Note-3 When no operation of Dual Media Filter (F-101A,B) will be done, by-pass line of F-101A,B shall be operated. (V-114 open)

Note-4 When the quality of the treated seawater will be over the limit (fouling index will be more than 4.0), the treated seawater of Dual Media Filter (F-101A,B) shall be re-treated by Dual Media Filter (F-101A,B).

Note-5 When water in the tank will be drained out, these valves shall be open.

Note-6 The by-pass line of the respective machine or unit such as HE-201, HE-301, UV-201, UV-203 will be operated, by-pass valves such as V-203, V-208, V-303, V-308 shall be open.

Note-7 When no operation of Heater (HE-201, 202, 301, 302) will be done, the following procedure shall be carried out.

V-218, 318, 230, 330	Close
V-219, 319	Open

Note-8 See "Chemical Cleaning of RO Module".

Note-9 When the permeate of S.W. RO system and/or H.F. RO system will be recirculated, the permeate shall be flowed back to the respective "Feed Tank" (T-201 or T-301).

b) Verification for automatic valves

Valve No.	Situation	Remarks
AV-101	Open	
AV-102	Open	
AV-103	Close	
AV-104	Close	Note-1
AV-105	Close	
AV-106	Close	
AV-107	Close	
AV-108	Close	
TSU-401	Open	Note-2

Note-1 Automatic operation of Dual Media Filter (F-101A) is as follows:

Machine No. Valve No.	Service	Backwash					
		Drainage	Air Bubbling	Pause	Back-washing	Pause	Flashing
AV-101							
AV-102							
AV-103							
AV-104							
AV-105							
AV-106							
AV-107							
AV-108							
P-101							
P-102							
P-103							
Operating Time	24 Hrs	3 min	10 min	3 min	15 min	5 min	10 min
Flow Rate	7.0m³/Hr	-	36m³/Hr	-	25m³/Hr	-	7.0m³/Hr

The above processes are automatically operated by pre-setting timer.

All selector switches for automatic valves are in AUTO positions.

3) Verification for instrumental setting points

Verify all set points and timer setting based on 6.0 "LIST OF SETTING".

4) Turn on the main circuit breaker for incoming power and then turn on all circuit breakers located in control panel.

Confirm air compressor start working.

5) Turn selector switches for chemical dosing pumps to AUTO position.

6) Turn on push button for air compressor.

7) S.W. type RO system start procedure

When all equipments are ready for automatic operation, S.W. type RO system is operated as follows:

Push button of S.W. type RO system ON

P-201, P-202, P-503A, P-504A, P-504B,
UV-201 ON

(10 sec.)

P-203 ON

8) H.F. type RO system start procedure

When all equipments are ready for automatic operation, H.F. type RO system is operated as follows:

Push button of H.F. type RO system ON

P-301, P-302, P-501B, P-503B, UV-301 ON
(10 sec.)
P-303 ON

9) Check and adjust all necessary items and correct based on "Operation Summary".

2) Stop Procedure

(1) Stop RO System

1-1) S.W. Type RO System

Automatic stop procedure is as follows:

Push STOP button

P-504C ON
(2 min.)
P-203, P-504C STOP
(3 sec.)
P-201, P-202, P-503A, P-504A, P-504B, UV-201 STOP

1-2) H.F. Type RO System

Automatic stop procedure is as follows:

Push STOP button

P-303 STOP
(4 sec.)
P-301, P-302, P-501B, P-503B, UV-301 STOP

(2) Pretreatment

Turn on the selection switches of all equipment to "AUTO".

P-101 start, AV-101, AV-107 open

(Flashing of Dual Media Filter - A (F-101A) is carried out before service.)

10 min.

AV-102 open, AV-107 close

(Then, Dual Media Filter is in service.)

24 Hrs or pressure drop of F-101A will reach 0.5 kg/cm^2.

Backwash process is automatically carried out.

(Drainage - Air bubbling - Pause - Backwashing - Pause - Flashing)

Service

4) Turn off all circuit breakers on the control panel and close all valves, when the next start is not expected soon.

3) Emergency Stop

(1) S.W. Type RO System

1-1) Abnormal condition of Oxygen Reduction Potential Meter (ORPA-201).

P-203 stop, P-504C start, Annunciator
(2 min.)
P-504C stop
(3 sec.)
P-202, P-503A, P-504A, P-504B stop

1-2) Abnormal low pressure at the suction of P-203 (PSA-201).

P-203 stop, P-504 start, Annunciator
(2 min.)
P-504C stop
(3 sec.)
P-202, P-503A, P-504A, P-504B stop

1-3) Low water level in Feed Tank (T-201) (LSA-201)

P-504C start
(3 min.)
P-203 stop
(3 sec.)
P-202, P-503A, P-504A, P-504B, P-504 stop

1-4) Booster Pump (P-202) motor trip

P-503A, P-504A, P-504B, UV-201 stop
(2 sec.)
P-203 stop, P-504C start
(2 min.)
P-504C stop

In any emergency stop, RO system does not start automatically.
After checking, correcting and readjusting, re-start of RO system shall be made.

(2) H.F. Type RO System

2-1) Abnormal pH (PHRA-301 $pH < 4$ or $pH > 7$)

Annunciator 9pH low or pH high)

P-303 stop
(4 sec.)
P-302, P-501B, P-503B, UV-301 stop

2-2) Abnormal low pressure at the suction of P-303 (PSA-301)

Annunciator ($P < 0.1\ kg/cm^2$)

P-303 stop
(4 sec.)
P-302, P-501B, P-503B, UV-301 stop

2-3) Low water level in Feed Tank (T-201)

(LSA-301)

P-303 stop

(4 sec.)

P-302, P-501B, P-503B, UV-301 stop

2-4) Booster Pump (P-302) motor trip

P-501B, P-503B, UV-301 stop

(2 sec.)

P-303 stop

The above chemical dosing rate is estimated value. The actual dosing rate shall be decided based on the field test.

4.0 Chemicals Handling

1) Handling

As a rule, polyethylene hand gloves and eye-glasses must be utilized for safety when handling chemicals. Dilution, mixing, conveying and container opening. Washing water must always be prepared for emergency.

2) Storage

Store any chemicals in cool and dark place completely closing chemical containers, bags, cans.

3) Spills

Wash with water to any chemical spills immediately. Splashing to human skin, machines, floor and any part of articles must immediately be flushed with water.

5.0 List of Setting

1) Pretreatment

Item	Setting Value (Estimated)
PI-101	2.0 kg/cm^{2}G or more
PI-102A	1.8 kg/cm^{2}G or more
PI-102B	1.2 kg/cm^{2}G or more
PI-103A	1.2 kg/cm^{2}G or more
PI-103B	0.6 kg/cm^{2}G or more
PI-104	0.8 kg/cm^{2}G or more
FI-101	5 $\sim$ 8 m^3/Hr

Item	Setting Value (Estimated)
FI-102	25 m^3/Hr
FI-103	36 m^3/Hr

2) S.W. Type RO System

Item	Setting Value (Estimated)
PI-201	2.5 kg/cm^2G or more
PI-202	3.0 kg/cm^2G or more
PI-203	1.0 kg/cm^2G or more
PI-204	50 kg/cm^2G or more
PI-205	50 kg/cm^2G or more
PSA-201	0.1 kg/cm^2G or less (annunciator)
FI-201	0.84 m^3/Hr
FI-202	1.25 ∿ 2.5 m^3/Hr
TI-201	21 ∿ 32°C
TI-202	20 ∿ 50°C
TI-203	20 ∿ 50°C
TI-204	20 ∿ 50°C
TA-201	55°C (annunciator)
ORPA-201	150 mV (annunciator)

3) H.F. Type RO System

Item	Setting Value (Estimated)
PI-301	2.5 kg/cm^2G or more
PI-302	3.0 kg/cm^2G or more
PI-303	1.0 kg/cm^2G or more
PI-304	50 kg/cm^2G or more
PI-305	50 kg/cm^2G or more

Item	Setting Value (Estimated)	
PSA-301	0.1 kg/cm^2G or less (annunciator)	
FI-301	0.84 m^3/Hr	
FI-302	1.25 m^3/Hr ∿ 2.5 m^3/Hr	
TI-301	21 ∿ 32°C	
TI-302	20 ∿ 50°C	
TI-303	20 ∿ 50°C	
TI-304	20 ∿ 50°C	
TA-301	55°C	(annunciator)
PHRA-301	4 or less	(annunciator)
	7 or more	(annunciator)

4) Utility

Item	Setting Value (Estimated)
PI-401	4.0 kg/cm^2G or more
PI-402	6.9 kg/cm^2G or more
PI-403	6.8 kg/cm^2G or more

CHAPTER IV. MAINTENANCE PROCEDURE

1.0 Trouble Shooting for Membrane

1) Introduction

It is recommended to evaluate always the membrane performance of running RO system for finding out future troubles, if it is going to happen, in early age.

The log sheet (see SHAPTER - will be forwarded to the agent and KURITA for this purpose.

The various figures in the log sheet will be plotted graphically for identification.

Salt rejection and the flux are main parameters to chase operating performance. Other various figures in the log sheet are giving the background of main parameters.

Depending on the fed-back log sheet, the evaluation of membrane performance is made.

2) On-line Evaluations

2-1) Performance Classifications

The performance of the membrane will be then classified to four (4) possible cases regarding behaviors of salt rejection and the flux.

The possible classifications (refer to CHAPTER -).

a) Case - 1

Salt rejection	:	Going constant
Flux	:	Going constant or on the line of reasonable compaction

Possible reason	Remedies
Stable operation	None

b) Case - 2

Salt rejection	:	Going down
Flux stable	:	Going constant or on the line of reasonable compaction

Possible reason	Remedies
(1) O-ring leaks	(1) Permeate check Check permeate conductivity on every pressure tube to find out leaks. Then, O-ring correction.
(2) Early age of membrane deterioration	(2) Permeate check For classification of deterioration

c) Case - 3

Salt rejection	:	Going down
Flux	:	Going down

Possible reason	Remedies
(1) Fouling	(1), (2) See CHAPTER -

(2) Scale precipitation

(3) Big salinity increase in raw water

d) Case - 4

Salt rejection :	Going down
Flux :	Going up

Possible reason	Remedies
(1) Physical deterioration	(1),(2),(3) See CHAPTER -
(2) Biological deterioration	
(3) Chemical deterioration	
(4) Released compaction	(4) Give compaction to membrane
(5) Serious O-ring leak	(5) Correct O-ring

2-2) Permeate Check

The permeate conductivity from individual pressure tubes occasionally suggest imporatnt aspect of membrane performance.

Not only O-ring leaks but also other kind of deterioration of membranes are identified by "Permeate check".

The evaluation will always be made by comparison of current values with original value of each permeate conductivity.

There are some classifications.

Case P-1

Almost same electric conductivity are seen in all 1st bank pressure tubes. Higher than 1st tank and almost same conductivity are seen in all 2nd bank pressure tubes.

Possible aspect	Remedies
Normal operation	No

Case P-2

Extremely high electric conductivity are seen on one or more pressure tubes irregularly.

Possible aspect	Remedies
(1) O-ring leaks	(1) Correct O-ring
(2) Biological attack	(2) See CHAPTER -
(3) In-correct brine seal setting or damage on brine seal	(3) Replace brine seal (if any)

Case P-3

Relatively high conductivity and or increasing conductivity are seen in all 1st bank pressure tubes while 2nd bank conductivity are stable.

Possible aspect	Remedies
(1) Physical deterioration is going to take place	(1) See CHAPTER -

Case P-4

High conductivity are seen on all banks pressure tubes.	
Possible aspect	**Remedies**
(1) Chemical deterioration	(1) See CHAPTER -

Case P-5

High electric conductivity are seen on all 2nd bank pressure tubes while all 1st bank conductivity are normal.	
Possible aspect	**Remedies**
(1) Scale precipitation	(1) See CHAPTER -

2-3) Off-line Evaluations

Off-line evaluation will be done after on-line evaluation through both of performance classification and permeate check.

Off-line evaluation necessitates removing membrane elements from pressure tubes for identification.

The following will be clarified by this off-line evaluation at site.

a) Weight measuring

Extremely heavy membrane is accumulating fouling or scale deposit.

Usually weight measuring is carried out after 1 hr drainage of water from membrane element standing feed side up.

Scale accumulating membrane must be replaced.

b) Visual check

Deformations like telescoping of membrane element, U-seal (brine seal) mis-setting or damage, O-ring damage, and etc. are checked and corrected at site.

2-4) Labo-evaluations

For further evaluation, KURITA carryes out labo-investigation to the troubled membrane sent back to Japan in the case that above field evaluation was not enough for trouble shooting.

2) Cleaning frequency

Two times of routine cleanings per year is expected for normal operation. It is recommended to do this two times cleaning per year without reason.
The frequency of cleaning will be increased when upset on the pretreatment occur and or other disturbances.

3) When is RO cleaning made?

a) Six (6) months elapsed since last RO cleaning
b) When salt passage is increased more than 20% not due to O-ring leaks or other obvious reason than fouling.
c) When permeate flux is decreased more than 10% not due to membrane compaction and or high osmotic pressure.

When RO system is in the state of above 1), b) and c) clean RO system without waiting delta-P developes across RO membranes.

d) When delta-P increased more than 30% accompanying salt rejection down and flux down not due to flows, water temperature changes.

4) Procedure of cleaning system

The following cleaning equipment and chemicals are provided.

- $0.5\ m^3$ of Cleaning Tank (T-601) with necessary nozzles and flexible hoses

• SBS	100% crystal
• Citric acid	100% powder
• Ammonia	25% sol
• Formalin	37% sol
• Sodium hexa-meta phosphate	100% powder

The following procedure for chemical cleaning shall be performed:

a) Connect the necessary line from cleaning tank to RO system (permeate, concentrate and chemical feed line).
Necessary nozzles for the above connection have been provided.

b) Prepare chemical solutions.
pH of chemical solution must be checked and corrected by adding ammonia solution.

c) Booster Pumps (P-202, P-302) are used for chemical recirculation. Recirculation time will be 20 to 30 min. so that all membrane elements are completely soaked to the cleaning chemicals.

d) Stop recirculation by stopping Booster Pumps (P-202, P-302) and leave it for 8 to 12 Hrs.
The fouling matters, metal oxides and/or biological matters whatever will be dissolved and/or removed during this soaking time.

Then, RO system will be flushed by RO feed water. The flushing is carried out without high pressure pump running but RO booster pump. Flushing water will be drained through cleaning outlet valve.
The flushing will be continued for more than 2 hours until pH value of flushing water become same as RO feed.
After flushing, RO system is then put into running however, permeate water must be drained at least one hour since start up.

2.0 RO Membrane Cleaning

1) Cleaning Chemicals

a) S.W. type RO system

Name of Chemicals	Necessary for One Time Cleaning
1. Citric acid (powder)	10 kg
2. Ammonia (25% sol) (For adjusting pH 4)	18 kg
3. Formalin (37% sol)	6.8 kg
4. Water (permeate)	0.5 m^3 (net)

In addition to above chemicals, sodium hexa-meta phosphate will be utilized for removal of scale fouling when necessary.

b) H.F. type RO system

Name of Chemicals	Necessary for One Time Cleaning
1. Citric acid (powder)	10 kg
2. Ammonia (25% sol) (For adjusting pH 4)	18 kg
3. SBS (crystal)	250 g
4. Water (permeate)	0.5 m^3 (net)

In addition to above chemicals, sodium hexa-meta phosphate will be utilized for removal of scale fouling when necessary.

3.0 Membrane Element Replacement

More than 2 gangs are recommended when removing RO membrane elements.

Remove the membrane elements from each pressure tube as follows:

1) S.W. Type RO Membrane Element (Rotary SP-120)

1.1) Removal

a) Disconnect victaulic couplings of feed/concentrate connecting tubes (Fig. 7-1) and permeate connecting tubes at each end of the pressure tube. The flexible tubing may remain attached to the end plates. Mark or tag all items removed for return to the same location.

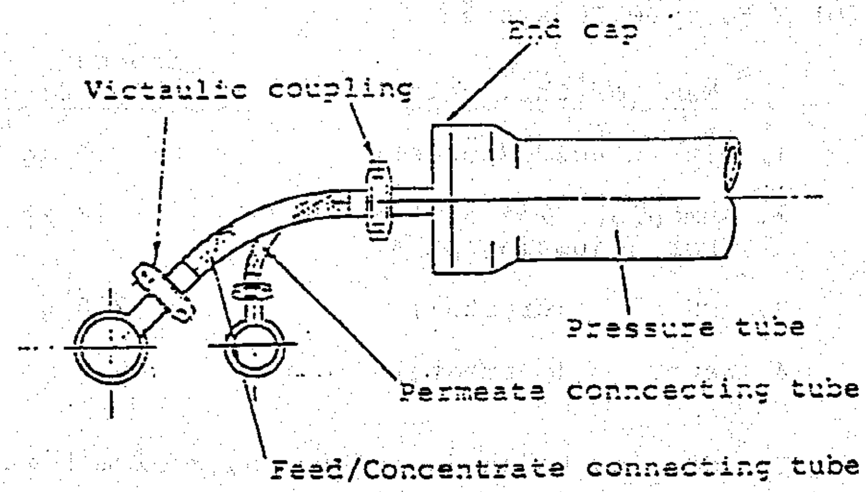


Fig. 7-1

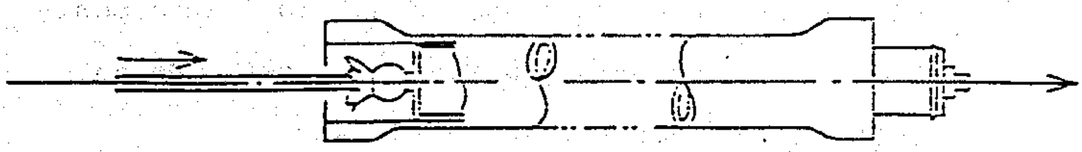
b) Remove clamp nuts and then remove end cap assembly (end plate and end cap) from each end of pressure tube as follows:

i) Remove all clamp nuts from end plate

ii) Carefully withdraw end cap assembly from end of pressure tube. Screw driver is not recommended for jack up. Thin and wider plate are used.

c) Push elements from feed end side with bar like a plastic pipe with one end swab.
The elements should be pushed out one at a time. And each element should be supported at the brine end side until free of the pressure tube as it is being pushed out from the opposite end. (Fig. 7-2)

Push elements from
feed end side



Receive element
not to drop down

Fig. 7-2 Membrane Removal

d) Each removed element has to be marked as it was loaded. And has to be kept on clean desk or others. The permeate tube end must be protected so that O-ring can seal pressure with tube end surface.

1.2) Loading

a) Remove end cap assembly as stated in item 1.2 in para. 3.0 Membrane elements removal.

b) Spray clean water through the open pressure tubes to remove any dust or other forign matter.

Note: In the event that additional cleaning is needed, improvise a swab large enough to fill the inside diameter of the pressure tube. Soak the swab in a glycerine water solution and force it through the pressure tube until clean.

c) Set O-ring to the all necessary positions Lubricate all O-ring seals with vaseline or glycerine. When setting, do not roll into positions. Expand O-ring slightly to set. Do not pull O-ring over any sharp edges.

d) Ensure all brine seals (U-seals) for membrane elements are properly located and lubricated with vaseline.

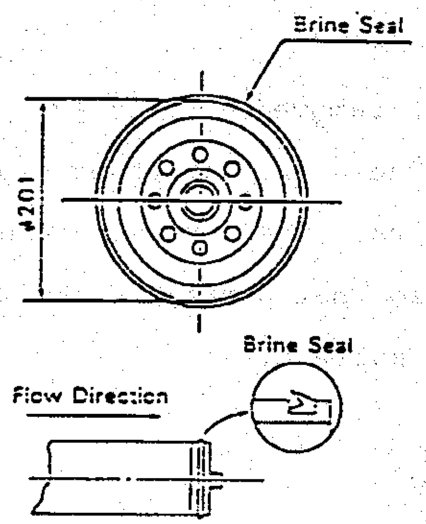


Fig. 7-3

e) Confirm direction of membrane elements loading not to insert reversely. (Insert brine end and push feed end). Set brine end-connector into permeate tube of membrane element on brine side with lubricated O-ring.

f) Place the brine end of the tail end element in the pressure tube and slide it in about three quarters of the element.

g) Set inter-connector with 2 lubricated O-rings into permeate tube of tail end element on feed side.

h) Lift the next RO membrane element into position and insert its brine-end permeate tube into the inter-connector on the tail end elements. The tail end element in this moment must be fixed not to travel. The two elements (tail end element and next element) must be aligned and levelled each other for correct connection. Be very careful to hold the next element so that the weight is not supported by the inter-connector.

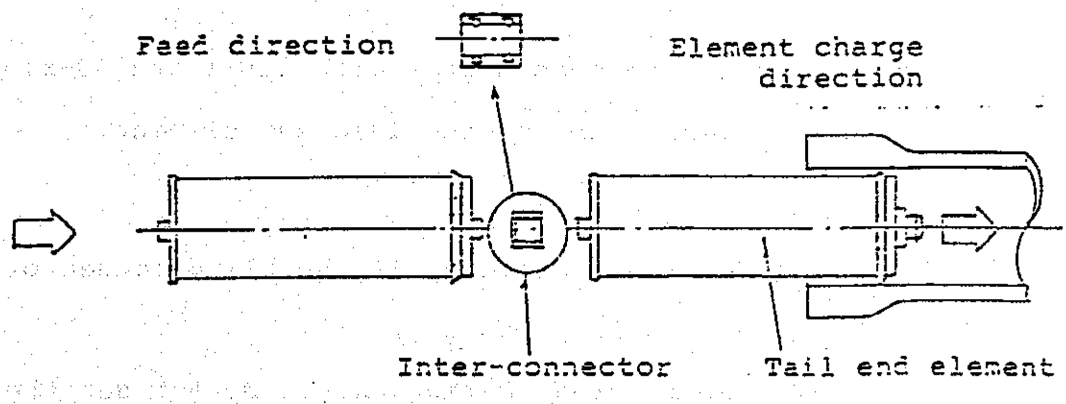


Fig. 7-4 Membrane Loading

i) Push the element into the pressure tube until about one quarter of the second element extends from pressure tube.

j) Repeat steps g), h) and i) until all membrane elements are loaded into the pressure tube.

k) Push again the elements-train to the concentrate side so that tail end element extends approx. 2 to 3 cm from pressure tube brine-end.

l) Set the end cap assembly into the end-connector located on tail end element after lubrication.

m) Push back elements-train with end cap assembly sliding on the guide-stud bolts. And set all clamp nuts with finger-tightening.

Note: Do not over tighten.
Finger tightening plus half turn is the most recommended.

n) Set the feed-end-connector with lubricated O-ring into permeate tube of the lead end element.

Notes:

(1) Feed-end-connector is the blind connector. Not hollow connector.

(2) Set internal O-ring only. Do not set the external O-ring. (important)

(3) Feed-end-connector is also named the feed-end-adopter.

o) Measure the clearance between the shoulder of feed end connector and the inner face of end cap.
Put the adopter spacers to avoid clearance if there is.

p) Set the end cap assembly after lubrication.
Tighten clamp nuts with finger plus half turn.
Do not over tighten.

Note: Set end cap assembly to assure proper alignment with connecting tubes

q) Set the each victaulic couplings properly.

Note: Do not make any clearance between each half of victaulic coupling.
Do not pressurize RO if there is clearance between each half of victaulic coupling.

1.3) Reducing Membrane Numbers in Pressure Tube for S.W. Type RO System

Reduce membrane element numbers in pressure tube as following procedure (when necessary by some reasons).

a) It is necessary to unload all membranes out from pressure tube even when reduce one or two elements.

b) Repeat same procedure as stated 3.0 for membrane replacement.

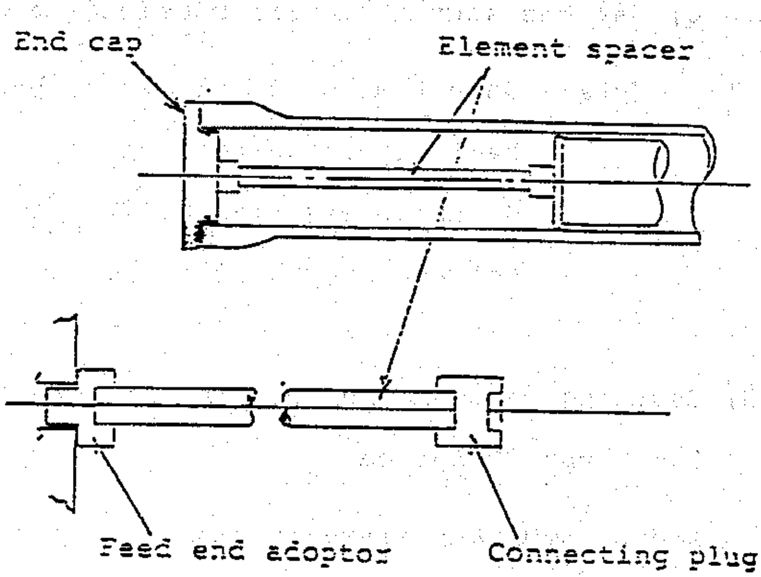
c) Delete membrane element from lead and position which is feed-inlet side.

c) Load elements as stated turn but only for last element (lead end element), place "Element spacer" instead of the last element.

Notes:

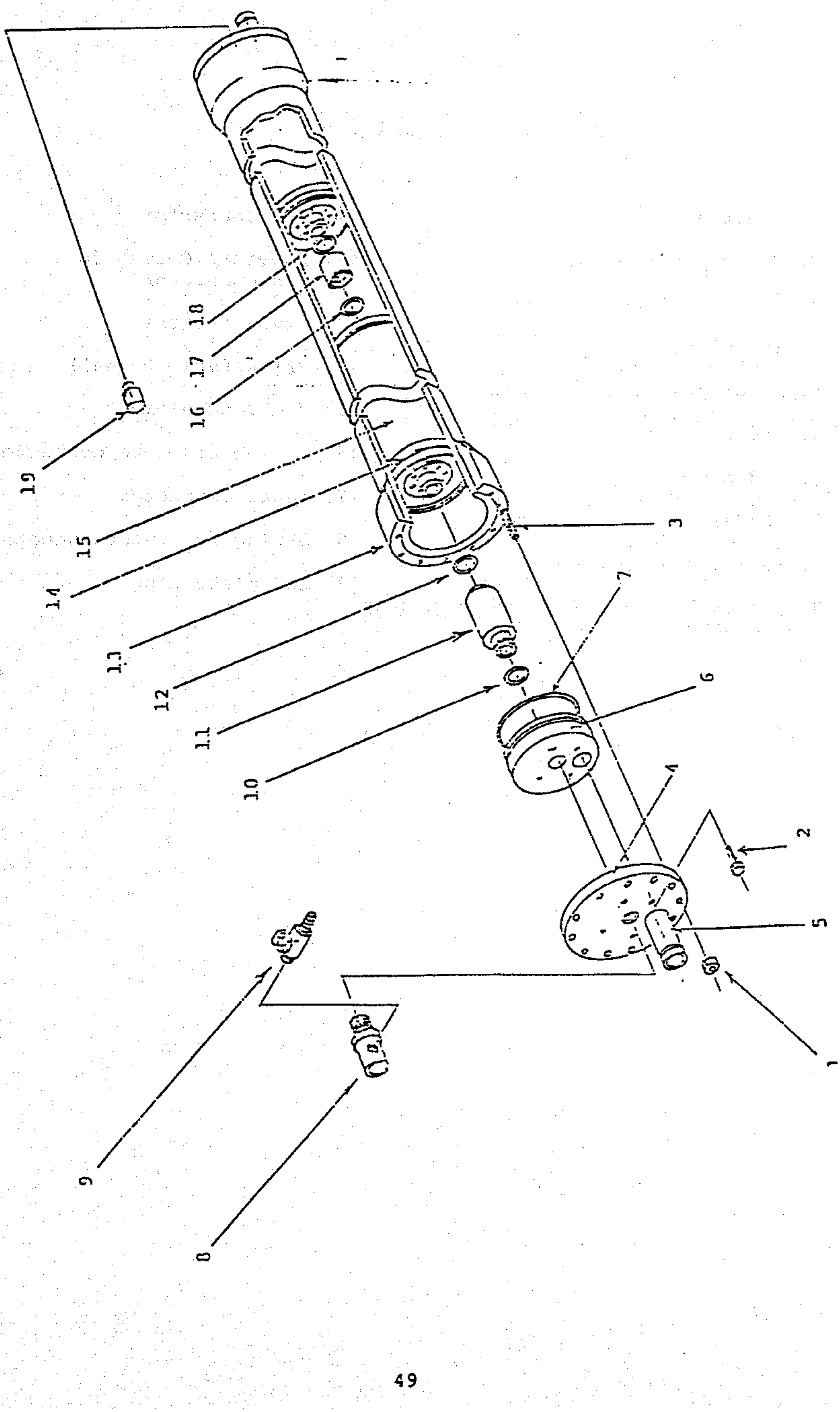
(1) Set the connecting plug (blind inter-connector) instead of inter-connector at feed end of 2nd element.

(2) The same procedure is taken for feed end adopter.



Adoptor, spacer may be necessary to avoid clearance.

Fig. 7-5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Pressure Tube Assembly

1. Clamp nut
2. End cap fixing bolt
3. Pressure tube stud bolt
4. End plate
5. Feed/connectrate nozzle
6. End cap
7. End cap O-ring
8. Permeate hose connector
9. Permeate sample cock
10. External O-ring for end connector end connector
11. End connector
12. Internal O-ring for end connector
13. Pressure tube
14. Brine seal (U-seal)
15. Membrane element
16. O-ring for interconnector
17. Inter-connector
18. O-ring for interconnector
19. End plate plug

2) H.F. Type RO Membrane Element

(Toyobo HM8255, HR8355)

2.1) Removal

a) End plate A (product outlet side) shall be removed, and then the support plate on tube sheet shall be taken out of the shell.

b) The element shall be push out of the shell up to the point where O-ring #2 appears by feed water pressurized at 3 kg/cm².

c) The element shall be pulled out from the shell by hands. When tube sheet is caught by the stopper ring, the element can be turned in the shell slightly in order to be pulled out easily.

d) End plate B (feed water inlet side) shall be removed as the above manners.

e) Inside wall of the shell shall be washed by a sponge with soap.

2.2) Loading

a) A new element is sealed by laminate films filled with 0.8 wt% formalin and packed in a carton box.

b) Before unsealed, the element shall be investigated if there is no defect on the surface or O-ring of the element.

Then new element shall be pulled out from the films.

c) Insert of new element into the shell

- O-ring #2 shall be covered slightly with silicon grease and it shall be fitted with O-ring slit on tube sheet.
- The element shall be put into the shell by hands with care to kept streight on.
- When the element could not reach smoothly the point illustrated in Figure 1, use an element insertion flange (exclusive jig) for insertion. In this case, be careful not to hit the element at the center.
- Tube sheet would be damaged by colliding with the stopper ring, if the element would be forced to be put into the sheel exceeding the point indicated in Figure 1.

d) A supporting plate shall be attached on the open end of the tube sheet.

e) Assembly of end plate A
After checking O-ring #4 has no defect, end plate A shall be fastened.
The torque must be kept less than 200 kg-cm.

f) Assembly of end plate B
After checking O-ring that O-ring #3 is fitted in a connector and that O-ring #1 has no defect, end plate B shall be set on the shell by using a guide rod in the manner illustrated in Figure 2.

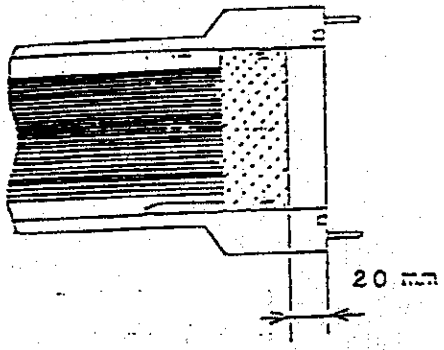


Figure 1

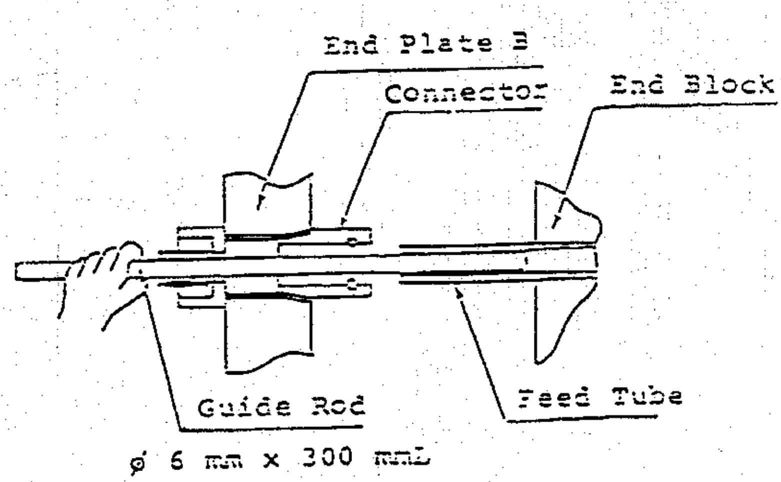
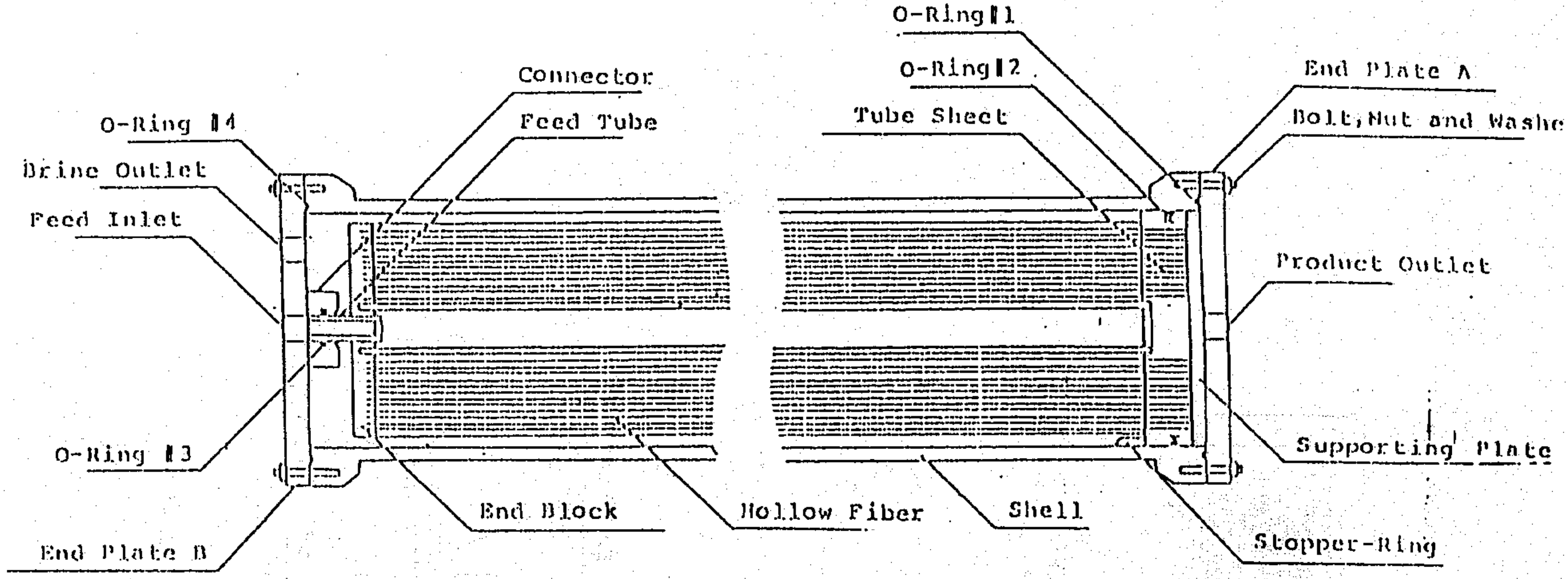
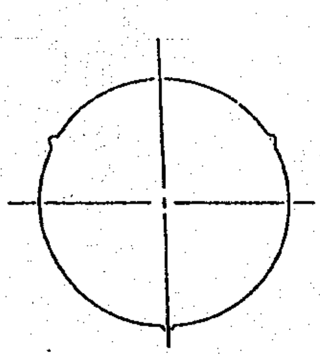


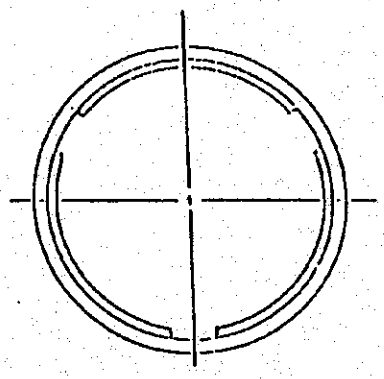
Figure 2

Figure 3 Structure of HOLLOSEP





Cross Section's Outline of End Block



Cross Section of Shell on Stopper-Ring part

CHAPTER V. WHAT IS RO?

1.0 Principle of Reverse Osmosis

1) Introduction

In this section, we will attempt to provide a basic description of the Reverse Osmosis (RO) theory briefly. We hope clients understand the theory logically and utilize the principles reasonably.

2) RO Principles

RO is one of the membrane permeation processes for separating pure water (or other solvent) from a less pure solution. A semipermeable membrane and an appropriate pressure are indispensable, that is, the solution is passed over the surface of an appropriate semipermeable membrane at a pressure in excess of the effective osmotic pressure of the feed solution and only pure solvent permeate through the membrane and then solutes are rejected and concentrated at the feed solution side. Solvent is mostly water but any other liquid is applicable, and solutes are mostly inorganic salts but any other organic salts or organic compounds are to be applied.

To understand how RO works, consider natural osmosis. In Figure 1.a, when fluids of different degrees of concentration are separated by a semipermeable membrane, the water (or solvent) permeates through the membrane from the dilute solution into the concentrated solution. This is known as "Osmosis".

The osmotic flow continues until a state of equilibrium is reached. Once equilibrium is attained, the difference in fluid level becomes equal to what is known as "Osmotic Pressure" of the solution (See Fig. 1.b).

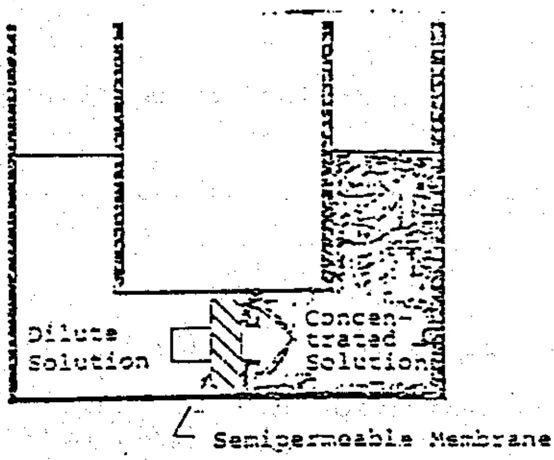


Fig.1a Osmosis

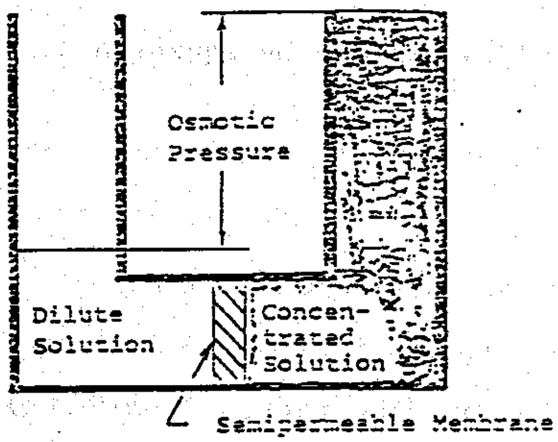


Fig.1b Osmotic pressure

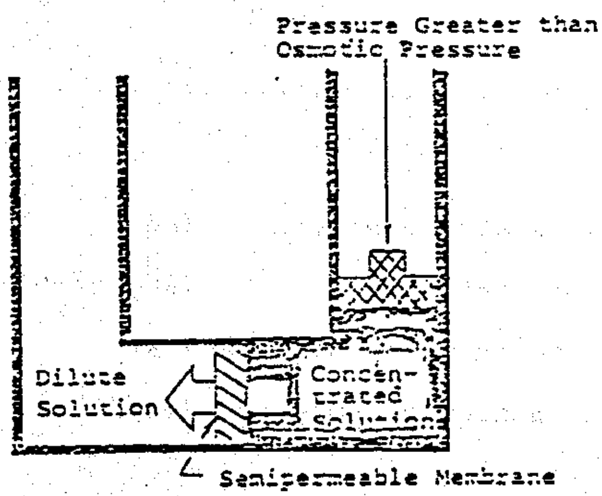


Fig.1c Reverse osmosis

Fig.1 Reverse osmosis principle

The term of "Rejection" is defined by equation 3.

$$Ref. = (1 - \frac{C_p}{C_M}) \times 100 \quad \text{.....................} \quad (3)$$

where,

Rej.:		rejection of solute	(%)
C_P	:	solute concentration in permeate	(g/ℓ, mol/ℓ)
C_M	:	solute concentration on membrane surface	(g/ℓ, mol/ℓ)

The term "Recovery" is defined by equation 4.

$$R_C = \frac{Q_P}{Q_F} \times 100 \quad \text{.............................} \quad (4)$$

where,

R_C	:	recovery or conversion	(%)
Q_P	:	product solution flow rate	($g/cm^2 \cdot sec$)
Q_F	:	feed solution flow rate	($g/cm^2 \cdot see$)

And the ideal "Osmosis Pressure" is defined by equation 5.

$$\Pi_{id} = R\ T \sum_s C_s \quad \text{.............................} \quad (5)$$

where,

Π_{id}	:	ideal osmotic pressure	(atm)
R	:	gas constant	(atm·ℓ/mol·°K)
T	:	absolute temp. of solution	(°K)
C_s	:	concentration of solutes	(mol/ℓ)
$\sum_s$	:	summation	

If the osmotic pressure is overcome, as in Fig. 1.c, by the application of an external pressure to the concentrated solution, the water (or solvent) in this solution will permeate into the dilute solution. This is called "Reverse Osmosis".

As mentioned above, RO is a process involving neither phase transition nor chemical reactions. So, RO process has a merit especially in saving energy and can be applied to any water purification process or solutes recovery process requiring the separation of fluids into permeate and concentrate forms.

3) Performance Variables

To a first approximation, two equations define the passage of solvent (water) and solute (dissolved solids) through the semipermeable membrane:

$$Q_{solvent} = A\,(\Delta P - \Delta \Pi) \qquad (1)$$

$$Q_{solvent} = B \cdot \Delta C \qquad (2)$$

where,

Q :	solvent or solute flow through membrane	$(g/cm^2 \cdot sec)$
A :	membrane permeability coefficient for solvent	$(g/cm^2 \cdot sec \cdot atm)$
B :	membrane permeability coefficient for solute	(cm/sec)
ΔP:	applied pressure differential	(atm)
$\Delta \Pi$:	osmotic pressure differential	(atm)
ΔC:	solute concentration differential	(g/cm^3)

2.0 Characteristics of Membrane

1) Net Effective Pressure

The most significant driving force to the Reverse Osmosis membrane performance is the pressure applied to the membrane among various factors which are giving effects to membrane performance.

Generally, the applied pressure to the membranes are illustrated in following equation:

$$Pa = Pn + Po + \frac{1}{2}\text{ delta-P} + Pb$$

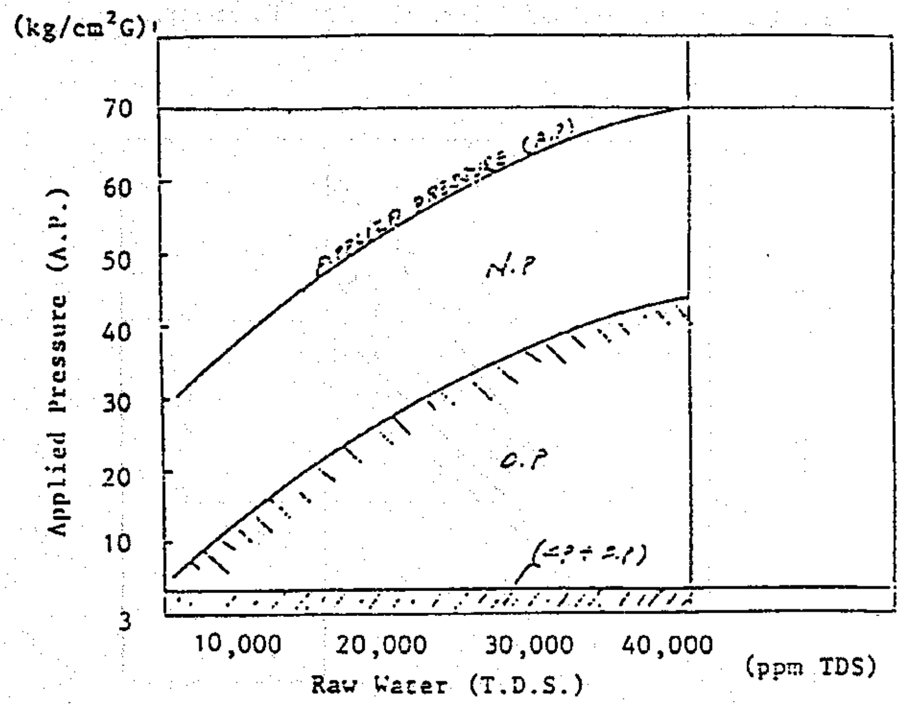
where,

Pa	:	applied pressure to the membranes and shown as reading of RO inlet pressure gauge (kg/cm²G)
Pn	:	net effective pressure which gives performance to the membranes
Po	:	mean osmotic pressure of concentrated water in the RO membrane system (kg/cm²G)
$\frac{1}{2}$ delta-P	:	50% of delta-P across membrane system and can be obtained from the pressure difference between applied pressure and outlet pressure of concentrate water (kg/cm²G)
Pb	:	the back pressure on the permeate water line which is given by the locations and piping resistance (kg/cm²G)

As shown in above equation, the applied pressure Pa is the total sum of various component of pressure. And the net pressure Pn is actual driving force to the performance of membrane. Besides, standard performance of the membrane is designed and defined by each membrane manufacturer as of under the standard operating conditions which give certain amount of net effective pressure.

Applied pressure Pa would be constant to give constant performance to membranes when Po and delta-P are constant.

- See Applied Pressure - Raw Water TDS Curve -



Note: Delta-P and back pressure on permeate line are almost constant as they are matters of pretreatment and the plant piping design.

2) Membrane Flux

Membrane flux (permeate flow rate) varies proportionally to net effective pressure under the constant water temperature. And also membrane flux varies with power to water temperature.

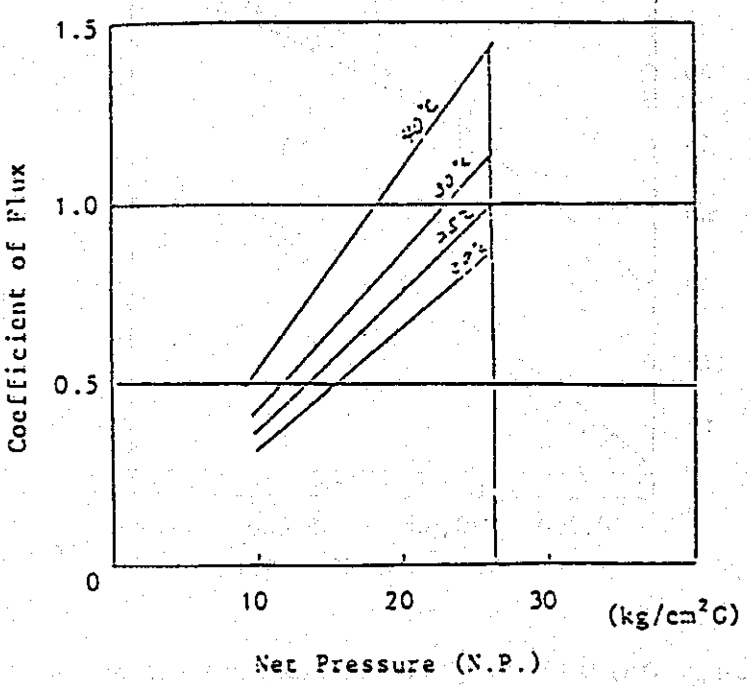
Fough equation:

$$\text{Flux multiplier} = 1{,}028^{(t - 25)}$$

where, t: water temperature

Thus, the flux is the function of net effective pressure and water temperature.

- See Coefficient of Flux VS Net Pressure -



3) Salt Rejection

The salt rejection (%) of membrane also varies reverse-proportionally to net effective pressure.

- See Salt Rejection VS Net Pressure -

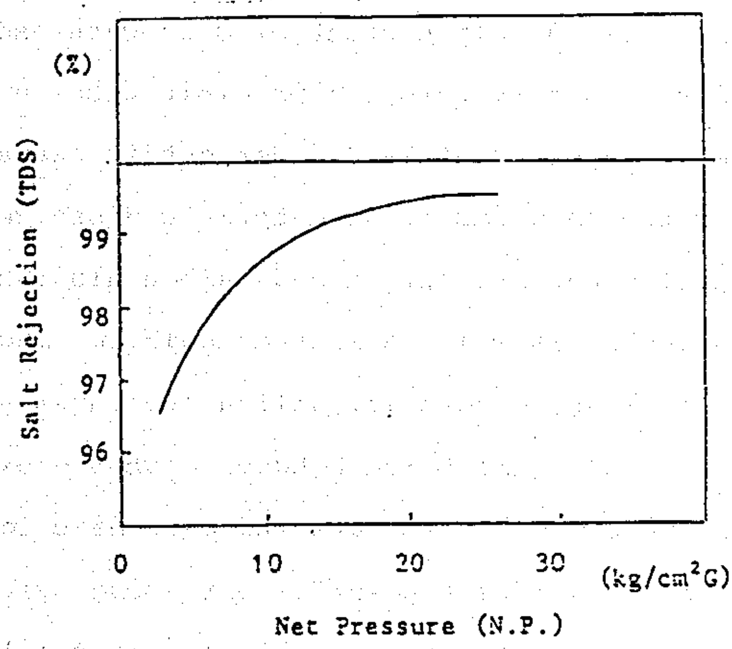


Fig. 3 N.P. - Salt Rejection

4) Water Recovery Rate

The water recovery rate (conversion rate) determines the concentration of water in RO membrane system and give directly effect to permeate water quality (TDS ppm) in the constant salt rejection condition.
For higher TDS feed water, RO system will be operated in a lower recovery rate to keep requested permeate

quality (TDS ppm). And for lower TDS feed water, higher recovery rate can be applied within the range of scale precipitation inhibition.

5) Feedwater Treatment Required for Membrane

Pretreatment Considerations

The dissolved salt content of most water sources varies from near zero for precipitation in remote areas to approximately 3.5 percent in seawater. Among the more imporatnt materials dissolved in natural water are oxygen and carbon dioxide from the atmosphere, as well as ions of calcium, magnesium, sodium, iron, manganese, silica, sulfates and chlorides. The equilibrium between carbon dioxide in the atmosphere and bicarbonate and carbonate ions in solution provides a powerful buffering system, so that natural water nearly always fall in a fairly neutral pH range of 5 to 9.

Pretreatment of the feed is necessary in all desalination methods, and reverse osmosis is no exception. In general, feed and brine streams are treated for the following purposes:

i) To remove excess turbidity or suspended solids.
ii) To adjust and control the pH and temperature of the feed.
iii) To inhibit or control the formation of compounds,

which when precipitated will plug the water passages or coat the membranes.

iv) To disinfect and prevent slime growths or prevent contamination of the equipment.

v) To remove emulsified and unemulsified oil or similiar organics.

Flux decline with time is the most serious operational problem. It is common to all reverse osmosis design concepts and other membrane processes as well. Flux decline is the sum of membrane compaction and fouling. At low operating pressures (35 kg/cm or less and 30°C feed water temp.), the latter effect usually predominates.

The major pretreatment requirement for any RO device is the prevention of membrane fouling. Fouling, a complex phenomenon, affects all types of membranes and devices, although the degree of severify may vary. Five types of fouling should be considered, (a) membrane scaling, (b) fouling by metal oxides, (c) device plugging, (d) colloidal fouling, and (e) biological fouling. Membrane fouling can sometimes be minimized by periodic cleaning. The proper amount of pretreatment (and cleaning), therefore, is a major decision in reverse osmosis design.

The quality of feed water required by membrane processes is shown below. All membrane configurations, except tubular, have limited capabilities for treatment of feed water containing suspended solids. The smaller the clearance between the adjacent membranes, the tighter the requirements are for turbidity and silting index - plugging factor - of the feed water as noted also, below:

a) Feed water identification

Fouling index 4.0 or less

b) Allowable SDI (Silt Density Index)

SDI < 5.0

Each membrane process has established limits on most of the dissolved solids which tend to form insoluble precipitates within the membrane elements. Among these are iron, manganese, strontium, barium and silica. Iron and manganese seem to be of major concern to each membrane process, with maximum levels much lower than the other dissolved solids. Chlorine is used to inhibit organic growths in feed water. The membrane systems, however, have a limited tolerance to residual chlorine. The maximum permissible and minimum suggested residuals are,

0.3 - 1.0 ppm

However, non-cellulose acetate membrane (composite membrane) is strictly inhibited residual chlorine and dissolving oxygen.

The maximum permissible and minimum suggested values are,

Residual chlorine	0 ppm
Dissolving oxygen	Max. 0.5 ppm

The membrane processes recommend (a) addition of 2 to 20 ppm of sodium hexametaphosphate (SHMP) to the feed water to suppress scale precipitation, and (b) adjusting pH to the values 4 to 6 to prevent calcium carbonate formation and/or to prevent hydrolysis of the cellulose acetate membranes. The maximum recommended operating water temperature is 35°C. Short period of higher water temperature is also acceptable unless it is over 40°C. Operation at temperature above these limits results in accelerated deterioration of membrane performance.

3.0 Chemicals Compartibility

This Chapter discusses the chemical compartibility of the membrane.

1) Effect of Low pH

Very low pH adversely affects membrane performance and integrity by hydrolysis. With respect to low pH, the recommendation is,

a. The pH in the membrane element must be 4.0 or more for continuous operation.

b. Membrane elements must not be exposed to pH 2.0 or less for more than 60 minutes at such time of chemical cleaning and/or start up time.

2) Effect of High pH

High pH adversely affects the membranes. With respect to high pH the recommendation is,

a. The pH in the membrane elements must be 6.5 or less for continuous operation.

b. The membrane accept higher pH than 6.5 up to 7.5 for short time but limited by $CaCO_3$ scale precipitation.

c. The membrane must not be exposed to higher pH than 8.0.

3) Long Term Exposure to Following Oxidants

a. The cellulose acetate membranes are degraded by oxydants.

H_2O_2, KM_3O_4, O_3, Na_2SO_5, CH_3CO_3H, etc.

Residual chlorine of more than 1 ppm is not recommended for long term operation.

b. The non-cellulose acetate membrane (composite membranes) are strictly inhibited oxidants.

4) Long Term Exposure to the Solvents Containing Water

When RO feed water contains the solvents to membrane, membrane performance will be degraded. The solvents will be numerous kinds such as aromatic substances in the chemical processes and others.

In general, water soluble organic compounds must be individually tested for compartibility.

Waste water from aromatic chemical processes must be avoided for safety.

5) Effect of Scale Inhibitors

Following scale inhibitors are chemically compartible to the membranes:

a. SHMP (Sodium Hexa Metha Phosphate)

b. Sodium polyacrylate

c. Organic polyphosphonate

d. Chlorine max. 1.0 ppm as Cl_2

6) Cleaning Agent

a. Citric acid (But compartible pH range only)

b. EDTA (But compartible pH range only)

c. Ammonia (But compartible pH range only)

d. Formalin (But compartible pH range only)

Max. 5,000 ppm

e. SHMP

f. Triton X-100 (as detergent)

7) Lubricants

a. Vaserine

b. Glycerine

4.0 Spiral Wound Element and Hollow Fiber Element

1) Introduction

Currently more than 4 kinds of commercially available membranes are utilized in Reverse Osmosis application field.

They are,

a. Spiral wound type

b. Hollow find fiber type

c. Tubular type

d. Plate and frame type

Aboves are the classification based on the membrane configurations. The spiral wound type and hollow fine fiber type are mainly utilized for both brackish and seawater desalination. The tubular and the plate and frame type are utilized mainly for waste water reclamation and/or foods-concentration.

a) Comparison of spiral wound type and hollow fine fiber type

The comparison on the membrane configuration is represented by the comparison of S.D.I. (Silt Density Index) value required for RO feed water.

SDI for spiral wound :	Max. 5.0
SDI for hollow fiber :	Max. 3.0

Obviously spiral wound membrane accept wider range of pretreatment. And hollow fiber membrane requires more severe pretreatment.

b) Membrane materials

Generally membrane materials can be classified into two groups.

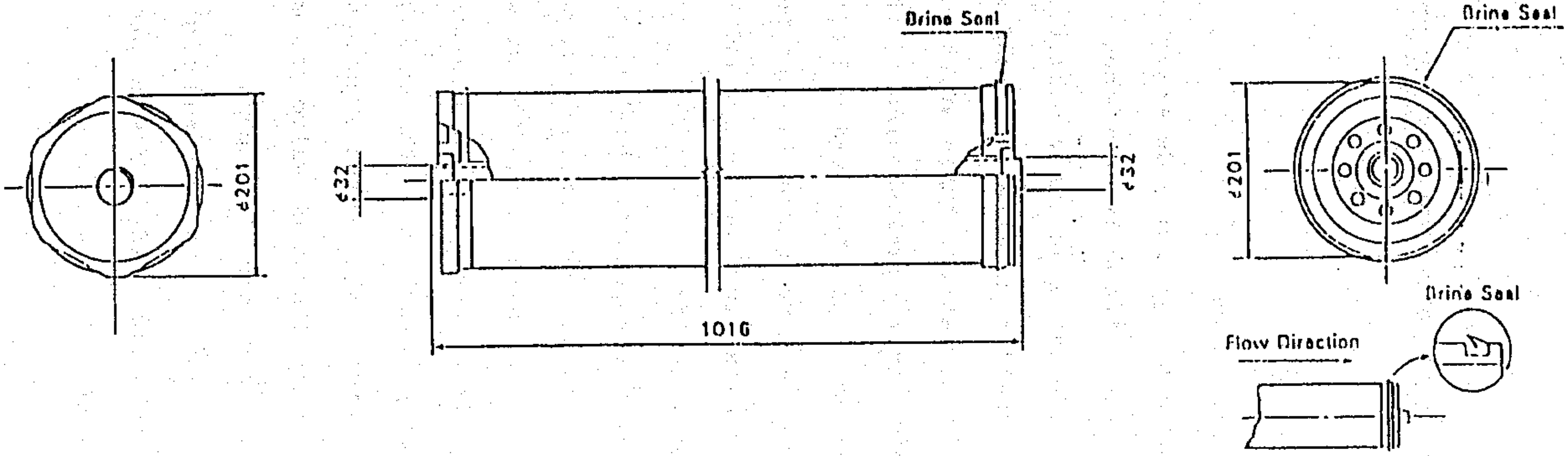
i) Cellulose acetate group
ii) Aromatic polyamide group

Each material has its advantage and disadvantage as follows:

	CA	PA
Allowable pH range	4 ∿ 7.5	4 ∿ 9
Residual chlorine tolerance	3.0 ∿ 1.0 ppm as Cl_2	0.0 ppm as Cl_2
Max. water temp. acceptable	40°C	35°C

Usually, membranes are selected by the plant requirements and circumstances. Such as salt rejection, pretreat, water temperature acceptability, and etc. Then RO system is designed and is operated so as to meet membrane requirement.

TYPE SC-3200 ELEMENT



CHAPTER VI. MEMBRANE DETERIORATION AND REJUVENATIONS

1.0 Membrane Deteriorations

1) Physical Deterioration

When membranes are physically deteriorated by some reasons, membranes gradually lose their salt rejection and increase simultaneously permeate flux.
In this deterioration usually, the load end elements in the first bank pressure tubes start to deteriorate in a short time after commissioning of the RO system. And in the extreme case, the lead end element may completely lose salt rejection in one week time accompanying permeate flux increasing and has no more ability of desalination.
Not only the lead elements in the first bank pressure tubes but also 2nd elements in the same pressure tubes will be deteriorated next, 3rd, 4th, as well.
This happens under certain physical conditions created by high pressure valve throttling, feed/concentrate velocities, high pressure pump selection, delta-P across pump discharge valve and etc. And will proceed very swiftly once it happens.
It is very important accordingly and highly recommended to follow strictly the guide lines to protect deterioration of membranes.

Guide Lines

a. Do not throttle pump discharge valve more than allowable limitation 10 kg/cm^2G delta-P across valve.

b. 60 kg/cm^2G or higher pressure be applied.

c. Delete and add membrane elements so as to meet above conditions a. b.
When necessary, delete lead and elements in first bank pressure tubes and put element spacers for fixing.

d. Do not give higher feed flow rate than max. allowable 3.4 m^3/Hr to the individual pressure tubes.
Above guide lines should be followed unless otherwise indicated.
High pressure pipes and valves are sized and selected so as to meet specified flow rate and pressure. The big percentage of nominal capacity change (capacity decreasing) are not recommended.

2) Biological Deterioration

When membranes are biologically deteriorated, membranes gradually lose their salt rejection and increase simultaneously permeate flux.
This biological deterioration may happens either in running RO or in long term - shut down RO when conditions are met.

Membranes exposed to biological attack lose salt rejection in a short time and increase permeate flux. And generally deteriorations happen at random and difficult to find out certain relation between location of membrane and deterioration.
It is very important accordingly and highly recommended to follow strictly the guide lines to protect deteriorations of membranes.

<u>Guide Lines</u>

- For Running RO -

a. Keep chlorine residual 0.3 to 1.0 ppm all the time.
   (This will be the perfect remedy for operating RO.)

b. Lower RO feed pH in the case that residual chlorine cannot be kept by some reasons.
   (This is temporary remedy only.)

c. Minimum two times RO cleaning annually adding formalin solution.

- For Shut down RO -

a. Soak membranes in 0.5% formalin solution pH controlled 4.0 to 4.5.
   (For long term shut down)

b. Replace soaking solution of 0.5% formalin pH controlled 4.0 to 4.5 monthly. (For long term shut down)

The monthly replacement of formalin solution must be strictly followed.

c. It is not necessary to remove membrane elements during long term shut down unless ambient temperature goes up over acceptable limit.

d. Shut down less than 2 weeks doesn't require formalin solution treatment but weekly or more frequent flushing using conditioned water is necessary. This must also be strictly followed.

3) Chemical Deterioration

Chemical deteriorations including hydrolysis of membranes happen in following cases:

a. Long term operation on unusual RO feed pH

The recommended feed pH range is 4 to 6 (6.5). And even in allowable pH range for membrane 3.0 to 4.0 and 6.5 to 8.5, hydrolysis may take place in long term operation. For higher pH operation, not only hydrolysis but also $CaCO_3$ precipitation may take place.

As summary, pH control on RO feed must be strictly followed.

b. Long term exposure to following oxidants

The cellulose acetate membranes are degraded by oxidants.

H_2O_2, KM_3O_4, O_3, Na_2SO_5, CH_3CO_3H, etc.

Residual chlorine of more than 1 ppm is not recommended for long term operation.

c. Long term exposure to the solvent containing water

When RO feed water contains the solvent to cellulose acetate membrane, membrane performance will be degraded.

The solvents to cellulose acetate will be numerous kinds such as aromatic substances in the chemical processes and others.

In general, water soluble organic compounds must be individually tested for compartibility.

Waste water from aromatic chemical processes must be avoided for safety.

When chemical deterioration happens, membranes gradually lose salt rejection and increase simultaneously permeate flux. And deterioration takes place almost all membranes exposed to the same kind of water.

4) Fouling/Scale Precipitation

When membranes are accumulating fouling matters and/or scale precipitations on their surface, the performance of the membrane will be degraded.

The degradation will appear on salt rejection and flux.

That is, flux decrease and salt rejection decrease.

And in extreme case, delta-P across membrane will be increased.

a. Fouling

Fouling is not deterioration of membrane and it is possible to restore membrane performance by cleaning. The most popular fouling matters will be ferric iron and/or organic matters. As described above, salt rejection goes down accompanying flux decreasing. This phenomena can be foreseen by routine millipore check and others.

To avoid fouling, following guide lines must be followed:

Guide Lines

i. Always ensure pretreatment operation and keep millipore check colour grade less than 10 and less than 5 minutes filtration time.

ii. If fouling happens or going to happen, don't wait delta-P across membranes increase.
Chemical cleaning should be done to restore salt rejection and flux. And correct pretreatment.

b. Scale precipitation

It is important and be underlined that it is impossible to remove scale precipitation once it is precipitate and deposit on membrane surface. And scale deposit will grow up once it is formed.

No chemical cleaning, no flushing will help to remove except $CaCO_3$ scale.

$CaCO_3$ (calcium carbonate) scale will be formed under high pH operation. And can be removed by acid cleaning and/or low pH operation.

Other precipitations such as $CaSO_4$, $BaSO_4$, SiO_2, etc. cannot be removed completely by any chemical cleaning.

Perhaps membrane elements must be disposed and replaced once scale precipitation and deposition take place on membrane surface, no way to restore.

Following guide lines therefore strictly followed:

Guide Lines

i. Ensure dosing of scale inhibitor in accordance with instruction.

ii. Make flushing using conditioned feed water at every shut down to displace brine water from RO system.

iii. Do not increase water recovery rate than specified unless otherwise indicated.

iv. Lower pH operation necessary for silica saturation water.

2.0 Rejuvenation

It is possible to restore performance which was deteriorated during operation or shut down unless it was degraded due to scale precipitation.

1) RRC

Rejuvenating chemical RRC will be used for this purpose after correcting source of deteriorations.
The RRC is the chemical, food additive grade and is dosed to RO feed line by chemical feeder while RO is in running.
Then performance of membranes will be restored in a short time. RRC is so called "Hole plugging rejuvenation" and will be effective to the deterioration of membranes which have decreased salt rejection and increased flux.

2) Method of RRC Dosing and Rejuvenation

Dissolve RRC 10% or less in filtered water (not in permeate water, usually in neutral pH water) and dose to running RO system using chemical feeder.
The injection point will be up stream of micron filter.
Dosing rate to RO feed is in the wide range of 1 ppm - 100 ppm.
Watching to permeate conductivity, flux and pressure is necessary during dosing. And stop dosing immediately when target performance are restored.

Generally, flux will gradually decrease, permeate conductivity will also be gradually decreased and operating pressure will increase by this RRC dosing.

3) Post Treatment for RRC Dosing

It is standard procedure to lower pH 4.0 - 3.0 at RO feed for stabilization of RRC.
The permeate flux will be decreased extremely by this 4.0 - 3.0 feed pH.
Perhaps flux will drop down to 20 to 30% of designed flux in this moment. Keep lower pH for 2 to 3 Hrs. to stabilize RRC.
Adjust RO feed pH to normally operating value 6.0 to 5.8 after stabilization. Permeate flux will come up to normal value.

4) pH Sensitivity

RRC treated RO membranes are extremely pH sensitive.
In 5.5 or less pH, flux decreases extremely (to 20 - 30% of original value). Usually 6.0 pH is the most adequate operating pH.
An automatic pH control loop must not be used when RRC is applied to membranes. Manual set pH control only.

5) Storage

RRC solution will be stored in cool and dark place.
And the life will be more than 2 years unless container is opened and exposed to air.

CHAPTER VII. LOG TAKING AND COMMUNICATION

1.0 Necessary Communications

It is essential to communicate each other; plant user and supplier, or plant user, local agent and plant supplier. It is strongly recommended for the plant user to forward operation log sheet at least monthly filling up necessary items and in turn, plant supplier give comments of the users report.

In the case that local agent service net work is available, the communications will be done through local agent or firm.

The followings are normal communications summarized:

1) Operation log sheet forwarding monthly (through agent)
2) Comments on operation from supplier (through agent) Telex or letter whichever
3) Telephone/telex communication when urgent on any problem happend.

Above communications is necessary from start up time for long life of the plant.

2.0 Minimum Log Taking

1) Log Sheet

The operating log sheet describes the performance of the RO system. The operating data must be routinely filled up in log sheet during the life of the plant.

They must include:

- Flows (product and brine)
- Pressures (high pressure pump suction, discharge, RO inlet, and brine outlet)
- Water temperature (RO feed)
- pH (RO feed)
- Conductivity (RO feed, permeate and brine)
- Chemical consumptions (chlorine, scale inhibitor, acid SBS)
- Milli-pore check (colour grade, filtration time)
- Hours of operation
- Unusual incidents (up sets in pretreatment, shut down, pH, pressure, etc.)
- Permeate check

2) Recommended Frequency of Data Collection

The minimum figures are as follows:

	Per Shift	Daily	Monthly
a. Flows	2 times		
b. Pressures	2 times		
c. Water temperature	2 times		
d. Conductivity & pH (panel)	2 times		
e. Residual $C\ell_2$ (RO feed)	2 times		
f. Milli-pore-check		1 time	
g. Running hrs		1 time	

	Per Shift	Daily	Monthly
h. Conductivity (potable)		1 time	
i. pH (potable)		1 time	
j. Salt rejection		1 time	
k. Chemical consumption		1 time	
l. Permeate check			2 times
m. Water analysis (raw permeate)			1 time

n. Unusual incident - on occurrence

3) Maintenance Log

a. Start up record

Record keeping must cover all supplied equipment such as lubricant changed, brand name, volume, bearing temperature, etc.

For RO membranes, it is recommended to record serial numbers of individual membrane elements charged to pressure tubes. Locations of elements, tag No. of pressure tube and serial number of elements must be clearly recorded for future maintenance.

b. Maintenance log

Maintenance record must be kept on the plant.

The logs include

- Routine maintenance
- Mechanical failure
- Membrane replacement
  Serial numbers, locations, etc.

- Cleanings (chemicals and conditions)
- Long term shut down (conditions)
- Frequency of micron filter backwash

Appendix 8.1.1-1

Trihalomethane Removal by reverse Osmosis

Behavior of Trihalomethane in Reverse Osmosis Sea-Water Desalination Process

It is a well-known fact that the membrane separation performance of trihalomethane in sea water feed to SWRO differs with the material of the RO membranes. On the other hand, the amount of trihalmethane generated can be suppressed by treating sea-water without free chlorine. A research report on the experiments carried out on this point.

1. Introduction

In the reverse osmosis (RO) desalination of seawater, chlorine is injected in the sea-water at the water intake to prevent biological fouling. As bromine and trace quantities of organic matter are contained in sea water; trihalomethane (THM), mainly bromoform, is generated with the addition of chlorine. Seawater desalination tests on sea water were, therefore, conducted using two types (cellulose acetate, and polyamide) reverse osmosis membrane. Treatment with chloramine, a sterilization agent was used instead of chlorine.

2. Test Procedures

(1) Treatment Flow of the Test Plant

The flow sheet of the test plant is indicated in Fig. 1. Sea water was taken from a depth of 3m. For chlorination, sodium hypochlorite was added at the water intake, and the concentration of free residual chlorine was 0.3mg/L. For treatment with chloramine, ammonium chloride and sodium hypochlorite were added at the outlet of the raw water tank to generate chloramine, ferric chloride was added as flocculant and sand filtration was conducted. For RO treatment with the polyamide membrane, sodium bisulfite was added in ahead of the cartridge filter to remove residual chlorine. The recovery of permeate by RO treatment was 40%. An operation pressure of 54 - 57kgf/cm^2 was applied to the cellu-

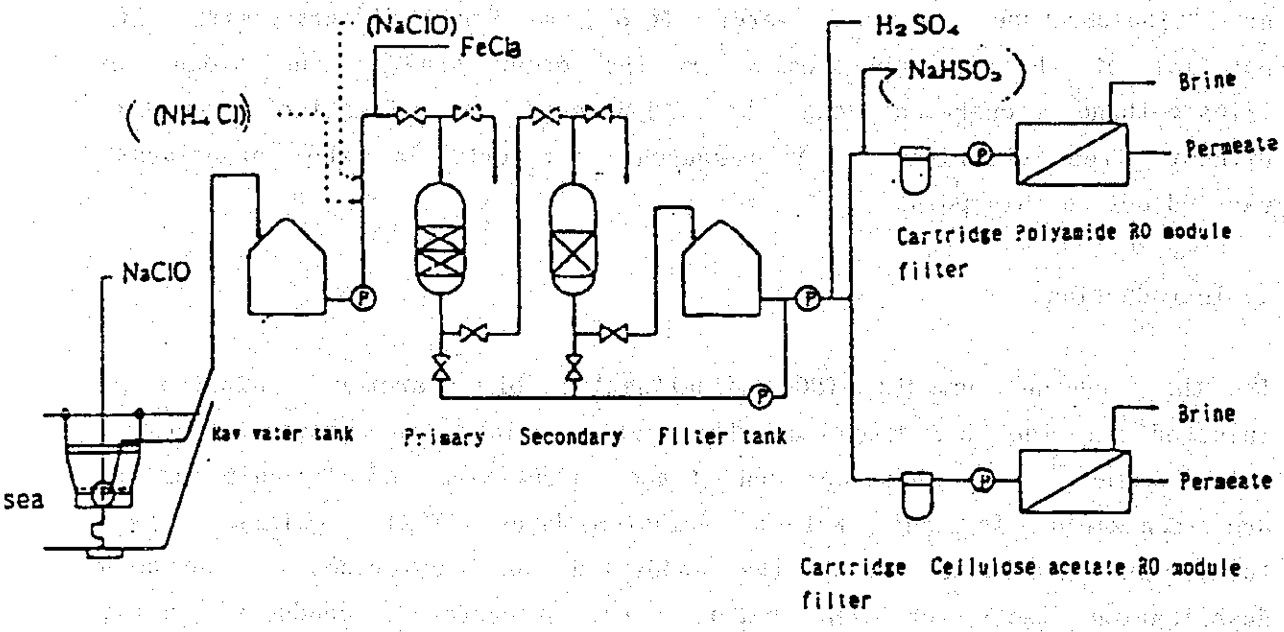


Fig. 1 . Flow Sheet

lose acetate membrane, and a pressure of 57 - 59kgf/cm^2 was applied to the polyamide membrane. The water temperature was 23 - 32°C.

(2) RO Module

Two Types of RO membranes were used in the tests (hollow-fiber type cellulose triacetate membrane and spiral wound type polyamid membrane). About 10m^3/d permeate can be obtained with one element. It is possible to sterilize the interior of the element by constantly maintaining the residual chlorine concentration at 0.2 - 1.0mg/L by the addition of chlorine. Conversely, if there is no residual chlorine, the membrane may deteriorated by bacteria. The spiral-wound type polyamide membrane produces 4m^3/d permeate from one element. As the membrane deteriorates with oxidizer, it is necessary to remove the residual chlorine from the feedwater. Three elements were used in the tests, and the target was to obtain 9m^3/d permeate at a recovery rate of 40%.

(3) Water Quality Analysis

Gas chromatography and the solvent extraction method were applied for the analysis of trihalomethane.

3. Test Results and Considerations

3-1. Permeate Quality

Results of water quality analysis are indicated in Table 1. The quality of the sea water used is quite normal for sea water found a along the coast of Japan. The SDI value of the RO feed water (filtrate) was always lower than 3, and the water satisfied the feed water conditions of both types of RO elements. Salt rejection of the cellulose acetate membrane was very high, 99,7% at the recovery rate of 40%. On the other hand, salt rejection of the polyamide membrane was lower than that of the cellulose acetate membrane, at 99.5%. The permeate satisfied the water quality standards of tap water, however, because the concentration of

Table 1 Results of ~~Water~~ Quality Analysis

Item	Unit	Sea water	RO feed water	RO permeate	
				CA Memb(*1)	PA Memb(*2)
pH	-	8.2	6.6	4.9	5.8
Conductiyity	μ/cm(25°C)	50400	50400	170	374
TDS	mg/ℓ	35600	35600	88	184
SDI value	-	>6	1.6		
Residual chlorine	mg/ℓ		(*3)0.3	0.3	0
Total alkalinity	mg/ℓ as$CaCO_3$	115	62.4		
Chlorine ion	mg/ℓ	18700	18700	46.1	106
Sulfate ion	mg/ℓ	2530	2560	2.9	1.8
Bromine ion	mg/ℓ	69			
Calcium hardness	mg/ℓ as$CaCO_3$	980	980	3.5	2.0
Magnesium hardness	mg/ℓ as$CaCO_3$	5460	5460	6.9	4.4
Feric ion	mg/ℓ	0.10	<0.02		
COD	mg/ℓ	2.1	0.5		

(*1): Cellulose acetate membrane (*2): Polyamide membrane
(*3): 0mg/ℓ for the polyamide membrane

Table 2 Trihalomethane in Chloramine Treatment

Operation time (hours)	Trihalomethane (μg/ℓ)				
	Feed water	Cellulose acetate membrane		Polyamide membrane	
		Permeate	Brine	Permeate	Brine
80	<1.0	1.0	<1.0	<1.0	1.1
270	<1.0	<1.0	<1.0	<1.0	1.0
580	<1.0	<1.0	<1.0	<1.0	<1.0

evaporation residue was about 200mg/L. Compared with the cellulose acetate membrane, the polyamide membrane's salt rejection of divalent ion such as sulphate ion, calcium, and magnesium, was higher. The difference in the charge on the membrane surface is considered to be the cause for the difference in the rejection of divalent ion. As the polyamide membrane's salt rejection sometimes drops sharply when a trace quantity of heavy metal is contained in the feed water, utmost care is required in operation.

3-2. Removal of THM

(1) Chlorination

Results of THM analysis with feed chlorination are discussed. In the 2 - 4 hours retention time after the addition of chlorine, the concentration of THM in the RO feed water was 15 - 25 μg/L, and most of the THM was bromoform. In the RO process THM rejection differed greatly with the type of membrane used. When treated with the cellulose acetate membrane is used the THM in the permeate was 1.2 - 1.5 times as much as that in the feed water. THM was not removed by the RO membrane. On the contrary, the THM concentration became higher on the side of the permeate. Presumably THM has a strong affinity to the cellulose acetate membrane, and its permeability is higher than that of water. On the other hand, when treated with the polyamide membrane. THM in the permeate was about 10 - 20% of that in the feed water. That is, about 80 - 90% of THM was removed by the RO membrane. The THM is removed in the brine of the polyamide membrane. And it was found that THM is not adsorbed to the membrane, but is separated by the polyamide membrane.

(2) Chloramine Treatment

Results of THM analysis chloramine as disinfectant are indicated in Table 2. THM was scarcely generated in the chloramine treatment. The concentration of THM in the feed water was less than
1 μg/L, and about 1 μg/L THM was sometimes detected in the permeate

of the cellulose acetate membrane and in the brine of the polyamide membrane.

(3) Trihalomethane FP (THMFP)

Results of THMFP analysis are discussed. While the concentration of THMFP in the sea water was 37 - 55μg/L, and 33 - 42μg/L in the RO feed water, the concentration of THMFP in the permeate of the cellulose acetate membrane was 22 - 33μg/L, which is less than that in the feed water by about 20 - 40%. Although the concentration of the THM generated becomes high on the permeating side of the cellulose acetate membrane, the concentration is believed to fall because the precursor that causes THMFP is removed by the membrane. THM concentration prescribed by the water quality standard is less than 100μg/L and the concentration of THMFP in the permeate of the cellulose acetate membrane was about 1/4 - 1/3 of the prescribed value.

4. Conclusion

Large-sized RO sea water desalination facilities are now being planned in Japan as a countermeasure against water shortage. It is expected that RO sea water desalination will contribute to the stable supply of water when proper processes (including proper pretreatment) are selected on the basis of not only desalination property, but also the behavior of trihalomethane and other components.

REFERENCE

1)Y.Kozima, et al;The 45th National Service Water Research Presentation Conference (May 1994). Sendai City.

Appendix 8.1.2-1

Fluorophotometric Oil Content Measurment Manual