agitation of the solution will be needed to evenly dissolve DSS. To minimize foam formation, use low rpm stirrer.

For example: To prepare1’000 l of the solution 2 kg of DSS are used.

3) Monitor pH value

The pH of the detergent solution should be in the range of 7 - 10. If pH is outside this range, adjustment is required. The expected pH of DSS solution is 7.

## 3. Circulate cleaning solution

When starting circulation of the cleaning solution, discard the first 10 - 15 % of returned liquid directly before tank inlet, since this part will hold high concentrations of contaminants and should not be re-used.

Low feed water pressure should be applied during circulating period. Higher temperature is preferable for better cleaning efficiency.

**Note**: 35 °C may not be exceeded. A longer period of circulation is preferable for cleaning, but may be limited by increasing temperature, (refer to RSU-532).

To minimize foam formation, design return line and permeate return line such that end piece is below surface of cleaning solution inside tank.

Soaking of the elements in cleaning solution is effective to dissolve metal foulants. Repeated and alternating soaking and recirculation of cleaning solution is recommended.

## 4. Flush elements

Discard all spent cleaning solution. The cleaning tank is completely emptied. Flush out and completely displace any residual cleaning solution from the modules, pressure vessels and pipe lines with feed water or permeate. This is easiest done by filling cleaning tank with water and directing the return line to drain, directly before tank, (see RSU-531).

## 5. 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: $CH_3(CH_2)_{11}SO_3Na$ Dodecyl Sodium Sulfate (Sodium Lauryl Sulfate)

CAS no.: 151-21-3

Safety precautions:

- 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 diarrhea. Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention. If conscious, induce vomiting.

- Skin Contact: Mildly irritating to skin, causes dryness and a rash on 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

- Consult MSDS of supplier of DSS before use.

# P3-aquaclean SAL cleaning procedure

## 1. Flushing of elements

Prior to cleaning with P3-aquaclean SAL solution, it is advisable (especially with hard raw water) to flush elements using softened water or permeate, (see RSU-531).

## 2. Preparation of a 0.5 % P3-Aquaclean SAL solution

1) Fill cleaning tank with water

Cleaning tank is filled with permeate or tap water, free of oxidizing agents. The amount of cleaning water is determined by the volume size of RO system and degree of fouling, (see RSU-532).

2) Dissolve P3-Aquaclean SAL

Add P3-Aquaclean SAL (clear brown liquid) to cleaning water to obtain a 0.5 % (by weight) - solution. Continuous, slow agitation of the solution will be needed to evenly dissolve P3-Aquaclean SAL. To minimize foam formation, apply low mixer rpm.

For example: To prepare1’000 l of the solution 5 kg of P3-Aquaclean SAL are used.

3) Monitor pH value

The pH of the detergent solution should be close to, but < 11. pH adjustment is required using hydrochloric acid (HCl). The expected pH of 0.5 % P3 Aquaclean SAL solution is 11 - 12.

## 3. Circulate cleaning solution

When starting circulation of the cleaning solution, discard the first 10 - 15 % of returned liquid directly before tank inlet. This part will hold high concentrations of contaminants and should not be re-used.

Low feed water pressure should be applied during circulating period. Higher temperature is preferable for better cleaning efficiency.

**Note**: 35 °C may not be exceeded. A longer period of circulation is preferable for cleaning, but may be limited by increasing temperature, (refer to RSU-532).

To minimize foam formation, design return lines such that end piece is below surface of cleaning solution inside tank.

Soaking of the elements in cleaning solution is effective to dissolve metal contaminations. Repeated and alternating soaking and recirculation of cleaning solution is recommended.

If pH value during circulation drops below pH 9, add more P3-Aquaclean SAL until pH value is close to, but < 11. If pH value rapidly drops below pH 9, discard cleaning solution, prepare fresh solution and repeat cleaning procedure to reach best cleaning efficiency.

## 4. Flush elements

Discard all spent cleaning solution. The cleaning tank is completely emptied. Flush out and completely displace the residual cleaning solution from modules, pressure vessels and pipe system with treated feed water or permeate. This is easiest done by filling the cleaning tank with water and directing the return line to drain, directly before tank, (see RSU-531).

## 5. General description of P3-aquaclean SAL

Appearance: clear, brownish liquid

pH 1 % solution: 12 – 12.4

Density: 1.1 – 1.2 g/cm³ (20 °C)

Charge: Anionic

Main components: Dispergants, anorganic and organic complexation agents, anionic tensides

Safety precautions: see MSDS and spec sheet for P3-aquaclean SAL

# P3-Aquaclean SAL + P3-Aquaclean BUF Cleaning Procedure

## 1. Flushing of elements

Prior to cleaning with P3-aquaclean BUF/SAL solution, it is advisable (especially with hard raw water) to flush elements using softened water or permeate, (see RSU-531).

## 2. Preparation of a 2.5 % P3-Aquaclean BUF solution

1) Fill cleaning tank with water

Cleaning tank is filled with permeate or tap water, free of oxidizing agents. The amount of cleaning water is determined by size of RO system (number of modules, module volume, pipe lines and cleaning tank) and degree of fouling, (see RSU-532).

2) Dissolve P3-Aquaclean BUF

Add P3-Aquaclean BUF (clear, colorless liquid) to the water to obtain a 2.5 % (by weight) - solution. Continuous agitation of the solution will be needed to evenly dissolve the P3-Aquaclean BUF.

For example: To prepare 1’000 l of cleaning solution, 16.7 l of P3-Aquaclean BUF is needed.

3) Adding and Dissolving P3-Aquaclean SAL

Gradually add P3-Aquaclean SAL to the BUF solution until you reach a pH value of close to, but < 11. To minimize foam formation, we recommend mixing of the cleaning solution at low stirrer rpm.

4) Checking pH value

The pH of the detergent solution (P3-Aquaclean BUF & SAL) should be close to, but < 11. If pH drops below 9 during cleaning, add P3-aquaclean SAL until pH approaches 11. If pH 11 is exceeded, adjust using hydrochloric acid (HCl). The expected pH of 2.5 % P3 Aquaclean BUF solution is 8.7 – 9.3.

## 3. Circulate cleaning solution

When starting circulation of the cleaning solution, discard the first 10 - 15 % of returned liquid directly before tank inlet. This part will hold high concentrations of contaminants and should not be re-used.

Low feed water pressure should be applied during circulating period. Higher temperature is preferable for better cleaning efficiency.

**Note**: 35 °C may not be exceeded. A longer period of circulation is preferable for cleaning, but may be limited by increasing temperature, (refer to RSU-532).

To minimize foam formation, design return line and permeate return line such that end piece is below surface of cleaning solution inside tank.

Soaking of the elements in cleaning solution is effective to dissolve metal contaminations.

Repeated and alternating soaking and recirculation of cleaning solution (2 times soaking 15 min. each during 1 h cleaning) is recommended.

If pH value during circulation drops below pH 9, add more P3-Aquaclean SAL until pH value is just < 11. If pH value rapidly drops below pH 8.5, discard cleaning solution, prepare fresh solution and repeat cleaning procedure to reach optimal cleaning efficiency.

## 4. Flush elements

Discard all spent cleaning solution. The cleaning tank is completely emptied. Flush out and completely displace residual cleaning solution from elements, pressure vessels and pipe lines with feed water or permeate. This is easiest done by filling cleaning tank with water and directing the return line to drain, directly before tank, (see RSU-531).

## 5. General Description of P3-Aquaclean BUF

Appearance: Clear colorless liquid

pH: 8.7 – 9. 3 as 1 % w/w solution

Density: 1.3 – 1.5 g/cm$^3$ (20 °C)

Safety precautions: Consult the P3-Aquaclean BUF safety and product data sheet.

# Sodium Hexa Meta Phosphate + hydrochloric acid Cleaning Procedure

## 1. Flushing of elements

Prior to this cleaning procedure it is advisable, especially with hard raw water, to flush elements using softened water or permeate, (see RSU-531).

## 2. Preparation of a 1 % SHMP solution

1) Fill cleaning tank with water

Cleaning tank is filled with permeate or tap water, free of oxidizing agents. The amount of cleaning water is determined by size of RO system and degree of fouling, (see RSU-532).

2) Dissolve SHMP

Add SHMP (white powder) to water to obtain a 1.0 % (by weight) - solution. Continuous agitation of the solution by motor mixer will be needed to evenly dissolve the chemical. SHMP should be added in small batches to avoid clogging.

For example: To prepare 1’000 l of cleaning solution, 10 kg of SHMP is needed.

3) Add hydrochloric acid

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

HCl is an aggressive anorganic acid, pay attention to safety regulations when handling it.

4) Checking pH value

The pH of the solution should be close to ,but > 2. If pH increases past 3.5 during cleaning, add HCl until pH just > 2 is reached. If pH drops below 2, adjust using caustic soda (NaOH).

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

## 3. Circulate cleaning solution

When starting circulation of the cleaning solution, discard the first 10 - 15 % of returned liquid directly before tank inlet. This part will hold high concentrations of contaminants and should not be re-used.

Low feed water pressure should be applied during circulating period. Higher temperature is preferable for better cleaning efficiency.

**Note**: 35 °C may not be exceeded. A longer period of circulation is preferable for cleaning, but may be limited by increasing temperature, (refer to RSU-532).

As SHMP enhances foam formation, design return line and permeate return line such that end piece is below surface of cleaning solution inside tank.

Soaking of elements in cleaning solution improves efficiency of the entire process. Repeated and alternating soaking and recirculation of cleaning solution (2 times soaking 15 min. each during 1 h cleaning) is a good schedule.

If pH value during circulation increases past pH 3.5, add more HCl until pH value is back in range > 2. If pH value quickly increases past pH 3.5, discard cleaning solution, prepare fresh solution and repeat cleaning procedure to reach optimal cleaning efficiency.

### 4. Flush elements

Discard all spent cleaning solution. The cleaning tank is completely emptied. Flush out and completely displace residual cleaning solution from elements, pressure vessels and pipe lines with feed water or permeate. This is easiest done by filling water into the cleaning tank and directing the return line to drain, directly before tank (see RSU-531).

### 5. General Description of SHMP $(NaPO_3)_n$

| | |
|---|---|
| Appearance: | white powder, odorless |
| pH: | approx. pH 7 (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:

- Normal safety-equipment like gloves and chemicals splash goggles should be worn during handling of SHMP
- In case of eye contact – flush eye immediately with large amount of water and consult a physician.
- Prolonged contact with skin should be avoided. Avoid breathing dust.
- Consult MSDS of supplier of SHMP before use.

## Sterilization/preservation methods for RO/NF – elements

To prevent propagation of bacteria, it is recommended to immerse elements in sterilizing solution of 0.2 - 0.3 weight-% formaldehyde (HCHO) at pH 6–8, adjusted by sodium bicarbonate ($NaHCO_3$).

Above method is most effective as sterilization and it is applicable during any period of shut-down.

This method is not applicable for new elements. Elements must be in use at least 72 hours before formaldehyde sterilization.

If formaldehyde sterilization cannot be applied to the system, following alternative solutions can be applied to each model of UTC membrane based elements:

| **Membrane Model:** | **Sterilization solutions:** |
|---|---|
| UTC-20 | Solution A or C or D |
| UTC-60 / 70 | Solution B or D or Chloramine |
| UTC-70U | Solution B or D or Chloramine |
| UTC-80 | Solution D |

Alternative sterilizing solutions and their applications are listed following. The elements can be immersed (not in operation) in these solutions for sterilization at system shutdown.

| **Sterilizing Solution** | **Concentration [ppm]** | **Duration of treatment** *1 |
|---|---|---|
| A: SR-400 *2 | 100 – 200 *3 | 1 – 3 *4 |
| B: Hydrogen Peroxide *5<br>$H_2O_2$ | 2000 – 10000 | 1 *4 |
| C: SR-500 *6 | 500 – 1000 *3 | 1 – 3 *4 |
| D: Sodium Bisulfite | 5000 – 10000 | no limit *4 |

**Notes:**

*1 Contact time with sterilizing solution must not exceed this duration to avoid performance decline.

*2 Quaternary Ammonium Salt (Benzalkonium chloride)

Toray approves following sterilizing reagent at SR-400 equivalent.

(1) GERMITOL ™ supplied by Sanyo Chemical Ind., Ltd.

*3 This solution must have a pH of 6 – 8. Feed pressure of this solution should be low and during circulation of the solution high pressure should not be used.

*4 After completion of sterilization with these solutions, flush system and fill up with clean water meeting specifications for resuming normal operation or entering prolonged shutdown periods.

*5 Hydrogen peroxide for this application must be prepared with de-ionized feed water with less than 0.2 ppb iron. Inadequate application of this solution may result in solute rejection decline.

*6 Amphoteric surface active agent

Toray approves the following sterilizing agents as SR-500 equivalent:

(1) Amogen K supplied by Daiichi Kogyo Seiyaku Co., Ltd.

(2) Tego Betaine L7 supplied by Goldschmidt Company.

1. The water used to prepare sterilizing solution must be free of residual chlorine or other equivalent oxidizing agents. (*)
2. All chemicals selected for application with membrane elements must match requirements for the respective membrane product.

**Note:**

(*) Chlorination is an applicable sterilization procedure for special cases; however Toray consultation will be required for planning and advice regarding execution. Element performance may be influenced by chlorine. In any case, acidic cleaning is required prior to application of chlorine; target is complete removal of any heavy metal residues. Chlorination in presence of heavy metal residues will lead to fast and irreversible damage of composite membranes.

## Sanitizing 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):

- Temperature slope during heating & cool down period max. 2.0 °C / minute
- Preferably use permeate, or at least softened water
- For effective pasteurization water temperature must be 72°C to 80°C. Below this range, effect is weak, above modules can be irreversibly damaged.
- Feed-pressure during hot water treatment must be always < 0.15 MPa
- Differential pressure max. 0.1 MPa / 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.
- Determine necessity and effectiveness of treatment by microbiological investigations.

## Membrane Treatment with Toray MT-701 resp. MT-801 Procedure

Note: This procedure should only be applied after consulting TORAY and in coordination with them. Evaluation and determination whether this procedure can be used, should be left exclusively to TORAY.

In most cases, flux is recovered largely by a careful chemical cleaning prior to membrane treatment.

In cases where restoration of salt rejection is found insufficient, membrane treatment (MT) procedure as described below is recommended.

1) Prior to carrying out MT, perform cleaning of elements to remove any contamination and/or scaling. This is necessary for the MT to be successful. A clean membrane surface is a prerequisite.

2) The MT is performed with the RO system running in regular operation.

   - Adjust pH of feed water during dosage to a range of 7.0 – 7.5.
   - Permeate must be discarded during treatment.
   - Record operating data before starting addition of MT chemical
   - Add MT to feed water for approx. 30 minutes. The concentration of MT in feed water should be approx. 1’000 ppm.
   - Total MT required is calculated as follow:

$$\mathbf{MT\ (kg) = (Feed\ flow\ (m^3/h)) \times (0.5) \times (1{,}000) \times 10^{-3}}$$

   - Viscosity of concentrated MT (as shipped) is high. Pre-dilution to a concentration of 5% or less is necessary before adding to the feed water with a suitable chemical metering pump.

3) After pH of feed water reaches indicated range, start dosing MT to reach a concentration of approx. 1’000 ppm MT in feed stream. For thorough mixing, dosing point of MT liquid is best situated after cartridge filters and before high pressure pump.

4) Operating conditions during MT dosing should be maintained as follows:

| | |
|---|---|
| Pressure: | 100 – 120 % of regular operating pressure, never less. |
| Permeate flow rate: | 100 - 120 % of the standard flow |
| Feed water: | Regular quality (except pH) |
| Temperature: | Regular |
| Recovery ratio: | Regular |
| Feed water pH: | 7.0 – 7.5 (always above 6.5) |

Time of treatment: 10 – 30 minutes. The duration of MT treatment should be determined by checking effect (recovered salt rejection, increasing feed pressure and decreasing permeate flow).

**NOTE**: MT may not be effective in some cases such as mechanical damage, or where salt rejection has deteriorated too much.

5) Recommended criteria for concluding MT are:

- Salt passage does not improve further / clearly.
- Permeate flow rate decreases approx. 10 % from MT start value at constant operating pressure.
- Net pressure to produce the same volume of permeate increases 10 % from MT start value at constant permeate flow.

6) Immediately after MT, adjust pH of feed water to 3 ~ 4, and maintain for 30 ~ 60 minutes with all other operation parameters as regular.

During MT and low pH operation, permeate should be drained.

7) Continue operation after low pH phase at regular conditions for at least 5 hours. Shut down shortly after MT may result in permeate flow decline.

# Storage and preservation

## 1. 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 needed for:

- Long term storage of new and used elements
- RO system shutdown $>$ 48 hours

## 2. Storage of new elements

Preferably, elements should be stored or shipped as packaged by TORAY, outside of pressure vessels, and loaded into pressure vessels directly before start - up. Adequate storage conditions will help to minimize bio growth during storage.

Toray specifies the following optimal storage condition:

1) Store elements in cool, dark and dry place inside closed building. Keep away from direct sunlight.
2) Avoid freezing and temperatures above 35 °C.
3) New elements are stored as shipped in preservation solution of 0.5 – 1 % sodium bisulfite solution ($NaHSO_3$).
4) New elements are vacuum-sealed in a bag made from oxygen impermeable special plastic and packaged in carton boxes of each one or two elements. The carton boxes should be opened directly before installation.

## 3. Storage / preservation of used elements

1) If TORAY elements were removed from pressure vessel for storage or shipping, they need to be preserved in a 500 – 1000 ppm sodium bisulfite solution. To make up the preservation solution, use food grade sodium bisulfite and good water. Usually, sodium disulfite $Na_2S_2O_5$ is used, which reacts with water forming bisulfite:

   $Na_2S_2O_5 + H_2O$ -------- $2\ NaHSO_3$

2) Use softened, chlorine-free water; preferably RO or NF permeate. After soaking elements for about 1 hour in the preservation solution, take them out of this solution and package them in an oxygen barrier bag. Seal and label the bag, indicating packaging date. Recommended oxygen barrier bags are sold by TORAY.
3) Instead of sodium bisulfite, formaldehyde can be used as preservation solution at 0.2 to 0.3% (by weight) concentration. Formaldehyde is a more effective biocide than Sodium bisulfite and is not decomposed by oxygen.

   Observe applicable safety regulations when working with formaldehyde.

⚠ Elements must be in operation for at least 72 hours under regular conditions before they can be preserved with formaldehyde, otherwise loss of flux can occur.

NOTE: Formaldehyde is harmful and, hence, forbidden for many food-related applications. Responsibility in any case rests with user.

4) After the elements are preserved and repacked, recommended storage conditions are the same as for new RO elements.

## 4. Preservation of RO system

The following procedure is applied in case of RO plant down times of > 48 hours. For shorter down time, simple flushing procedure is recommended, (refer to RSU-531).

1) Before any preservation, the system should be cleaned to remove contamination and fouling deposits on the membranes (This applies to cases where membranes are, or are assumed to be, contaminated). Use recommended standard cleaning procedures or consult TORAY for individual cleaning and disinfecting procedures before long-term system shut down. The preservation should follow as soon as possible after successful cleaning and disinfecting, maximum 12 hours after last cleaning / disinfection.

2) The preservation is done by recirculation of 500 – 1’000 ppm sodium bisulfite solution using the cleaning system. This way the elements are thoroughly wetted by preservation solution. Circulate solution through system in such a way that the remaining air is minimized after the recirculation is completed (approx. 1 hour). Make sure system is air-free and air-tight during conservation.

3) Close all valves on the feed and brine side. Any contact of the SMBS solution with outside air (oxygen) will oxidize sodium metabisulfite to sulfate and pH will drop continuously. After all bisulfite is consumed, remaining oxygen is not absorbed and biological status becomes unstable.

4) pH in the preserved RO system needs to be controlled regularly (at least once a month) to be sure that it does not drop below pH 3. If pH is found below pH 3 the preservation solution must be changed. The preservation solution must be changed once a month.

5) During shutdown period, maximum temperature should not exceed 40 °C.
Storage temperature > 0 °C.

6) Formaldehyde can be used - instead of sodium bisulfite – as a preservation solution at 0.2 to 0.3 % (by weight) concentration. Formaldehyde is a more effective biocide than bisulfite and is not decomposed by oxygen.

Observe applicable safety regulations when working with formaldehyde.

⚠ Elements must be in operation for at least 72 hours at regular conditions before preservation with formaldehyde, otherwise loss of flux can occur.

## Handling of New Elements

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

### 1. Precautions which should be taken during storage

1) The elements are shipped from TORAY sealed in oxygen impermeable plastic bags and packaged in carton boxes. Open carton boxes directly before installation.

2) Elements can be stored within a temperature range of 5 °C to 35 °C. Avoid storage in direct sunlight.

   If outside temperature may drop to < 0 °C, cover cartons with insulating material and / or heat storage room. Do not allow elements to freeze.

3) Don’t stack more than 5 layers of carton boxes. Make sure boxes are kept dry.

### 2. General notes for installation into pressure vessels.

1) Carefully open plastic bags at one end and do not tear open, for possible re-use.

2) Keep part of the packaging material for the event that elements must be removed and stored.

3) Enumerate pressure vessels and record installation location of each membrane element with exact sequence of elements inside each pressure vessel. The recorded information must be updated upon installation of new elements or change of element positions.

4) To avoid damage of elements, handle with care and do not drop. Touch elements with clean hands or gloves only and avoid contamination where possible.

5) Take care to keep the exterior of element clean.

6) See detailed procedures in RSU-620.

# Fitting of RO elements into pressure vessels

## 1. Prior to installation - preparations

1) Before directing pre-treated feed water to elements, make sure piping system and pressure vessels are free of dust, oil, metal residues etc. In case of severe pollution by foreign contaminants, it may be effective to clean pressure vessels by soft rotary brush flushing with pre-treated water. In no case the inside of the pressure vessels may be damaged or scratched. This procedure also applies in case of element replacement or renewal

2) Examine feed water quality

Flush system with pre-treated raw water for approx. 30 minutes.

3) Remove end plates from both ends of pressure vessel, check the inside of the vessel and if necessary clean mechanically, (see fig. 620.1 to 620.4).

4) Install permeate adapter with O-rings into the permeate port of concentrate end plate. Lubricate both parts using only glycerin.

⚠ DO NOT install „thrust ring“ if SU types will be fitted into pressure vessel. Necessary only for TM element types.

5) 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.

6) Prepare the necessary parts as shown in the following table:

| **Parts** | **required quantity** | |
|---|---|---|
| | **SU type** | **TM type** |
| Brine seals | m | m |
| O-Rings | 2 x m | 4 x m |
| Permeate adaptor open | n | n |
| Permeate adaptor closed | – | n |
| Interconnectors | m – n | m – n |
| Product tube cup | n | – |

m : number of elements

n : number of pressure vessels

**Note:** The above parts except the vessel’s permeate adapter are shipped with each element package. Permeate adaptors are shipped with pressure vessels. When ordering pressure vessels, please specify type of RO element to be installed.

7) Attach O-rings

Apply glycerin to the O-ring. Attach O-rings to the interconnectors and product tube caps.

## 2. Insertion of elements

Note: This is best done by a team of two persons.

1) Take an RO element out of the carton and the plastic bag.

**Note:** The shipping bags are made of a material with extra high oxygen rejection, which improves lifetime of preservation solution. If bags are cleanly cut open at one end, some can be kept and re-used in case any RO elements must be conserved or shipped.

⚠ The element is conserved in 0.5 % to 1 % sodium bisulfite solution! Protect eyes and skin.

2) Apply glycerin to outer (SU type) resp. inner (TM type) surface of the element's product tube. Install brine seal on the element as in fig. 620.1. Be sure to attach the brine seal correctly.

Note: Brine seal should be installed at feed end of each element.

3) Insert element from feed side end into the pressure vessel about 2/3 (see fig. 620.2), after lubricating brine seals and vessel's inner surface with glycerin. Insert element carefully and smoothly, especially the first element.

4) Attach inter-connector to product tube at the feed end of the inserted element (see fig. 620.3)

5) Attach brine seal to the second element as described for first element. Connect the two elements at the inter-connector, see fig. 620.3. 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.

6) Repeat procedures described in step (4) to (5) (see Fig. 620.3). Insert elements one by one into the pressure vessel.

7) After inserting last element, attach tube cap resp. end plug to front end of permeate tube for SU-, SUL-, TR- and FR-types, or the correct permeate adaptor for TM types (see Fig.630.4 and 630.5).

8) Push the last element home until the first (downstream) element's permeate tube is firmly connected

9) Check distance „A“ between product tube cap and plug installed in permeate adaptor of feed side end plate. If all elements are correctly inserted, the distance „A“ must be < 5 mm, (see Fig. 620.6). This procedure is only required if a tube cap or a plug is used.

10) Attach the feed side end plate of pressure vessel, and fit piping system to brine port of end plate

## 3. Initial start-up checks

After finishing of piping and installation work, successively carry out initial start-up checks according to RSU-410

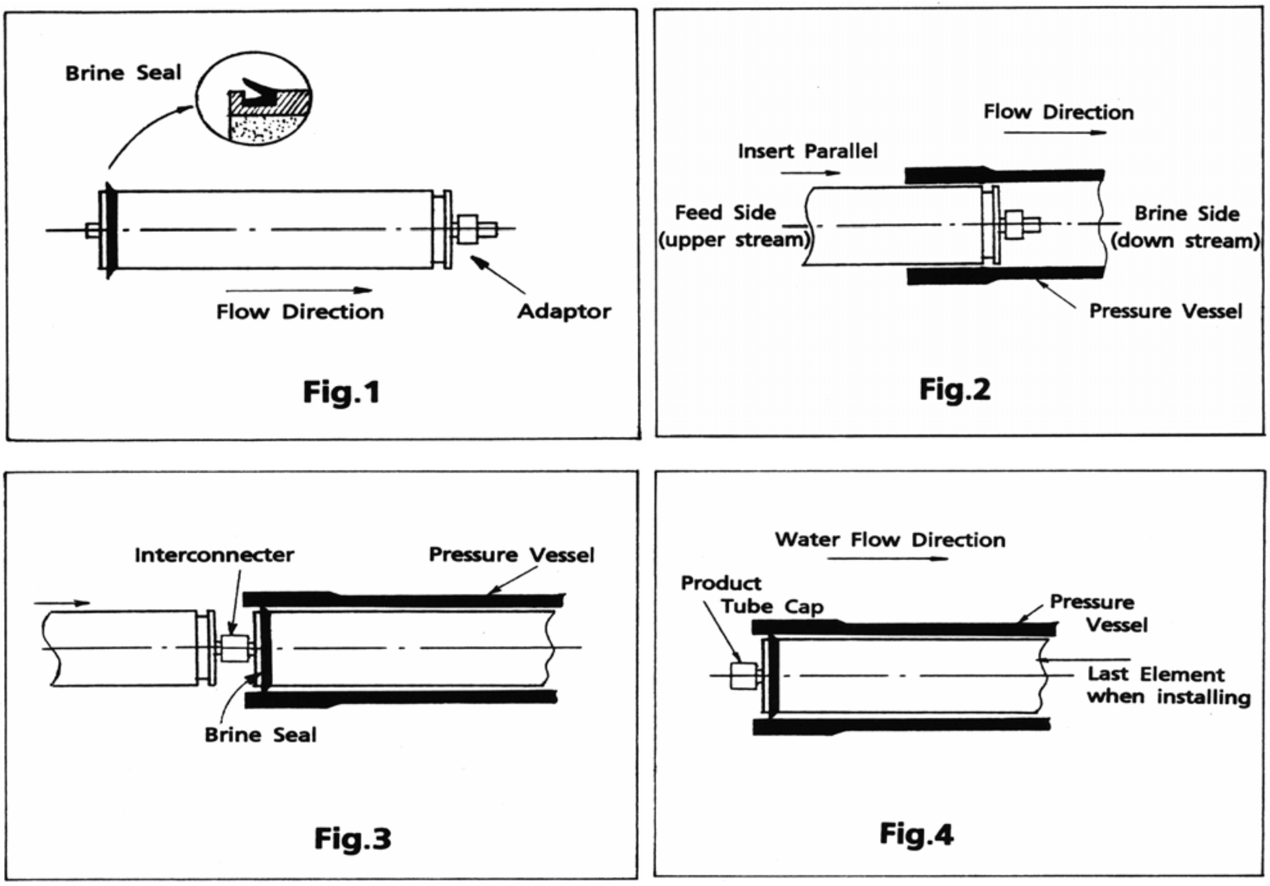


**Fig 620.1 to 620.4: Insertion of elements**

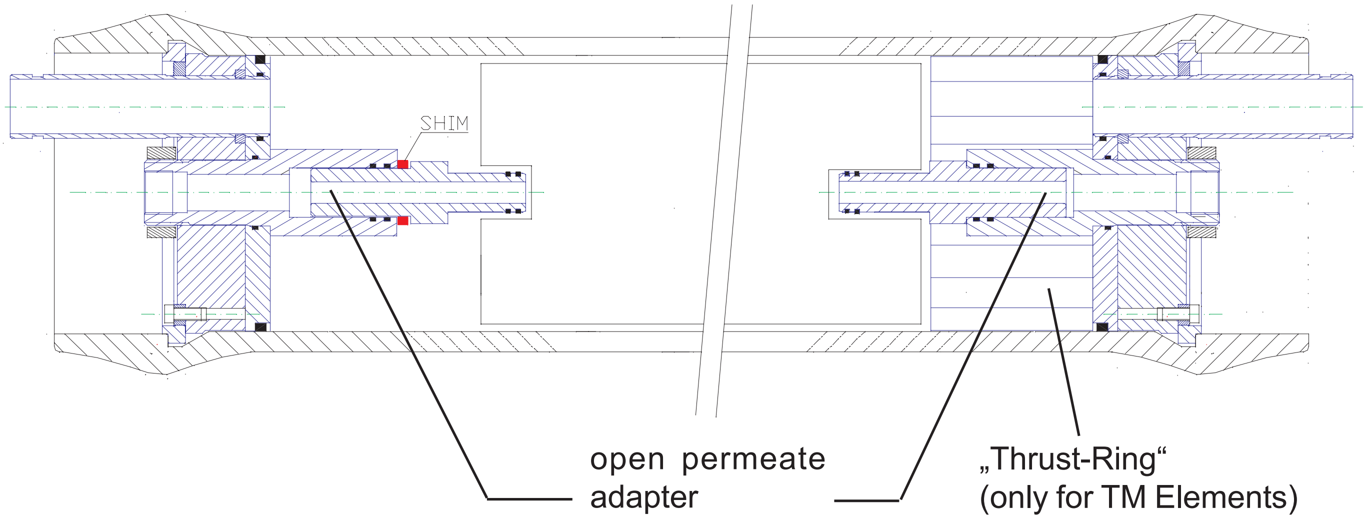


**Fig. 620.5: TM module 8 inch with thrust-ring on the concentrate side**

### 4. Distance A (SU-, SUL-, TR-, FR element types):

After installing all membranes (see Fig. 620.1 – 620.4), use shim rings provided by the pressure vessel manufacturer to make sure that the distance „A“ (Fig. 620.6) is < 5mm (0.2 inch). If distance „A“ is too large, element stack will move too much, causing damage of O rings (interconnectors and/or permeate adapter) and disconnection of permeate adapter. In both cases brine/feed water will leak into permeate and spoil product quality. The risk of mechanical disconnection of permeate adapters is especially high if the permeate header is connected to feed side of pressure vessel. Therefore TORAY highly recommends to install permeate system on the brine side of pressure vessels only.

On the feed side of element stack, use the product tube cap (Fig. 620.4) supplied by TORAY instead of the permeate adapter which may be supplied by the pressure vessel manufacturer. This provides best protection against „short-circuit“ of permeate and brine. For end plate‘s permeate port, use a correctly shimmed plug (available from pressure vessel manufacturer, to indicate when ordering).

For SU elements, DO NOT install „thrust rings“ supplied by vessel manufacturer. Construction of SU elements is such that axial forces (resulting from delta p) are absorbed by permeate tube. The fiberglass wrapping of SU is not suitable for absorbing axial forces. Use of thrust rings may result in damage to ATD, fiberglass wrapping or the element itself.

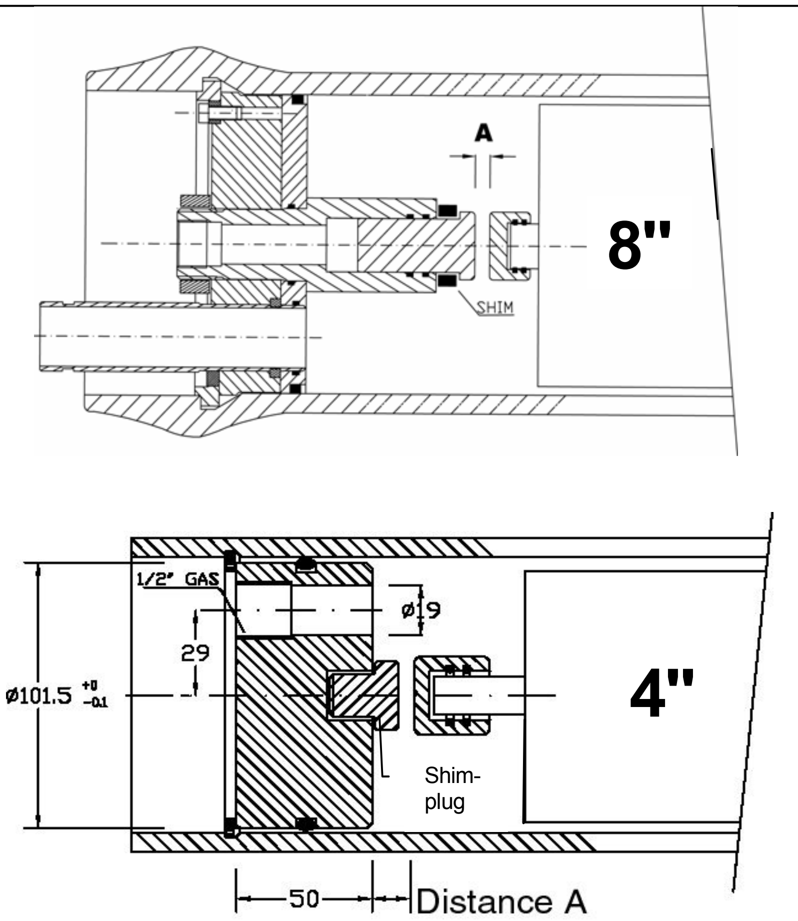


Fig. 620.6: Distance A between end cap and shim plug

# Removal of elements

If elements have to be removed from pressure vessels, e.g. for inspection, storage, shipment or replacement, proceed as following:

1. Disconnect feed, brine and permeate ports of pressure vessel, and remove connected fittings
2. Remove end plates from both sides of the pressure vessel.
3. Push elements from the feed side  until end of the downstream element appears at the brine side.
4. Pull out the element from the brine side slowly. Remove the interconnector from the next element.
5. Repeat this process, if necessary use e. g. a plastic pipe for pushing the elements through
6. If re-installation of elements is foreseen, they are to be packed directly into clean plastic bags, (see RSU-600). For re-fitting elements, proceed according to RSU-620.

## Preface and references to troubleshooting

Potential problems in an RO system can be recognized early by monitoring the changes of permeate flow rate (*), salt passage (*) (salt rejection) and pressure drop of the RO membrane modules.

It is, therefore, recommended for the system operator to record and review daily operation data and to take prompt and appropriate countermeasures or to correct any concerns or problems to prevent future complications.

Normalization of the value marked with * is required in order to properly understand the operation data. Procedures for normalization are described in the O & M section of this manual operation monitoring methods of RO system.

Typical performance changes and their countermeasures are shown in the following chapter.

The steps of troubleshooting are briefly summarized below:

**Check:** Calibration of Instruments

↓ Pressure, Temperature, Conductivity, pH, flow rate, meters etc

**Review:** Record of daily operation data, normalization
plant history and plant specification

↓

**Investigate:** Reason of performance change and possible causes

↓ Refer to RSU-720

**Troubleshoot:** Corrective measures, performed in time

Chemical cleaning, sterilization,

Replacement of necessary parts,

Change of operating conditions, etc.

## Typical Performance Changes and Countermeasures

The following points are conditional for determination of performance changes. It is assumed that the following requirements have been complied with:

1. Regular calibration of measuring instruments and maintenance of plant components.
2. Logging and evaluation of operating data, monitoring of system operation

This section is about problems and countermeasures regarding salt passage and permeate flow rate. The role of feed water conditions such as pressure, temperature, concentration, pH and recovery ratio in the system performance is discussed in RSU-430.

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

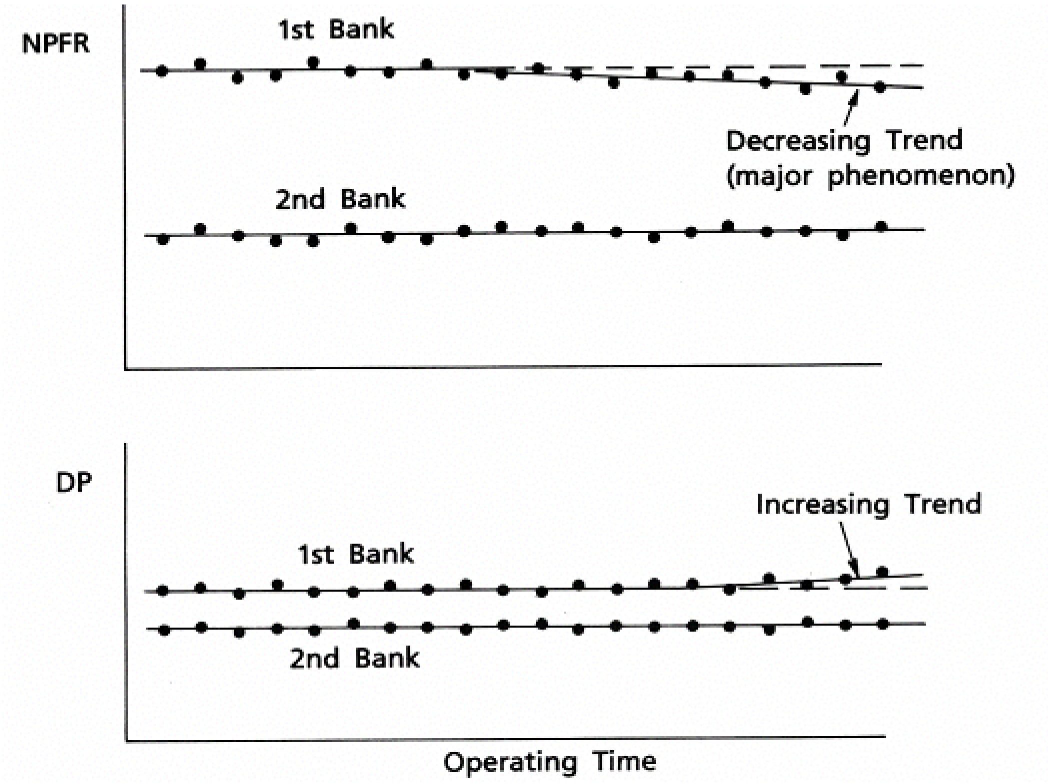


Figure 720.1: NPFR and DP in first concentrate stage

| Potential Causes | Countermeasures |
|---|---|
| (1) Change in feed water quality | Check operating parameter (recovery, flux,..)<br>Optimize pretreatment, check cartridge filters (both installation and replacement status) |
| (2) Fouling by metal hydroxides, inorganic colloids, organic or bacterial matter | Optimize pretreatment, |
| (3) Mechanical fouling due to particles. | Analysis of foulant followed by appropriate chemical cleaning and/or sterilization (see RSU-530, RSU-540) |
| | Chemical cleaning,<br>Optimize pretreatment, check cartridge filters |

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

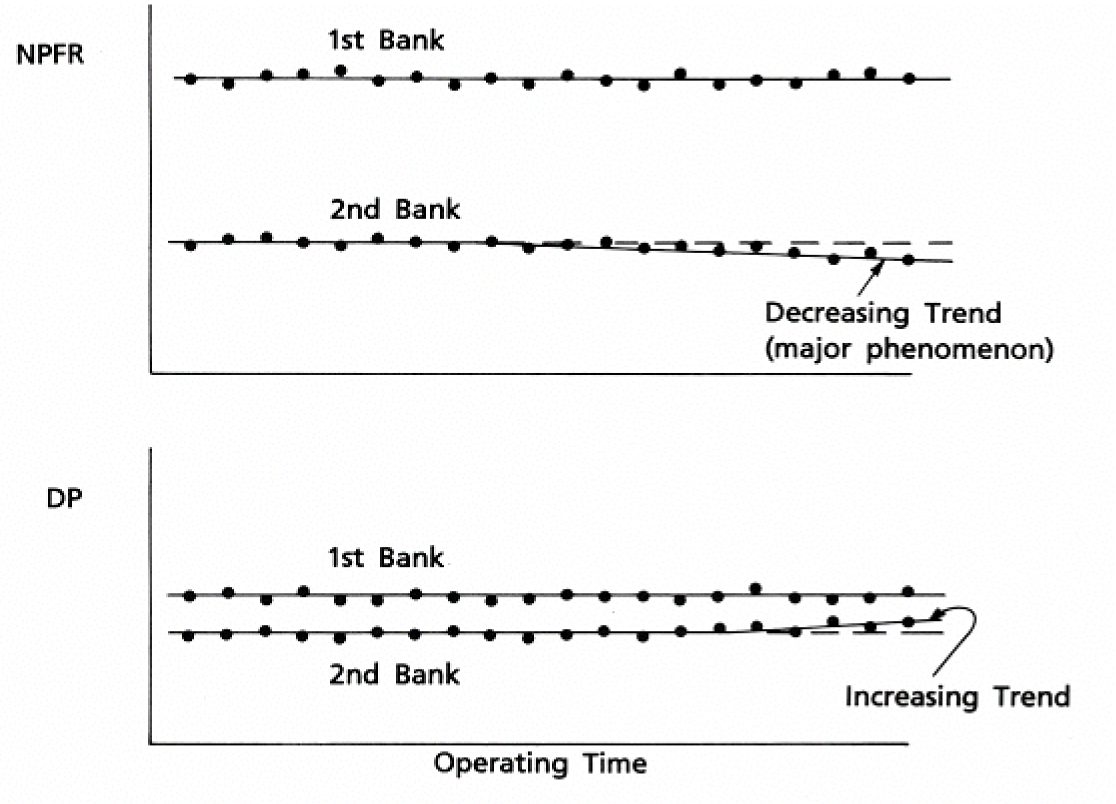


**Figure 720.2: NPFR and DP in last concentrate stage**

| Potential Causes | Countermeasures |
|---|---|
| (1) Change in feed water quality | Check operating parameter (recovery, flux, ..)<br>Optimize pretreatment, esp. regarding scaling inhibition. |
| (2) Fouling by metal hydroxides, inorganic colloids, organic or bacterial matter | Check & optimize pretreatment,<br>Analysis of foulant<br>Chemical cleaning and/or sterilization<br>(see RSU-530, RSU-540) |
| (3) Mechanical fouling due to particles. | Analysis of precipitate, followed by chemical cleaning. |

### Case C: Normalized Salt Passage (NSP) Increase – Almost All Vessels

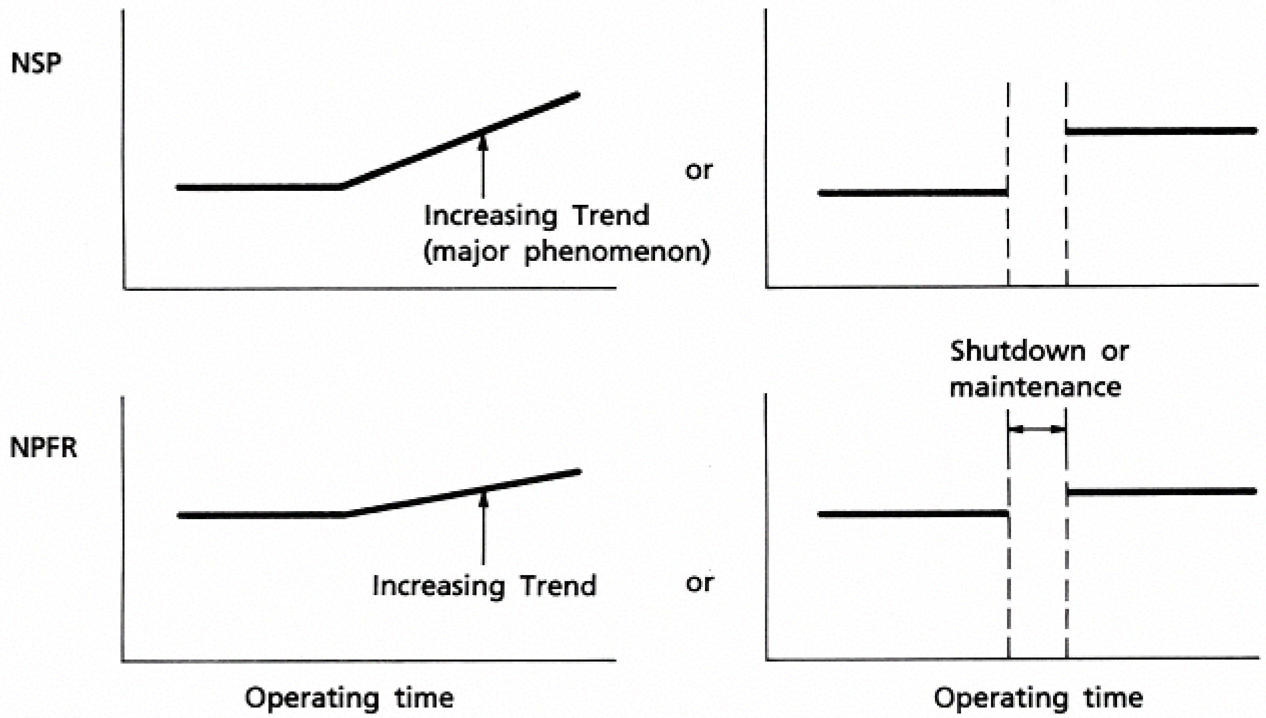


**Figure 720.3: Normalized Salt Passage (NSP) increase – all banks**

| **Potential Causes** | **Countermeasures** |
|---|---|
| (1) Membrane affected by exposure to oxidants,<br>use of non-guideline chemicals,<br>operation outside recommended parameter range | Check, modify and/or optimize chemicals applied to the system<br>Check and adjust operating conditions according to recommendations of manufacturer |
| (2) Mechanical damage do to precipitation of sparingly soluble salts | Check pH adjustment and / or dosing rate of scale inhibitor;<br>Adjust recovery according to limits given by water chemistry |

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

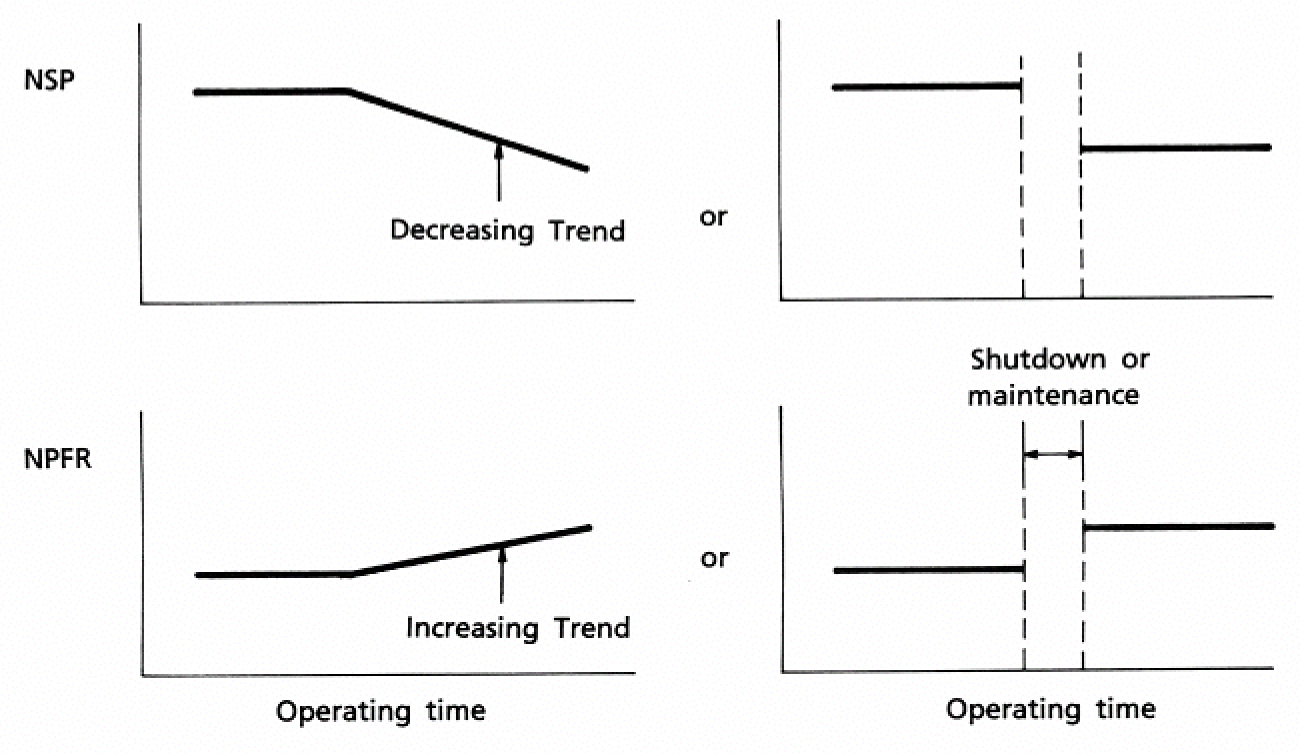


**Figure 720.4: Normalized Permeate Flow Rate (NPFR) – all banks**

| Potential Causes | Countermeasures |
|---|---|
| (1) Membrane affected by exposure to oxidants,<br>use of non-guideline chemicals,<br>operation outside recommended parameter range. | Check, modify and/or optimize chemicals applied in system and maintenance. |
| (2) Excessive concentration polarization | Check and adjust operating conditions according to recommendations of manufacturer, in particular for recovery and concentrate flow<br>Check and improve pretreatment, if needed, reduce recovery<br>Check and replace brine seals if necessary |

### Case E: Differential pressure (DP) increase

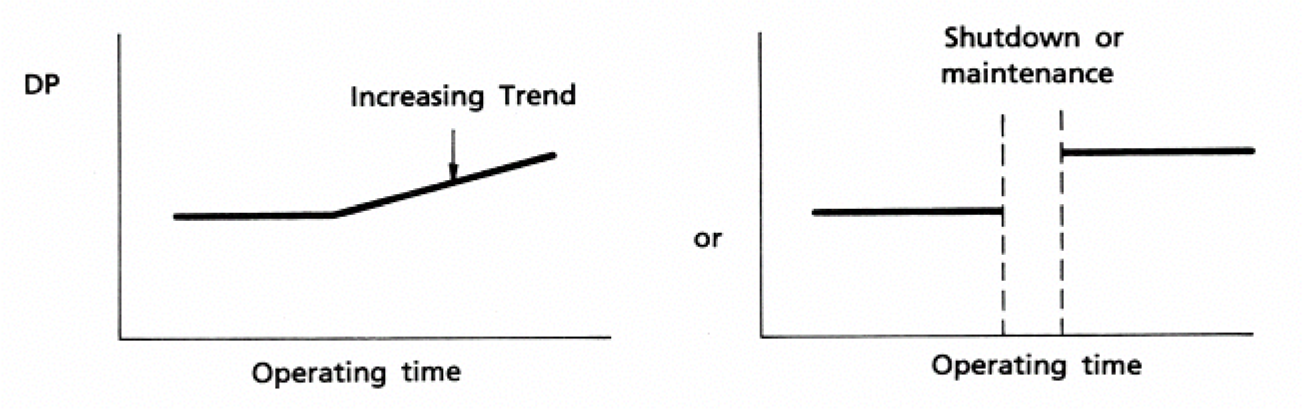


**Figure 720.5: Differential Pressure (DP) increase**

| Potential Causes | Countermeasures |
|---|---|
| (1) Contamination | Refer to Case A and B |
| (2) Excessive concentration polarization | Check and adjust operating conditions according to recommendations of manufacturer, in particular for recovery and concentrate flow |

### Case F: Normalized salt passage (NSP) Increase – partial vessel

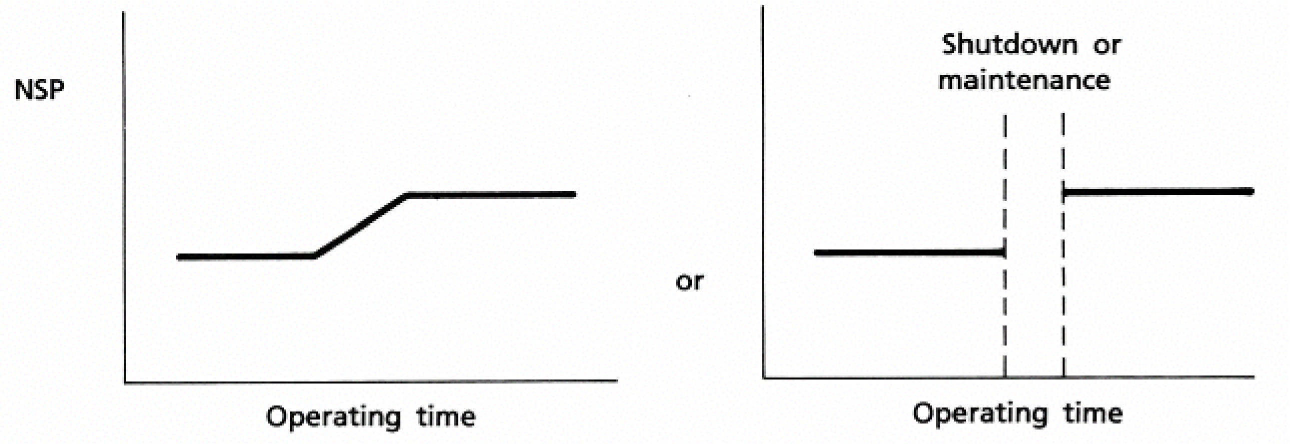


**Figure 720.6: Normalized Salt Passage (NSP) increase**

| Potential Causes | Countermeasures |
|---|---|
| (1) Mechanical leakage due to<br>- O-ring seal damage<br>- excessive feed flow<br>- excessive pressure drop<br>- excessive back pressure | Detect location of leakage in a particular vessel by permeate sampling probe<br>Make sure that back pressure (permeate minus feed or brine pressure) is less than 0.07 MPa at any time<br>Check and adjust operating conditions according to recommendations of manufacturer, in particular for recovery and concentrate flow<br>Make sure that these values are not exceeded under start-up and shut-down conditions |

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