Appendix 7.1.1-1

Technical Document Summary of Commercial RO Element

Attached Material-1

Expected RO performance of the test plant
Modules:TOYOBO, HM8255FI + HR8355FI

Attached Material-2

Expected RO performance of the test plant
Modules:TOYOBO, HM8255FI

Attached Material-3

Stand-by Requirement for "HOLLOWSEP" Modules

Attached Material-4

JIS(Japanese Industrial Standard) Testing Methods for Solute Rejection and Water Flux of Reverse Osmosis Membrane Element and Module using Aqueous Solution of Various Solutes, JIS K 3805-1990, Translated and Published by Japan Standards Association

Attached Material-5

Standard Practice for Standardizing Reverse osmosis Performance Data ASTM D 4516-85(Reproved 1989)

Attached Material-6

Temperature correction factors for NITTO DENKO RO flat sheet membrane

Attached Material-7

Temperature correction factors for TOYOBO hollow fiber type module HM8255FI

Attached Material-8

Temperature correction factors for NITTO DENKO spiral-wound type module

Attached Material-9.

Instruction manual for NITTO DENKO RO/UF test cell C70-F

Attached Material-1

Expected RO performance of the test plant
Modules:TOYOBO, HM8255FI + HR8355FI

TYB-019411 RE: HO/WRPC-AL-JUBAIL (HM8255FI+HR8355FI)

TECHNICAL PROPOSALS

111 Our design basis:

AA Water analysis of raw seawater based on your information;

TDS	44000.0 ppm				
Total hardness	7650.0 ppm as CaCO3				
Total alkalinity	130.0 ppm as CaCO3				
Na	15000.0 ppm	Cl	23500.0 ppm	SiO2	2.0 ppm
Ca	500.0 ppm	SO4	3400.0 ppm	Fe	0.0 ppm
Mg	1555.0 ppm	NO3	0.0 ppm	Mn	0.0 ppm
K	580.0 ppm	HCO3	158.0 ppm	pH	8.20 V
Ba	0.0 ppm	Br	70.0 ppm		
Sr	0.0 ppm	F	0.0 ppm		

BB Water analysis of feed water after pretreatment

Na	15000.0 ppm	Cl	23500.0 ppm
Ca	500.0 ppm	SO4	3450.8 ppm
Mg	1555.0 ppm	NO3	0.0 ppm
K	580.0 ppm	HCO3	93.4 ppm
Ba	0.0 ppm	Br	70.0 ppm
Sr	0.0 ppm	F	0.0 ppm
T.Cation	17635.0 ppm	T.Anion	27114.3 ppm
SiO2	2.0 ppm	Other ions	0.0 ppm
TDS	44751.3 ppm	pH	6.50 √

CC Permeated water during initial 1 year period;

Quantity requested	more than 24.7 tpd at 25 deg.C
Salinity requested	less than 500 ppm as TDS at 35 deg.C
	less than 250 ppm as Chloride at 35 deg.(

DD Operating conditions of RO section;

Array of permeators	single stage
Model of permeators	HOLLOSEP HM8255FI+HR8355FI
Water temperature	25.0 to 35.0 deg.C
Working pressure	60.0 to 65.0 kg/cm2G
Recovery ratio	37.0 pct.
Replacement ratio	0 pct. for initial 1st year

TYB-019411 RE: HO/WRPC-AL-JUBAIL (HM8255FI+HR8355FI)

222 Layout of permeators:
AA Number of permeators — HM8255FI 1 pc. +HR8355FI 1 pc.
BB Arrangement of permeator — horizontal position in single

333 Material balance of RO section:

	Quantity (tpd)	Salinity (ppm as TDS)
feed water	66.8	44751.3
permeate	24.7	459.8
brine	42.1	70763.7

444 Expected analysis of the permeate at the end of 1st year:

Na	172.1 ppm	Cl	245.8 ppm
Ca	2.1 ppm	SO4	14.4 ppm
Mg	6.5 ppm	NO3	0.0 ppm
K	6.1 ppm	HCO3	12.1 ppm
Ba	0.0 ppm	Br	0.7 ppm
Sr	0.0 ppm	F	0.0 ppm
T.Cation	186.7 ppm	T.Anion	273.1 ppm
SiO2	0.0 ppm	Other ions	0.0 ppm
TDS	459.8 ppm	pH	5.64

555 Required conditions of feed water after pretreatment:

AA	TDS	below 44752 ppm
BB	Chloride	below 23500 ppm
CC	Turbidity	below 4.0 FI(SDI)
DD	pH range	6.0 to 6.5
'E	Residual chlorine range	0.1 to 0.2 ppm as Chlorine
FF	Silica	below 2 ppm as SiO2
GG	Total iron and manganese	below 0.1 ppm as Fe plus Mn
HH	Oily matter	not detected
II	Harmful matter to membrane	not detected

666 Required operating conditions of RO section:

AA Water temperature	ordinary 25.0 deg.C range 25.0 to 35.0 deg.C
BB Working pressure	ordinary (95 minus tc) kg/cm2G maximum 65 kg/cm2G where tc=water temperature, deg.C
CC Recovery ratio at any time	below 37.0 pct. per permeator
DD Flow rate at all times	
feed water	above 66.8 tpd
brine	above 42.1 tpd

777 Required maintenance of permeators:

AA Flushing;

If the plant is shut down for any reason, automatic or manual, flush the permeators from the feed side to waste for more than ten minutes through the fully opened brine control valve. Pretreated water or permeated water meeting the following conditions should be used for flushing.

feed flow rate	42 to 120 tpd per permeator
working pressure	3 to 35 kg/cm2G
water temperature	25 to 35 deg.C

BB Precautions on shut-down;

In order to prevent dehydration of the membranes in the permeator (caused by backward flow of permeate because of natural osmosis at the shut-down of the high pressure pump), the intermediate reservoir with effective capacity of more than 125 liters for permeated water should be installed on the position between the permeators and the tank for product water.

CC Storaging;

When any permeator is shut down for more than 3 days, the permeator should be filled with 0.5 to 1.0 pct. formalin to protect biological growth to the membrane.

Attached Material-2

Expected RO Performance of the Test Plant
Modules:TOYOBO, HM8255FI

TYB-019411 RE: HO/WRPC-AL-JUBAIL (HM8255FI)

TECHNICAL PROPOSALS

111 Our design basis:

AA Water analysis of raw seawater based on your information;

TDS	44000. 0 ppm				
Total hardness	7650. 0 ppm as CaCO3				
Total alkalinity	130. 0 ppm as CaCO3				
Na	15000. 0 ppm	Cl	23500. 0 ppm	SiO2	2. 0 ppm
Ca	500. 0 ppm	SO4	3400. 0 ppm	Fe	0. 0 ppm
Mg	1555. 0 ppm	NO3	0. 0 ppm	Mn	0. 0 ppm
K	580. 0 ppm	HCO3	158. 0 ppm	pH	8. 20
Ba	0. 0 ppm	Br	70. 0 ppm		
Sr	0. 0 ppm	F	0. 0 ppm		

BB Water analysis of feed water after pretreatment;

Na	15000. 0 ppm	Cl	23500. 0 ppm
Ca	500. 0 ppm	SO4	3450. 8 ppm
Mg	1555. 0 ppm	NO3	0. 0 ppm
K	580. 0 ppm	HCO3	93. 4 ppm
Ba	0. 0 ppm	Br	70. 0 ppm
Sr	0. 0 ppm	F	0. 0 ppm
T. Cation	17635. 0 ppm	T. Anion	27114. 3 ppm
SiO2	2. 0 ppm	Other ions	0. 0 ppm
TDS	44751. 3 ppm	pH	6. 50

CC Permeated water during initial 1 year period;

Quantity requested	more than 20 tpd at 25 deg. C
Salinity requested	less than 500 ppm as TDS at 35 deg. C
	less than 250 ppm as Chloride at 35 deg. C

DD Operating conditions of RO section;

Array of permeators	single stage
Model of permeators	HOLLOSEP HM8255FI
Water temperature	25. 0 to 35. 0 deg. C
Working pressure	60. 0 to 65. 0 kg/cm2G
Recovery ratio	30. 0 pct.
Replacement ratio	0 pct. for initial 1st year

TYB-019411 RE: HO/WRPC-AL-JUBAIL(HM8255FI)

222 Layout of permeators:
AA Number of permeators HM8255FI 1 pc.
BB Arrangement of permeator horizontal position in single
333 Material balance of RO section:

	Quantity (tpd)	Salinity (ppm as TDS)
feed water	66.7	44751.3
permeate	20.0	329.3
brine	46.7	63789.2

444 Expected analysis of the permeate at the end of 1st year:

Na	122.8 ppm	Cl	173.3 ppm
Ca	1.5 ppm	SO4	10.2 ppm
Mg	4.6 ppm	NO3	0.0 ppm
K	4.3 ppm	HCO3	12.1 ppm
Ba	0.0 ppm	Br	0.5 ppm
Sr	0.0 ppm	F	0.0 ppm
T.Cation	133.2 ppm	T.Anion	196.1 ppm
SiO2	0.0 ppm	Other ions	0.0 ppm
TDS	329.3 ppm	pH	5.64

555 Required conditions of feed water after pretreatment:

AA	TDS	below 44752 ppm
BB	Chloride	below 23500 ppm
CC	Turbidity	below 4.0 FI(SDI)
DD	pH range	6.0 to 6.5
E	Residual chlorine range	0.1 to 0.2 ppm as Chlorine
FF	Silica	below 2 ppm as SiO2
GG	Total iron and manganese	below 0.1 ppm as Fe plus Mn
HH	Oily matter	not detected
II	Harmful matter to membrane	not detected

666 Required operating conditions of RO section:

AA Water temperature	ordinary 25.0 deg. C
	range 25.0 to 35.0 deg. C
BB Working pressure	ordinary (95 minus tc) kg/cm2G
	maximum 65 kg/cm2G
	where tc=water temperature, deg. C
CC Recovery ratio at any time	below 30.0 pct. per permeator
DD Flow rate at all times	
feed water	above 66.7 tpd
brine	above 46.7 tpd

777 Required maintenance of permeators:

AA Flushing;

If the plant is shut down for any reason, automatic or manual, flush the permeators from the feed side to waste for more than ten minutes through the fully opened brine control valve. Pretreated water or permeated water meeting the following conditions should be used for flushing.

feed flow rate	46 to 120 tpd per permeator
working pressure	3 to 35 kg/cm2G
water temperature	25 to 35 deg. C

BB Precautions on shut-down;

In order to prevent dehydration of the membranes in the permeator (caused by backward flow of permeate because of natural osmosis at the shut-down of the high pressure pump), the intermediate reservoir with effective capacity of more than 125 liters for permeated water should be installed on the position between the permeators and the tank for product water.

CC Storaging;

When any permeator is shut down for more than 3 days, the permeator should be filled with 0.5 to 1.0 pct. formalin to protect biological growth to the membrane.

Attached Material-3

Stand-by Requirement for "HOLLOWSEP" Modules

STAND-BY REQUIREMENTS FOR "HOLLOSEP" MODULES

To achieve satisfactory performance and system after re-start, this requirements cover to provide users of "HOLLOSEP" RO Modules with information regarding stand-by of the modules.

1. The stand-by requirements for RO modules are as follows:

① Normal shut-down

Just before and after a planned shut-down of RO system, the RO modules should be flushed with pretreated feed water or permeate.

② Emergency shut-down

RO modules should be cleaned with suck-backed permeate by natural osmosis at the emergency shut-down of the plant.

2. The preservative method for stand-by of the modules should be observed according to the period of shut-down of RO system as shown in the following table:

Shut-down period	Procedures before stand-by for module
less than 3 days	1st flush with the pretreated feed water. 2nd seal the system.
less than 1 week	1st flush with permeate. 2nd fill with the preservative solution. 3rd seal the system.
more than 1 month	1st flush with permeate. 2nd preform the chemical cleaning. 3rd flush with permeate. 4th fill with the preservative solution. 5th seal the system.

Attached Material-4

UDC 66.064:66.067.38

JIS

JAPANESE INDUSTRIAL STANDARD

Testing Methods for Solute Rejection and Water Flux of Reverse Osmosis Membrane Element and Module using Aqueous Solution of Various Solutes

JIS K 3805-1990

Translated and Published

by

Japanese Standards Association

In the event of any doubt arising,
the original Standard in Japanese is to be final authority.

UDC 66.064:66.067.38

JAPANESE INDUSTRIAL STANDARD

J I S

Testing Methods for Solute Rejection and Water Flux of Reverse Osmosis Membrane Element and Module using Aqueous Solution of Various Solutes

K 3805-1990

1. Scope

This Japanese Industrial Standard specifies testing methods for solute rejection and water flux of reverse osmosis membrane element and module using aqueous solution of three types of sodium chloride, magnesium sulfate and isopropanol (isopropyl alcohol) (hereafter referred to as the "aqueous solution").

Remark: In this Standard the units and numerical values shown in { } are in accordance with the traditional units and are Standard values.

Applicable Standards:

JIS B 7413-Etched-Stem Mercury-in-Glass Thermometer (Partial Immersion Type)

JIS B 7505-Bourdon Tube Pressure Gauges

JIS B 7551-Variable Area Flowmeters

JIS G 4304-Hot Rolled Stainless Steel Plates and Sheets

JIS G 4305-Cold Rolled Stainless Steel Plates and Sheets

JIS K 0101-Testing Method for Industrial Water

JIS K 0114-General Rules for Analytical Method in Gas Chromatography

JIS K 0552-Testing Methods for Electric Conductivity of Highly Purified Wate

JIS K 0805-Continuous Total Organic Carbon Analyzer

JIS K 1522-Isopropyl Alcohol (Isopropanol)

JIS K 3802-Technical Terms for Membranes and Membrane Processes

JIS K 8150-Sodium Chloride

JIS K 8995-Magnesium Sulfate

JIS Z 8802-Methods for Determination of pH of Aqueous Solutions

2. Definitions

For the purposes of this Standard main definitions are in accordance with JIS K 3802 and further the following definition applies:

Brine seal [1] The seal member to separate feed water and concentrated water, which is used when the spiral type membrane element and pleated type membrane element are tested.

Note [1] The brine seal is also called U packing.

3. Testing Conditions

3.1 Concentration and Operating Pressure The concentration [2] and operating pressure of aqueous solution used for test shall be of the values described in the instruction manual of manufacturer. An example is shown in (1) to (3).

Note [2] The concentration of aqueous solution is to be ± 5 % of designated concentration.

(1) In the Case of Sodium Chloride Aqueous Solution

Table 1. Type of Each Module and Concentration and Operating Pressure of Sodium Chloride Aqueous Solution (An Example)

Type of module	Concentration of sodium chloride aqueous solution (mg/l)	Operating pressure (kPa {kgf/cm²})	Remark
High pressure type	30000 to 35000	5000 to 6000 {50 to 60}	It is used for desalination of sea water.
Medium pressure type	500 to 2000	2000 to 4500 {20 to 45}	These are used for brackish-water treatment and ultrapure-water manufacturing.
Low pressure type		1000 to 2000 {10 to 20}	
Ultralow pressure type		to 1000 { to 10}	It is used for ultrapure-water manufacturing.

(2) In the Case of Magnesium Sulfate Aqueous Solution

Table 2. Type of Each Module and Concentration and Operating Pressure of Magnesium Sulfate Aqueous Solution (An Example)

Type of module	Concentration of magnesium sulfate aqueous solution (mg/l)	Operating pressure (kPa {kgf/cm2})	Remark
Medium pressure type	-	-	These are used for brackish-water treatment and ultrapure-water manufacturing.
Low pressure type	500 to 2000	1000 to 2000 {10 to 20}	
Ultralow pressure type		to 1000 { to 10}	It is used for ultrapure-water manufacturing.

(3) In the Case of Isopropanol (Isopropyl Alcohol) Aqueous Solution

Table 3. Type of Each Module and Concentration and Operating Pressure of Isopropanol (Isopropyl Alcohol) Aqueous Solution (An Example)

Type of module	Concentration of isopropanol (isopropyl alcohol) aqueous solution (mg/l)	Operating pressure (kPa {kgf/cm2})	Remark
Medium pressure type	100 to 1500	2000 to 4500 {20 to 45}	These are used for brackish-water treatment and ultrapure-water manufacturing.
Low pressure type		1000 to 2000 {10 to 20}	
Ultralow pressure type		to 1000 { to 10}	It is used for ultrapure-water manufacturing.

3.2 Temperature and pH Value of Feed Water The temperature and pH value of feed water shall be as follows.

(1) Temperature An arbitrary temperature at 10 to 40°C, and the variation of temperature during test is ± 1°C.

(2) pH Value The pH value is pH described in instruction manual of manufacturer and is to be kept at constant during testing period ([3]).

Note ([3]) Generally, in many cases pH value of 6.5 ± 0.5 is used.

3.3 <u>Concentrated Water Flow Rate or Recovery</u> The concentrated water flow rate (4) or recovery for each type of module shall be the value described in instruction manual of manufacturer. An example of concentrated water flow rate is shown in Table 4 and an example of recovery, in Table 5.

Note (4) The concentrated water flow rate is to be ± 5 % of designated flow rate.

Table 4. Concentrated Water Flow Rate for Each Type of Module (An Example)

Unit: mm

<table>
<tr><th rowspan="3">Type of module</th><th colspan="3">Concentrated water flow rate (l/min)</th></tr>
<tr><th colspan="3">Module nominal dimensions
Diameter x length</th></tr>
<tr><th>65 x 1000</th><th>100 x 1000</th><th>200 x 1000</th></tr>
<tr><td>High pressure type</td><td rowspan="2">5</td><td rowspan="3">10</td><td rowspan="3">40</td></tr>
<tr><td>Medium pressure type</td></tr>
<tr><td>Low pressure type</td><td rowspan="2">10</td></tr>
<tr><td>Ultralow pressure type</td><td>20</td><td>80</td></tr>
</table>

Remark: The module nominal dimensions, in the case of inch marking, 65 x 1000 is 2.5 x 40, 100 x 1000 is 4 x 40, 200 x 1000 is 8 x 40.

Table 5. Recovery for Each Type of Module (An Example)

<table>
<tr><th>Type of module</th><th>Recovery (5) (%)</th></tr>
<tr><td>High pressure type</td><td>10 to 35</td></tr>
<tr><td>Medium pressure type</td><td rowspan="3">10 to 75</td></tr>
<tr><td>Low pressure type</td></tr>
<tr><td>Ultralow pressure type</td></tr>
</table>

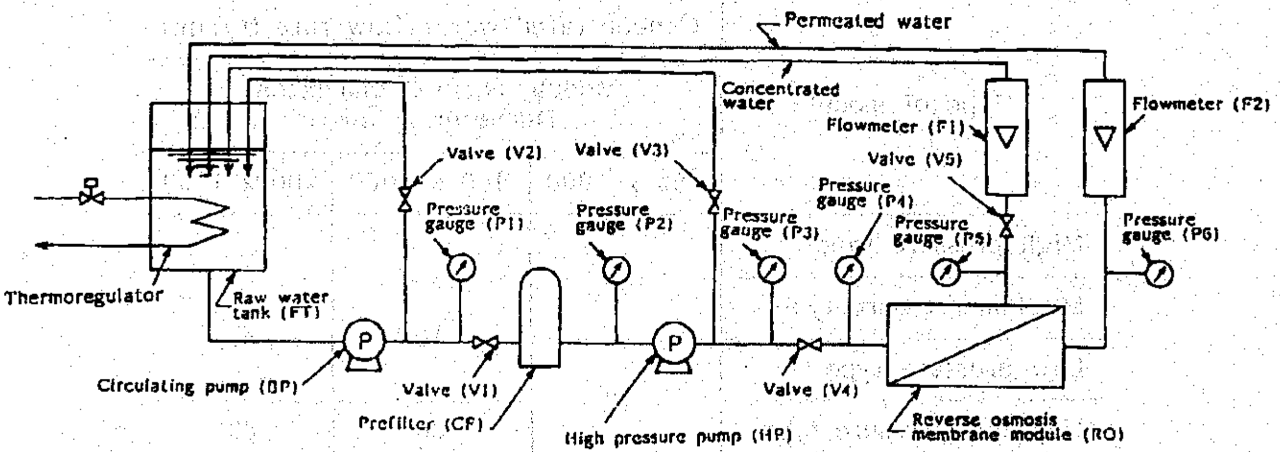
Note (5) The recovery is different according to type of module.

4. Apparatus

The apparatus shall be as follows:

4.1 Performance Tester The performance tester (hereafter referred to as the "tester") consists of pipings, valves, raw water tank, pump, prefilter, reverse osmosis module, flowmeter, pressure gauge, thermoregulator, etc. A construction example is shown in Figure.

Figure. Tester for Solute Rejection Performance (An Example)



(1) Pipings Pipings, generally, shall be made of stainless such as SUS 316 specified in JIS G 4304 or JIS G 4305 or plastics, free from corrosion, generation of rust, etc. and, endurable to operating pressure.

(2) Valves Valves shall be the diaphragm valve, ball valve, three-way valve, etc. and, endurable to corrosion.

(3) Raw-Water Tank The raw-water tank is to prepare the aqueous solution to be used for test, to store the raw-water to supply to module, able to endure corrosion, and shall be provided with a stirrer or of such structure that the transmitted water and the concentrated water are mixed sufficiently in tank.

(4) Pump The pump is to press feed the raw-water to supply to module and shall endure the corrosion.

(5) Prefilter The prefilter is to remove suspensoid in raw-water to supply to module, at upstream of high-pressure pump.

(6) Flowmeter Out of the flowmeters specified in JIS B 7551, the flowmeter of which the minimum graduation is 5 to 10 % of measuring flow rate and the maximum graduation shall be able to measure the degree of 1.5 to 2 times the measuring flow rate.

(7) Pressure Gauge The pressure gauge shall be that having accuracy equivalent or superior to the same grade as Bourdon tube pressure gauge specified in JIS B 7505 and of which the maximum pressure shall be able to measure the degree of 1.5 to 2 times the measuring pressure. The accuracy grade shall be 1.5 grade or superior (6).

Note (6) There are cases where errors are generated in indicated values due to pressure vibration or the like, and therefore it is preferable to carry out the periodic calibration according to standard pressure gauge by using a pressure gauge attached with vibration control mechanism.

(8) Thermoregulator The automatic thermoregulator containing heating and cooling apparatuses.

4.2 Appliances

(1) Thermometer A glass stem thermometer of 100 P specified in JIS B 7413, digital thermometer according to semiconductor senser system and the thermometer according to other system which is preliminarily calibrated by standard thermometer.

(2) pH-meter A pH-meter of model II specified in 4.2 of JIS Z 8802 (7).

Note (7) It is to be calibrated preliminarily according to the method specified in 11. (4) of JIS K 0101.

(3) Electric Conductivity Meter An electric conductivity meter specified in 12. of JIS K 0101 (8).

Note (8) For every measuring cell to be used, by using the standard solution of solute prepared according to mass method preliminarily examine the relation between the solute concentration and the electric conductivity.

Further, in the case where the electric conductivity of material is not more than 10 μS/cm, when the electric conductivity meter specified in 5. of JIS K 0552 is used, the error becomes less.

(4) Continuous Total Organic Carbon (TOC) Analyzer An analyzer for general use specified in JIS K 0805.

(5) Gas Chromatograph The gas chromatograph specified in JIS K 0114.

5. Reagents

Main reagents to be used in this Standard shall be as follows:

(1) Sodium Chloride The sodium chloride specified in JIS K 8150.

(2) Magnesium Sulfate The magnesium sulfate specified in JIS K 8995.

(3) Isopropanol (Isopropyl Alcohol) The isopropanol (isopropyl alcohol) specified in JIS K 1522.

(4) Pure Water According to the type of solute the pure water of Table 6 shall be used.

Table 6. Types of Solute and Classes of Pure Water

Type of solute	Class of pure water
Sodium chloride	Those of electric conductivity of not more than 10 μS/cm
Isopropanol (isopropyl alcohol)	
Magnesium sulfate	The city water or industrial water, after dechlorination treatment, performed with water purification treatment (9), which contains metallic ion not more than 1 mg/l.

Note (9) As to the methods of water purification treatment, there are ion exchange method, distillation method, reverse osmosis method, etc.

6. Preparatory Operation

The preparatory operation for solute rejection test shall be as follows:

(1) Cleaning of Apparatus The cleaning of apparatus before attaching module shall be carried out as follows (10).

Note (10) In the case where the stain of apparatus is less, this may be abbreviated.

(a) Put pure water into a raw-water tank (11).

Note (11) Corresponding to stains and material quality of apparatus, acid, alkalic for washing, surface active agent or fungicide may be used.

(b) By using a circulating pump (BP), wash the stains in all piping.

(c) Exhaust the washings after washing for a definite time, then by using pure water newly wash with rinsing the apparatus.

(2) Attaching and Washing of Module The attaching and washing (12) of module shall be carried out as follows:

Note (12) In the case where the stain of module is less, this may be abbreviated.

(a) Carry out the attaching of module according to the instruction manual of manufacturer.

(b) Put pure water into a raw-water tank.

(c) By using a circulating pump (BP), exhaust the preserving solution of module ([13]).

Note ([13]) For a definite time after starting of washing, do not return the transmitted water and concentrated water to the raw-water tank.

(d) Carry out washing by using cleaning agent or fungicide designated by the manufacturer.

(e) Exhaust washings after washing for a definite time, and then by using newly pure water carry out rinse-washing of module.

7. Operation

The operation shall be carried out as follows:

(1) Working Operation of Apparatus

(a) Put pure water into raw-water tank.

(b) Close the valve (V 1) set at a piping connected with module, work the circulating pump (BP) and circulate the pure water in the raw-water tank.

(c) Work the thermoregulator and regulate the temperature of raw-water so that the water temperature becomes constant.

(d) Put a rather little amount than the required amount of solute specified in 3.1 into the raw-water tank, and dissolve completely.

(e) By using a pH meter measure pH of aqueous solution. In that case, in the case where the measured pH exceeds by ± 0.5 from the specified pH value, by using the aqueous solution shown in Table 7, regulate in the range of specified pH value.

Table 7. Kind of Solute and Kind of Aqueous Solution for pH Regulation

Kind of solute	Kind of aqueous solution for pH regulation
Sodium chloride	Hydrochloric acid aqueous solution, sodium hydroxide aqueous solution
Magnesium sulfate	Sulfuric acid aqueous solution, sodium hydroxide aqueous solution ([14])
Isopropanol (isopropyl alcohol)	Hydrochloric acid aqueous solution, sodium hydroxide aqueous solution

Note ([14]) The adding amount of sodium hydroxide shall not exceed 2 mg/l as the concentration of raw-water.
In case of exceeding 2 mg/l, the regulating of raw-water is necessary.

(f) By using (3), (4) or (5) of 4.2, measure the solute concentration in aqueous solution, and regulate it so as to become the specified concentration. The type of appliance to be used shall be as given in Table 8 according to the kind of solute.

Table 8. Kind of Solute and Type of Concentration Measuring Appliance

Kind of solute	Type of concentration measuring appliance
Sodium chloride	Electric conductivity meter
Magnesium sulfate	Electric conductivity meter
Isopropanol (isopropyl alcohol)	Continuous total organic carbon (TOC) analyzer or gas chromatograph

(g) Leaving the circulating pump (BP) as it is working, open the valve (V 1) set at the piping connected to the module, supply module to aqueous solution in raw-water tank and draw out completely the air in module and concentrated water line.

(h) Actuate the high pressure pump (HP) so as the rapid pressure and flow rate not to apply to module.

(i) Regulate at the pressure and flow rate specified in 3.1 and 3.3 ([15]).

Note ([15]) Pressure raising rate shall at the degree of 50 kPa/s (0.5 $kgf/cm^2/s$).

(2) Measuring Operation The measuring operation shall be carried out as follows:

(a) After lapse of time of 20 min or more ([16]) since setting of test conditions, read out the supply water pressure and concentrated water pressure by the pressure gauge (P 1), (P 2) and the concentrated-water flow rate by the flowmeter and record them.

Note ([16]) It may be extended until the measuring value is stabilized. In order to intend the stabilization of performance, it is preferable preliminarily to immerse the module in water or to carry out water-passing treatment.

(b) Read out the permeated water amount by flowmeter and record.

(c) At the same time as the measuring of permeated water amount, measure the temperature of permeated water by using a thermometer ([17]) and record.

Note ([17]) The temperature measurement shall be carried out at a place near the outlet of module so as to make the influence of atmospheric temperature small.

(d) Carry out sampling of supply water, concentrated water and permeated water, by using (3), (4) or (5) of 4.2 measure each solute concentration ([18]) and record.

Note ([18]) Relating to the relation between the value to be obtained from the appliance and the solute concentration, prel[redacted]lly prepare the conversion table.

(e) Confirm that pH of raw-water is in compliance with the test conditions, and record the measured value.

8. Calculation

The calculation shall be as follows:

(1) Solute Rejection Rate The solute rejection rate shall be calculated according to the following formulae.

(a) Average Concentration Reference Solute Rejection Rate

$$R_1 = \left[1 - \frac{C_p}{\left(\frac{C_f + C_c}{2} \right)} \right] \times 100$$

where, R_1 : average concentration reference solute rejection rate (%)

C_p : permeated water solute concentration (mg/l)

C_f : supply water solute concentration (mg/l)

C_c : concentrated water solute concentration (mg/l)

(b) Inlet Concentration Reference Solute Rejection Rate

$$R_2 = \left(1 - \frac{C_p}{C_f} \right) \times 100$$

where, R_2 : inlet concentration reference solute rejection rate (%)

C_p : permeated water solute concentration (mg/l)

C_f : supply water solute concentration (mg/l)

(2) Water Permeate Flow Carry out the temperature correction according to the following formula.

$$Q_{ps} = \frac{Q_{pt}}{TCF_t}$$

where, Q_{ps} : water permeate flow at standard temperature ([19]) (m^3/d)

Q_{pt} : water permeate flow at test temperature ([20]) (m^3/d)

TCF_t : temperature conversion factor at test temperature ([21]) ([19])

Notes ([19]) Usually, 25°C is taken as the standard temperature.

([20]) The permeated water temperature measured at the same time as the measuring of permeated water amount.

([21]) Usually, the temperature conversion factor at 25°C is taken as 1.

(3) Recovery

$$R_r = \frac{Q_p}{Q_f} \times 100$$

$$Q_f = Q_c + Q_p$$

where, R_r : recovery (%)

Q_p : permeated water amount (m^3/d)

Q_f : feed water flow rate (m^3/d)

Q_c : concentrated water flow rate (m^3/d)

(4) Salt Passage

(a) Average Concentration Reference Flute Passage

$$SP_1 = \frac{C_p}{\left(\frac{C_f + C_c}{2}\right)} \times 100$$

(b) Inlet Concentration Reference Flute Passage

$$SP_2 = \frac{C_p}{C_f} \times 100$$

where, SP_1 : average concentration reference solute passage (%)

SP_2 : inlet concentration reference solute passage (%)

C_p : permeated water solute concentration (mg/l)

C_f : feed water solute concentration (mg/l)

C_c : concentrated water solute concentration (mg/l)

9. Standardization of Water Permeate Flow and Solute Rejection Data

The water permeate flow and solute rejection data shall be converted to standard condition according to Annex 1 and Annex 2.

10. Reporting Matters

The report shall be described relating to the following matters:

(1) Module tested (element)

(a) Classification

(b) Type

(c) Catalogue number

(d) Manufacturer's name

(e) Manufacturing number

(2) Test Conditions

(a) Pressures of feed water, concentrated water and permeated water

(b) Temperature of permeated water

(c) Solute concentrations of feed water, concentrated water and permeated water

(d) Concentrated water flow rate and water permeate flow

(e) pH of feed water

(f) Working time

(g) Test day and hour

(h) Name of testing person

(3) Test results

(a) Solute rejection and calculation reference

(b) Water permeate flow (in the case where converted to standard condition, the condition)

Annex 1. Standardization Method of Water Permeate Flow Performance Data of Reverse Osmosis Membrane Element and Module

1. Scope

This Annex specifies the standardization method of water permeate flow performance data of reverse osmosis membrane element and module.

2. Definitions

For the purposes of this Standard main definitions are in accordance with JIS K 3802, and for others the following definitions apply:

(1) operating pressure The pressure at the inlet of reverse osmosis membrane module.

(2) module differential pressure The difference of pressure between the operating pressure and the concentrated water pressure at outlet of reverse osmosis membrane module.

(3) standard working conditions Conditions to work the performance of reverse osmosis membrane element or module, which are described in instruction manual of manufacturer or the like.

(4) actual working conditions Working conditions at the time when the confirmation of performance of reverse osmosis membrane element or module is carried out, which are working conditions other than the standard working conditions.

(5) average solute concentration The average value of solute concentration of feed water to reverse osmosis membrane element or module and the solute concentration of concentrated water.

(6) membrane surface concentration The substantial solute concentration at membrane surface.

3. Standardization Conditions

The standardization conditions shall be as follows:

(1) Reverse Osmosis Membrane Element or Module to Be Applied Spiral type and hollow fibre type.

(2) Kind of Solutes An aqueous solution in which either one of sodium chloride, magnesium sulfate, or isopropanol (isopropyl alcohol) is dissolved in pure water.

(3) Concentration of Solute The concentration of dilute in feed water is ± 20 % under the standard working conditions.

(4) The measured water permeate flow Q_a is not less than 50 % of water permeate flow Q_s under the standard working conditions.

(5) Pressure, Temperature and Recovery These do not exceed the tolerance range applicable to reverse osmosis membrane element and module.

(6) Operating Pressure The operating pressure is ± 20 % of operating pressure under the standard working conditions.

(7) pH The pH of feed water is ± 0.5 of pH under the standard working conditions.

(8) Temperature The temperature of feed water is ± 15°C of temperature under the standard working conditions.

In others, if the limit conditions or permissible conditions described in instruction manual of manufacturer or the like exist, follow them.

4. Methods

4.1 Standardization of Water Permeate Flow Performance Data The water permeate flow under standard working conditions shall be calculated according to formula (1).

$$Q_{ps}=\frac{\left[P_{fs}-\frac{\Delta P_{fss}}{2}-P_{ps}-\psi\Pi_{fms}+\Pi_{ps}\right](TCF_s)}{\left[P_{fa}-\frac{\Delta P_{fsa}}{2}-P_{pa}-\psi\Pi_{fma}+\Pi_{pa}\right](TCF_a)}(Q_{pa}) \quad \cdots\cdots (1)$$

where,

Q_{ps} : water permeate flow under standard working conditions (m^3/d)

P_{fs} : operating pressure under standard working conditions (kPa)

ΔP_{fss} : module differential pressure under standard working conditions (kPa)

P_{ps} : pressure of permeation side under standard working conditions (kPa)

Π_{fms} : osmotic pressure of average solute concentration of feed side and concentration side under standard working conditions (kPa)

Π_{ps} : osmotic pressure of permeation side under standard working conditions (kPa)

TCF_s : temperature conversion factor under standard working conditions

Q_{pa} : water permeate flow under actual working conditions (m^3/d)

P_{fa} : operating pressure under actual working conditions (kPa)

ΔP_{fa} : module differential pressure under actual working conditions (kPa)

P_{pa} : pressure of permeation side under actual working conditions (kPa)

Π_{fa} : osmotic pressure of average dilute concentration of feed side and concentration side under actual working conditions (kPa)

Π_{pa} : osmotic pressure of permeation side under actual working conditions (kPa)

TCF_a : temperature conversion factor under actual working conditions

ψ : correction factor for estimating of membrane surface concentration [1]

Note [1] The value of ψ is a value to be determined by working conditions (feed water amount, kind of solute, recovery, etc.), and only in the case where it is designated by instruction manual of manufacturer or the like, it is used. However, in case of no designation, it is taken as 1.

4.2 Temperature Conversion Factor TCF_s and TCF_a used in formula (1) are different according to type of reverse osmosis membrane element or module and quality of membrane material. Relating to TCF_s and TCF_a, the data indicated in instruction manual of manufacturer or the like shall be used. However, in case of no data of manufacturer, the following formulae (2) and (3) may be used as the informative reference.

$$TCF_s = 1.03^{(T_s - 15)} \quad \cdots\cdots (2)$$

$$TCF_a = 1.03^{(T_a - 15)} \quad \cdots\cdots (3)$$

where, T_s : permeated water temperature under standard working conditions (°C)

T_a : permeated water temperature under actual working conditions (°C)

4.3 Calculation of Osmotic Pressure of Average Solute Concentration of Supply Side and Concentration Side Π_{fs} and Π_{fa} of formula (1) shall be calculated from solute concentration of feed water and concentrated water.

(1) Average Solute Concentration of Supply Side and Concentration Side As to the calculation formula for obtaining average solute concentration, there are two formulae of (4) and (5). Which method is to be used shall be in accordance with the instruction manual of manufacturer.

$$C_{fc} = \frac{(C_f + C_c)}{2} \quad \cdots\cdots (4)$$

$$C_{fc} = \frac{C_f}{Y} \times \ln \frac{1}{(1-Y)} \quad \cdots\cdots (5)$$

where, C_{fc} : average solute concentration of feed side and concentration side (mg/l)

C_f : solute concentration of feed side (mg/l)

C_c : solute concentration of concentration side (mg/l)

Y : recovery

(2) Calculation of Average Osmotic Pressure The osmotic pressure of aqueous solution of sodium chloride, magnesium sulfate, and isopropanol (isopropyl alcohol) shall be in accordance with the following ([2]).

(a) Sodium Chloride Aqueous Solution

$$\Pi_{fc} = \frac{0.2646\ (273.15+T)\ C_{fc}}{\left(1000 - \frac{C_{fc}}{1000}\right)} \qquad (6)$$

where, T : temperature (°C)

Provided that it is applied when C_{fc} is not more than 10000 mg/l.

(b) Magnesium Sulfate Aqueous Solution

$$\Pi_{fc} = \frac{0.08372\ (273.15+T)\ C_{fc}}{\left(1000 - \frac{C_{fc}}{1000}\right)} \qquad (7)$$

Provided that it is applied when C_{fc} is not more than 5000 mg/l.

(c) Isopropanol (Isopropyl Alcohol) Aqueous Solution

$$\Pi_{fc} = \frac{0.1384\ (273.15+T)\ C_{fc}}{\left(1000 - \frac{C_{fc}}{1000}\right)} \qquad (8)$$

Provided that it is applied when C_{fc} is not more than 3000 mg/l.

Note ([2]) In the case where C_{fc} exceeds the limited range in each formula, the error becomes large, and therefore in the case where the calculation method of osmotic pressure is indicated in the instruction manual of reverse osmosis element or module or the like, it may be followed.

Further, the unit symbol of osmotic pressure to be used in this calculation is kPa.

4.4 Module Differential Pressure As to the value of module differential pressure ΔP_{fcs} under the standard working conditions, the value indicated by the instruction manual of manufacturer or the like shall be used.

4.5 Osmotic Pressure of Permeated Water The osmotic pressure of permeated water shall be obtained by using solute concentration of permeated water instead of C_f, in each formula of 4.3 (2).

4.6 Pressure of Permeation Side Take the pressure P_p, of permeation side under the standard working conditions as 0. Also take the pressure P_p of permeation side under the actual working conditions as 0 (3).

Note (3) In case where the pressure loss by piping, valve, etc. at permeation side is anticipated, preliminarily obtain correct P_p, by using a pressure gauge.

Annex 2. Standardization Method of Inorganic Salt Rejection Data of Reverse Osmosis Element and Module

1. Scope

This Annex specifies the standardization method of inorganic salt rejection data of reverse osmosis element and module.

2. Definitions

For the purposes of this Standard main definitions are in accordance with JIS K 3802, and to others the following definitions apply:

(1) operating pressure The pressure at inlet of reverse osmosis module.

(2) module differential pressure The difference between the operating pressure and the pressure of concentrated water at outlet of reverse osmosis module.

(3) standard working conditions Conditions to mark performance of reverse osmosis element or module, which are described in instruction manual of manufacturer.

(4) actual working conditions Working conditions at the time when confirming the performance of reverse osmosis element or module which are other than standard working conditions.

(5) average inorganic salt concentration This expresses the average value of inorganic salt concentrations of feed water to reverse osmosis element or module and of concentrated water.

3. Standardization Conditions

The standardization conditions shall be as follows:

(1) Kind of Inorganic Salts The solution made by dissolving either sodium chloride or magnesium sulfate in pure water.

(2) Reverse Osmosis Element or Module to Be Applied The reverse osmosis membrane for medium pressure and high pressure which are spiral type and follow fibre type.

(3) Pressure, Temperature, Recovery These do not exceed the permissible range capable of applying reverse osmosis element or module.

(4) Measured Water Permeate Flow Q_{p} is to be not less than 50 % of water permeate flow under standard working conditions.

(5) Concentration of Inorganic Salts The concentration of inorganic salts of feed water is to be ± 20 % of standard working conditions.

(6) Pressure The operating pressure is ± 20 % of operating pressure under standard working conditions.

(7) <u>pH</u> The pH of feed water is ± 0.5 of pH under standard working conditions.

(8) <u>Temperature</u> The temperature of feed water is ± 15°C of temperature under standard working conditions.

In others, if limit conditions or permissible conditions are described in instruction manual of manufacturer or the like, follow them.

4. Methods

4.1 Standardization of Inorganic Salt Passage

4.1.1 <u>Calculation of Inorganic Salt Passage under Standard Working Conditions</u> The inorganic salt passage under standard working conditions shall be calculated according to formulae (1) and (2).

(1) <u>Standardization of Average Concentration Reference Solute Passage</u>

$$SP_{1s} = \frac{\left[P_{fa} - \frac{\Delta P_{fba}}{2} - P_{pa} - \psi \Pi_{fba} + \Pi_{pa}\right]}{\left[P_{fs} - \frac{\Delta P_{fbs}}{2} - P_{ps} - \psi \Pi_{fbs} + \Pi_{ps}\right]} \times (SP_{1a}) \cdots\cdots (1)$$

(2) <u>Standardization of Inlet Concentration Reference Solute Passage</u>

$$SP_{2s} = \frac{\left[P_{fa} - \frac{\Delta P_{fba}}{2} - P_{pa} - \psi \Pi_{fba} + \Pi_{pa}\right] \times (C_{fbs})(C_{fa})}{\left[P_{fs} - \frac{\Delta P_{fbs}}{2} - P_{ps} - \psi \Pi_{fbs} + \Pi_{ps}\right] \times (C_{fba})(C_{fs})} \times (SP_{2a}) \cdots\cdots (2)$$

where,

SP_{1s} : average concentration reference inorganic salt passage under standard working conditions (%)

SP_{2s} : inlet concentration reference inorganic salt passage under standard working conditions (%)

SP_{1a} : average concentration reference inorganic salt passage under actual working conditions (%)

SP_{2a} : inlet concentration reference inorganic salt passage under actual working conditions (%)

C_{fba} : average inorganic salt concentration of feed water and concentrated water under actual working conditions (mg/l)

C_{fbs} : average inorganic salt concentration of feed water and concentrated water under standard working conditions (mg/l)

C_{fa} : inorganic salt concentration of feed water under actual working conditions (mg/l)

C_{fs} : inorganic salt concentration of feed water under standard working conditions (mg/l)

P_{fs} : operating pressure under standard working conditions (kPa)

ΔP_{fbs} : module differential pressure under standard working conditions (kPa)

P_{ps} : pressure of permeation side under standard working conditions (kPa)

Π_{fbs} : osmotic pressure of average inorganic salt concentration of feed water and concentrated water under standard working conditions (kPa)

Π_{ps} : osmotic pressure of permeated water under standard working conditions (kPa)

P_{fa} : operating pressure under actual working conditions (kPa)

ΔP_{fba} : module differential pressure under actual working conditions (kPa)

P_{pa} : pressure of permeation side under actual working conditions (kPa)

Π_{fba} : osmotic pressure of average inorganic salt concentration of feed water and concentrated water under actual working conditions (kPa)

Π_{pa} : osmotic pressure of permeated water under actual working conditions (kPa)

ψ : correction factor for estimating of membrane surface concentration (1)

Note (1) The value of ψ is a value to be determined by working conditions (feed water amount, kind of solute, recovery, etc.) and is used only in the case where designated in instruction manual of manufacturer. However, in the case of no designation it is taken as 1.

Remark: In the case where the manufacturer offers the inorganic salt permeability rate correction factor *SPCF* defined by formula (3) by table or figure, utilize it.

$$SPCF = \frac{SP_a}{SP_s} \qquad (3)$$

4.2 <u>Calculation of Osmotic Pressure of Average Inorganic Salt Concentration of Feed Water and Concentrated Water</u> Π_{fbs} and Π_{fba} of formula (1) shall be calculated from inorganic salt concentration of feed water and concentrated water.

(1) Average Inorganic Salt Concentration of Feed Water and Concentrated Water As to the calculation formula for obtaining average inorganic salt concentration, either formula (4) or formula (5) shall be used according to instruction manual of manufacturer.

$$C_{fc}=\frac{(C_f+C_c)}{2} \qquad (4)$$

$$C_{fc}=\frac{C_f}{Y}\times\ln\frac{1}{(1-Y)} \qquad (5)$$

where, C_{fc} : average inorganic salt concentration of feed water and concentrated water (mg/l)

C_f : inorganic salt concentration of feed water (mg/l)

C_c : inorganic salt concentration of concentrated water (mg/l)

Y : recovery

(2) Calculation of Average Osmotic Pressure The calculation of osmotic pressure of sodium chloride and magnesium sulfate aqueous solution shall be in accordance with formulae (6) and (7) (2).

(a) Sodium Chloride Aqueous Solution

$$\Pi_{fc}=\frac{0.2646\ (273.15+T)\ C_{fc}}{\left(1\,000-\frac{C_{fc}}{1\,000}\right)} \qquad (6)$$

where, T : temperature (°C)

Provided that this applies in the case where C_{fc} is not more than 10000 mg/l.

(b) Magnesium Sulfate Aqueous Solution

$$\Pi_{fc}=\frac{0.08372\ (273.15+T)\ C_{fc}}{\left(1\,000-\frac{C_{fc}}{1\,000}\right)} \qquad (7)$$

Provided that this applies in the case where C_{fc} is not more than 5000 mg/l.

Note (2) In the case where C_{fc} exceeds the limit range in each formula, the error becomes larger, and therefore in the case where the calculation method of osmotic pressure is indicated in instruction manual of reverse osmosis element or module or the like, it may be followed.

Further, the unit symbol of osmotic pressure to be used in this calculation is kPa.

4.3 Module Differential Pressure As to the differential pressure of module under standard working conditions ΔP_{n} , the value indicated in instruction manual of manufacturer or the like shall be used.

4.4 Osmotic Pressure of Permeated Water The osmotic pressure of permeated water shall be obtained by using inorganic salt concentration of permeated water instead of C_{f} in each formula of 4.2 (2).

4.5 Pressure of Permeation Side The pressure of permeation side under standard working conditions P_{ps} shall be taken as 0. The pressure of permeation side under actual working conditions P_{p} shall be taken also as 0 (3).

Note (3) In case where generation of pressure loss by piping, valve, etc. in permeation side is anticipated, preliminarily obtain the correct P_{p} by using a pressure gauge.

Informative Reference

1. Concentration Rate

$$CF_c = \frac{C_c}{C_f}$$

where, CF_c : concentration rate

C_c : concentration of concentrated water solute (mg/l)

C_f : concentration of feed-water solute (mg/l)

2. Conversion Formulae of Electric Conductivity and Solute Concentration (Example)

2.1 Conversion Formula of Electric Conductivity and Sodium Chloride Aqueous Solution Concentration (Example) An example (1) of conversion formula of sodium chloride concentration in sodium chloride aqueous solution and electric conductivity is shown in the following.

Note (1) This conversion formula is an informative reference value and it is required to prepare working curve preliminarily for individual electric conductivity meter to be used.

$$E = 2.163\,65 fC$$

$$\log_{10} f = \frac{\sqrt{C}}{10\,000}\left(-\frac{3\,472.7}{244.2+\sqrt{C}} + 1.426\,3 - 0.000\,194\,42C^{0.799}\right)$$

(Water temperature 25°C)

where, E : electric conductivity of sodium chloide aqueous solution (μS/cm)

C : sodium chloride concentration in sodium chloride aqueous solution (mg/l)

f : conductivity coefficient (-)

Literature Values (2) and Errors of Approximation Formulae

Electric conductivity (μS/cm)	Concentration (mg/l)		Error (%)
	Literature value (C_1)	Approximation formula (C_2)	$(\frac{C_2}{C_1}-1)\times 100$
62.255	29.22	29.224	0.013
123.74	58.44	58.449	0.016
245.32	116.9	116.88	−0.018
603.00	292.2	292.04	−0.056
1 185.3	584.4	584.18	−0.038
2 315.2	1 168.9	1 167.74	−0.099
5 553.0	2 922.1	2 918.50	−0.123
10 674	5 844.3	5 841.69	−0.045
20 342	11 689	11 698.2	0.079
46 810	29 221	29 248.3	0.093
85 760	58 443	58 426.2	−0.029
149 420	116 886	116 778.1	−0.092

Note (2) The literature value is in accordance with Electrochemical Association editing, Electro chemistry Handbook Fourth Edition, Maruzen (1985).

2.2 Conversion Formula of Electric Conductivity and Concentration of Magnesium Sulfate Aqueous Solution (Example) An example (3) of conversion formula of concentration of magnesium sulfate in magnesium sulfate aqueous solution is shown in the following.

Note (3) This conversion formula is informative reference value, and it is required to prepare the working curve preliminarily for individual electric conductivity meter to be used.

$$C = 0.32 \times E^{1.138}$$

where, C : concentration of magnesium sulfate in magnesium sulfate aqueous solution (mg/l)

E : electric conductivity (μS/cm at 25°C)

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Attached Material-5
Standard Practice for Standardizing Reverse osmosis Performance Data
ASTM D 4516-85(Reproved 1989)

Designation: D 4516 – 85 (Reapproved 1989)

Standard Practice for Standardizing Reverse Osmosis Performance Data[1]

This standard is issued under the fixed designation D 4516; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the standardization of permeate flow and salt passage data for reverse osmosis (RO) systems.

1.2 This practice is applicable to waters including brackish waters and seawaters but is not necessarily applicable to waste waters.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 1129 Definitions of Terms Relating to Water[2]

D 4194 Test Methods for Operating Characteristics of Reverse Osmosis Devices[3]

3. Terminology

3.1 For definitions of terms used in this practice, refer to Definitions D 1129.

3.2 For description of terms relating to reverse osmosis, refer to Test Method D 4194.

4. Summary of Practice

4.1 This practice consists of calculating the permeate flow and salt passage of RO systems at a standard set of conditions using data obtained at actual operating conditions.

5. Significance and Use

5.1 During the operation of an RO system, system conditions such as pressure, temperature, conversion, and feed concentration can vary, causing permeate flow and salt passage to change. To effectively evaluate system performance, it is necessary to compare permeate flow and salt passage data at the same conditions. Since data may not always be obtained at the same conditions, it is necessary to convert the RO data obtained at actual conditions to a set of selected constant conditions, thereby standardizing the data. This practice gives the procedure to standardize RO data.

5.2 This practice can be used for both spiral wound and hollow fiber systems.

5.3 This practice can be used for a single element or a multi-element system. However, if the RO system is brine staged, that is, the brine from one group of RO devices is the feed to a second group of RO devices, standardize the permeate flow and salt passage for each stage separately.

5.4 This practice is applicable for reverse osmosis systems with high rejections and with no significant leaks between the feed-brine and permeate streams.

6. Procedure

6.1 *Standardization of Permeate Flow:*

6.1.1 Calculate the permeate flow at standard conditions using Eq 1:

$$Q_{ps} = \frac{\left[P_{fs} - \frac{\Delta P_{fbs}}{2} - P_{ps} - \pi_{fbs} + \pi_{ps}\right](TCF_s)}{\left[P_{fa} - \frac{\Delta P_{fba}}{2} - P_{pa} - \pi_{fba} + \pi_{pa}\right](TCF_a)}(Q_{pa}) \quad (1)$$

where:

Q_{ps} = permeate flow at standard conditions,
P_{fs} = feed pressure at standard conditions, kpa,
$\frac{\Delta P_{fbs}}{2}$ = one half device pressure drop at standard conditions, kpa,
P_{ps} = permeate pressure at standard conditions, kpa,
π_{fbs} = feed-brine osmotic pressure at standard conditions, kpa,
π_{ps} = permeate osmotic pressure at standard conditions, kpa,
TCF_S = temperature correction factor at standard conditions,
Q_{pa} = permeate flow at actual conditions,
P_{fa} = feed pressure at actual conditions, kpa,
$\frac{\Delta P_{fba}}{2}$ = one half device pressure drop at actual conditions, kpa,
P_{pa} = permeate pressure at actual conditions, kpa,
π_{fba} = feed-brine osmotic pressure at actual conditions, kpa,
π_{pa} = permeate osmotic pressure at actual conditions, kpa, and
TCF_a = temperature correction factor at actual conditions.

6.2 *Standardization of Salt Passage:*

6.2.1 Calculate the salt passage at standard conditions using Eq 2:

$$\%SP_s = \frac{\left[P_{fa} - \frac{\Delta P_{fba}}{2} - P_{pa} - \pi_{fba} + \pi_{pa}\right] \times (C_{fbs})(C_{fa})}{\left[P_{fs} - \frac{\Delta P_{fbs}}{2} - P_{ps} - \pi_{fbs} + \pi_{ps}\right] \times (C_{fba})(C_{fs})} \times [\%\ SP_a] \quad (2)$$

[1] This practice is under the jurisdiction of ASTM Committee D-19 on Water and is the direct responsibility of Subcommittee D19.08 on Membranes and Ion Exchange Materials.
Current edition approved Aug. 30, 1985. Published November 1985.
[2] *Annual Book of ASTM Standards,* Vol 11.01.
[3] *Annual Book of ASTM Standards,* Vol 11.02.

where:

% SP_s = percent salt passage at standard conditions,
% SP_a = percent salt passage at actual conditions,
C_{fba} = feed-brine concentration at actual conditions, mg/L NaCl,
C_{fbs} = feed-brine concentration at standard conditions, mg/L NaCl,
C_{fa} = feed concentration at actual conditions, mg/L NaCl, and
C_{fs} = feed concentration at standard conditions, mg/L NaCl.

6.3 In Eq 1, TCF_s and TCF_a are dependent on the type of device (spiral or hollow fiber) and on the membrane type (cellulose acetate, polyamide, composite). Obtain equations for TCF_s and TCF_a from the supplier of device. If unavailable use Eqs 3 and 4.

$$TCF_s = 1.03^{(T_s - 25)} \quad (3)$$

$$TCF_a = 1.03^{(T_a - 25)} \quad (4)$$

where:

T_s = temperature at standard conditions, °C, and
T_a = temperature at actual conditions, °C.

6.4 In Eqs 1 and 2, π_{fba} and π_{fbs} are calculated from the concentration of salt (expressed as mg/L NaCl) in the feed and brine streams. See Annex A1 for the procedure to calculate the concentrations of salt in feed stream as mg/L NaCl.

6.4.1 The concentration of salt in the brine stream is calculated using Eq 5:

$$C_b = C_f/(1 - Y) \quad (5)$$

where:

C_b = concentration of salt in the brine, mg/L NaCl,
C_f = concentration of salt in the feed, mg/L NaCl, and
Y = conversion, expressed as a decimal.

6.4.2 The feed-brine concentration for some RO devices is based on an average (Eq 6):

$$C_{fb} = (C_f + C_b)/2 \quad (6)$$

and for other RO devices, the feed-brine concentration is based on a log mean average (Eq 7):

$$C_{fb} = C_f \ln[1/(1 - Y)]/Y \quad (7)$$

Consult supplier of device to determine whether Eq 6 or 7 should be used.

6.4.3 Calculate π_{fb} using Eq 8:

$$\pi_{fb} = 0.2654\, C_{fb}\, (T + 273.15)/(1000 - C_{fb}/1000) \quad (8)$$

6.5 The value for $\Delta P_{fbs}/2$ in Eqs 1 and 2 is a selected and constant value. A realistic value can be obtained from the supplier of the RO device.

6.6 To calculate π_{ps} and π_{pa} in Eqs 1 and 2 use Eq 9 for brackish water and Eq 10 for seawater as follows:

$$\pi_p = 0.05\, \pi_{fb} \quad (9)$$

$$\pi_p = 0.01\, \pi_{fb} \quad (10)$$

6.7 To obtain the most accurate standardization, the standard conditions should be set close to the average actual conditions.

6.8 Proper calibration and reading of instrumentation is critical for accurate actual RO data.

6.9 For large differences in pressure between actual and standard conditions, the standardized salt passage can be inaccurate if ions whose passage are independent of pressure are present to a significant extent. Consult supplier of RO device to determine if modification to the salt passage equation is needed.

7. Use of Computers for Standardization

7.1 The calculations in this practice are adaptable to simple computer analysis.

ANNEX

(Mandatory Information)

A.1 CALCULATION FOR CONCENTRATION OF SALT IN RO FEED STREAM AS mg/L NaCl

A1.1 First calculate the osmotic pressure of the RO feed (π_f) in kPa using Eq A1.

$$\pi_f = 8.308\, \phi (T_f + 273.15)\, \Sigma \bar{m}_i \quad (A1)$$

where:

ϕ = osmotic coefficient,
T_f = temperature of feed stream, °C, and
$\Sigma \bar{m}_i$ = summation of molalities of all ionic and non-ionic constituents in the water.

NOTE—Estimates of osmotic coefficients for brackish and seawater of 0.93 and 0.90, respectively, can be used in Eq A1.

A.1.2 Calculate the concentration of salt in the RO feed (C_f) as mg/L NaCl using Eq A2:

$$C_f = 1000\, \pi_f/[0.2654\, (T_f + 273.15) + \pi_f/1000] \quad (A2)$$

Attached Material-6

Temperature correction factors for NITTO DENKO RO flat sheet membrane

Table 2 Flux conversion coefficient (f)

(25°C conversion)

T (℃)	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
10	1.448	1.444	1.448	1.436	1.432	1.428	1.424	1.421	1.417	1.413
11	1.409	1.406	1.402	1.398	1.394	1.391	1.387	1.383	1.380	1.376
12	1.372	1.369	1.365	1.361	1.358	1.354	1.351	1.347	1.344	1.340
13	1.337	1.333	1.330	1.326	1.323	1.319	1.316	1.313	1.309	1.306
14	1.302	1.299	1.296	1.292	1.289	1.286	1.283	1.279	1.276	1.273
15	1.270	1.266	1.263	1.260	1.257	1.254	1.250	1.247	1.244	1.241
16	1.230	1.235	1.232	1.229	1.226	1.223	1.220	1.216	1.213	1.210
17	1.207	1.204	1.201	1.199	1.196	1.193	1.190	1.187	1.184	1.181
18	1.178	1.175	1.172	1.169	1.167	1.164	1.161	1.158	1.155	1.153
19	1.150	1.147	1.144	1.142	1.139	1.136	1.133	1.131	1.128	1.125
20	1.123	1.120	1.117	1.115	1.112	1.109	1.107	1.104	1.101	1.099
21	1.096	1.094	1.091	1.089	1.086	1.083	1.081	1.078	1.076	1.073
22	1.071	1.068	1.066	1.063	1.061	1.059	1.056	1.054	1.051	1.049
23	1.046	1.044	1.042	1.039	1.037	1.035	1.032	1.030	1.027	1.025
24	1.023	1.020	1.018	1.015	1.014	1.011	1.009	1.007	1.005	1.002
25	1.000	0.998	0.996	0.993	0.991	0.989	0.987	0.984	0.982	0.980
26	0.978	0.976	0.974	0.972	0.969	0.967	0.965	0.963	0.961	0.959
27	0.957	0.955	0.953	0.950	0.948	0.946	0.944	0.942	0.940	0.938
28	0.936	0.934	0.932	0.930	0.928	0.926	0.924	0.922	0.920	0.918
29	0.916	0.914	0.912	0.910	0.908	0.906	0.905	0.903	0.901	0.899
30	0.897	0.895	0.893	0.891	0.889	0.888	0.886	0.884	0.882	0.880
31	0.878	0.876	0.875	0.873	0.871	0.869	0.867	0.866	0.864	0.862
32	0.860	0.859	0.857	0.855	0.853	0.851	0.850	0.848	0.846	0.845
33	0.843	0.841	0.839	0.838	0.836	0.834	0.833	0.831	0.829	0.828
34	0.826	0.824	0.823	0.821	0.819	0.818	0.816	0.814	0.813	0.811
35	0.810	0.808	0.806	0.805	0.803	0.802	0.800	0.798	0.797	0.795
36	0.794	0.792	0.791	0.789	0.787	0.786	0.784	0.783	0.781	0.780
37	0.778	0.777	0.775	0.774	0.772	0.771	0.769	0.768	0.766	0.765
38	0.763	0.762	0..760	0.759	0.758	0.756	0.755	0.753	0.752	0.750
39	0.749	0.747	0.746	0.745	0.743	0.742	0.740	0.739	0.738	0.736
40	0.735	0.733	0.732	0.731	0.729	0.728	0.727	0.725	0.724	0.723
41	0.721	0.720	0.719	0.717	0.716	0.715	0.713	0.712	0.711	0.709
42	0.708	0.707	0.705	0.704	0.703	0.702	0.700	0.699	0.698	0.696
43	0.695	0.694	0.693	0.691	0.690	0.689	0.688	0.686	0.685	0.684
44	0.683	0.681	0.680	0.679	0.678	0.677	0.675	0.674	0.673	0.672
45	0.671	0.669	0.668	0.667	0.666	0.665	0.663	0.662	0.661	0.660
46	0.659	0.658	0.656	0.655	0.654	0.653	0.652	0.651	0.650	0.648
47	0.647	0.646	0.645	0.644	0.643	0.642	0.641	0.640	0.638	0.637
48	0.636	0.635	0.634	0.633	0.632	0.631	0.630	0.629	0.628	0.626
49	0.625	0.624	0.623	0.622	0.621	0.620	0.619	0.618	0.617	0.616
50	0.615	0.614	0.613	0.612	0.611	0.610	0.609	0.608	0.607	0.606

Attached Material-7

Temperature Correction Factors for TOYOBO Hollow Fiber Type Module HM8255FI

Temperature Correction Factor
Feed Pressure :60 Kg/cm2
Feed TDS :45,000 mg/L
Module : HM8255FI

Temperature C	Recovery Ratio 20%	25%	30%	35%
20	0.922	0.923	0.923	0.930
21	0.942	0.943	0.946	0.949
22	0.960	0.961	0.963	0.965
23	0.973	0.973	0.975	0.977
24	0.987	0.987	0.988	0.989
25	1.000	1.000	1.000	1.000
26	1.013	1.012	1.012	1.010
27	1.026	1.025	1.023	1.020
28	1.038	1.036	1.034	1.030
29	1.049	1.047	1.045	1.039
30	1.060	1.058	1.054	1.048
31	1.071	1.069	1.064	1.056
32	1.082	1.079	1.074	1.064
33	1.093	1.089	1.083	1.070
34	1.103	1.098	1.090	1.077
35	1.112	1.106	1.098	1.083
36	1.120	1.115	1.106	1.088
37	1.129	1.123	1.112	1.093
38	1.137	1.130	1.119	1.097
39	1.144	1.138	1.124	1.100
40	1.151	1.144	1.130	1.103

Attached Material-8
Temperature correction factors for NITTO DENKO spiral-wound type module

Temperature Correction Factor(T.C.F) =

$$\frac{\text{Permeate Rate(25 degree C)}}{\text{Permeate Rate(t degree C)}}$$

(℃)	5	6	7	8	9
T.C.F*	1.919	1.853	1.793	1.730	1.672

(℃)	10	11	12	13	14
T.C.F	1.616	1.563	1.511	1.463	1.415

(℃)	15	16	17	18	19
T.C.F	1.370	1.326	1.284	1.243	1.204

(℃)	20	21	22	23	24
T.C.F	1.167	1.131	1.096	1.063	1.031

(℃)	25	26	27	28	29
T.C.F	1.0	0.970	0.941	0.914	0.887

(℃)	30	31	32	33	34
T.C.F	0.861	0.836	0.812	0.789	0.767

(℃)	35	36	37	38	39
T.C.F	0.745	0.724	0.704	0.685	0.666

(℃)	40
T.C.F	0.648

Attached Material-9

Instruction manual for NITTO DENKO RO/UF test cell C70-F

INSTRUCTION MANUAL FOR NITTO RO/UF TEST CELL C70-F

Membrane Division

NITTO DENKO CORPORATION

Issued in December, 1983
Revised in February, 1993

CONTENTS

1. INTRODUCTION

1.1 Outline

This cell ensures easy transmission experiment through reverse osmosis membrane and ultrafiltration membrane with the aid of plain membrane (ø75 mm).
Liquid to be transmitted is circulated by pump. So as to prevent concentration polarization the cross flow system is adopted. In this system the test liquid flows with high speed through the narrow passage between the membrane surface and the cell. The cell can be assembled and disassembled without using tools, so that stable test can be executed easily and efficiently.
For normal operation of the cell the equipments listed in Table 1 must be prepared.
It is required to read thoroughly the Instruction Manual so as to ensure safe and stable operation of the cell.

1.2 Before Use

Before using the cell, the user must prepare the following equipments and piping attachments.

Table 1 Peripheral equipments and piping attachments to be prepared before use

(1) Pump unit: 1 set

Max. pressure:
To be selected according to operating pressure (allowable pressure 70 kgf/cm^2)

Standard flow rate:
5 liters/min or more

Recommended models (example):
Small tester for NITTO membrane separation (Membrane Masters)*
For reverse osmosis and ultrafiltration:
RUW-5A, max. pressure: 50 kgf/cm^2
For ultrafiltration:
UW-1A, max. pressure: 7.0 kgf/cm^2

* The small testers are supplied by Nitto Denko Corporation.

(2) High pressure hose: 2 pcs.

Max. operating pressure:
1.5 times or more higher than operating pressure

Recommended models (example):

Hydraulic hose:	E606
Nipple (SUS316):	EA06NPF
Adapter (SUS316):	3001F06
Manufacturer:	Bridgestone Imperial

(3) Tank

Capacity: 10 liters or more (depends on hold-up of tester)

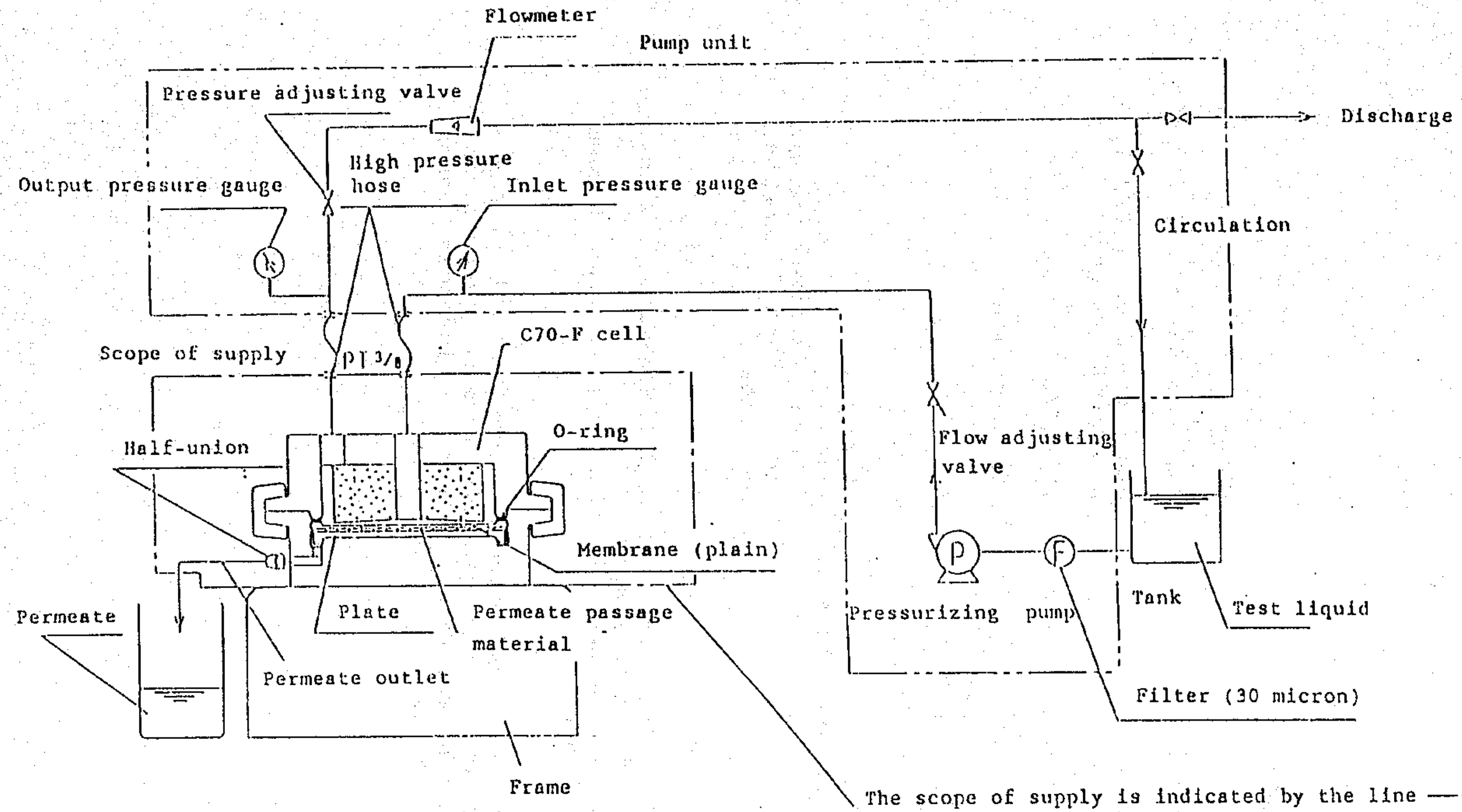
1.3 Connection to Equipments

Connect the peripheral equipments shown in item 1.2 and the cell according to the Standard Cell Piping, Figure 1, observing the following requirements.

(1) When installing the screw-joint pipings, wind the seal tapes around the threaded parts (2 or 3 wraps), and tighten the screw with the pipe wrench so as to engage more than 3 threads.
Hand tightening cannot ensure sufficient tightness and may cause seal leak and piping disconnection. Be sure to use the tool.

(2) Do not bend forcibly the high pressure hose. The bending radius must be more than 120 mm.

(3) When tightening the high pressure hose nipple and adapter, be sure to use the spanner or proper tightening tool.



The scope of supply is indicated by the line ———.
Other equipments should be prepared by the customer.

Figure 1 Standard cell piping

1.4 Specification

(1) Model: C70-F

(2) Dimension: 180 mm x 62 mm

(3) Material: Stainless steel (SUS316), polyacetal resin

(4) Max. operating pressure: 70 kgf/cm^2

(5) Max. flow rate: 15 liters/min

(6) Weight: 4 kgf

(7) Membrane to be used

OD:	75 mm
Effective membrane area:	32 cm^2
Type:	Various reverse osmosis and ultrafiltration membranes

(8) Attachments

A. O-ring (size P65, material FPM (Byton)): 2 pcs. (one of them is spare)
B. Permeate passage material: 3 pcs. (two of them are spares)

Note:
The cell is supplied without membrane. Nitto Denko Corporation can supply various reverse osmosis and ultrafiltration membranes suited to intended tests (refer to Appendix).

1.5 Appearance and Parts Names

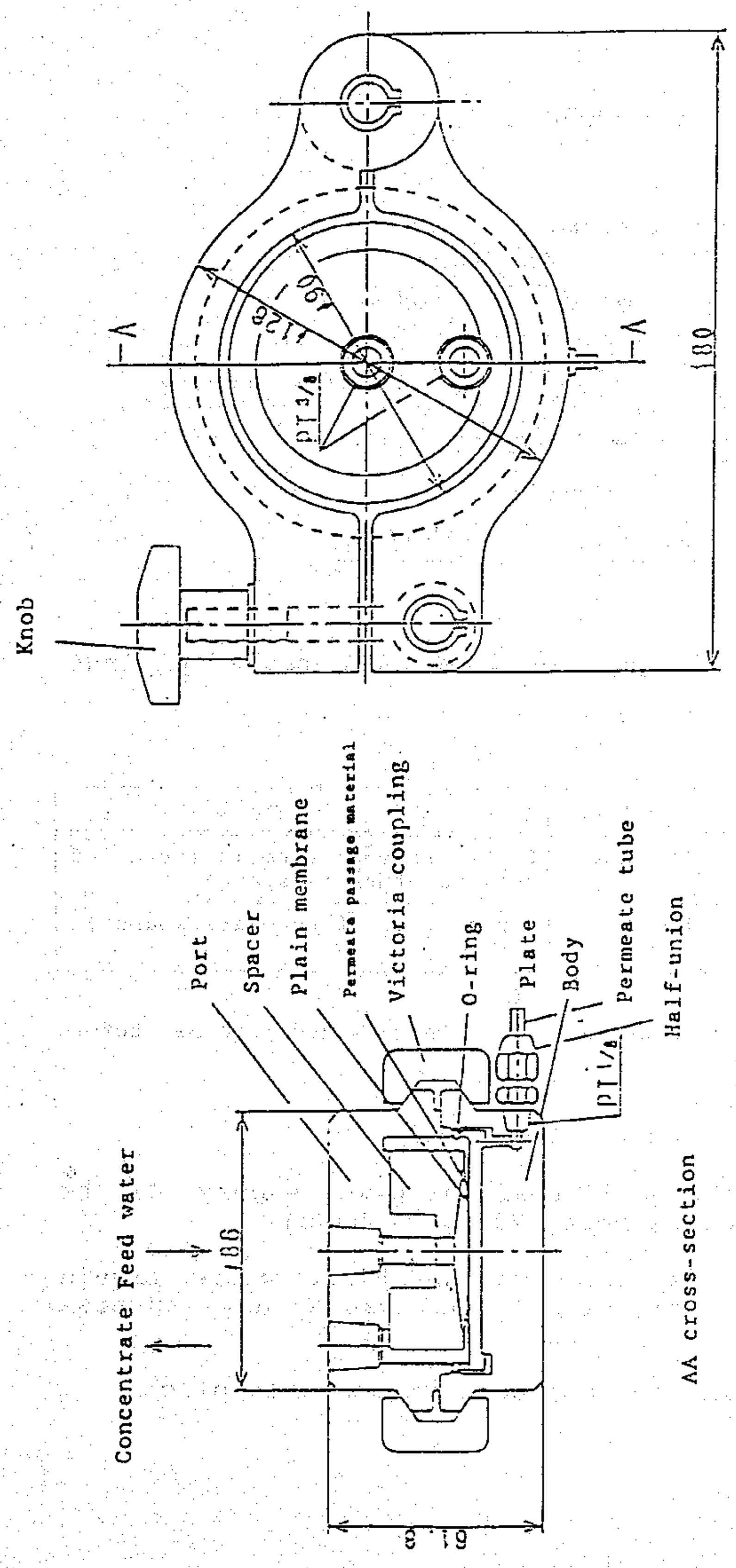


Figure 2 Cell piping connection diagram

2. Shipping Package

(1) Main body and attached piping

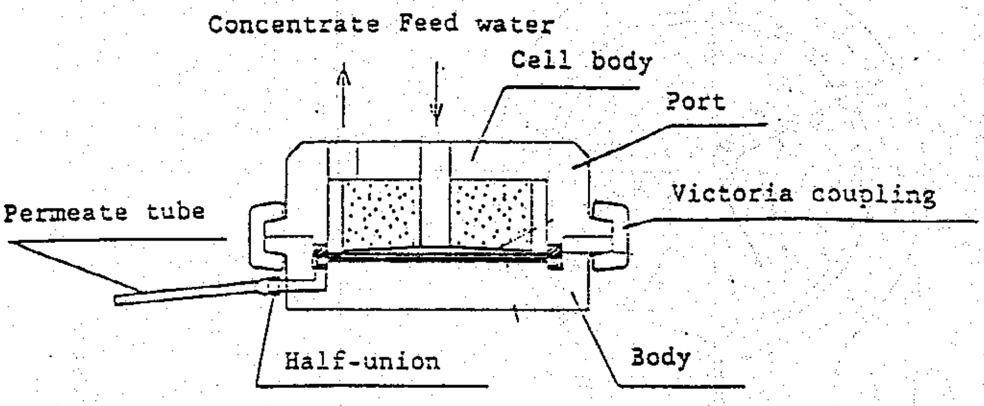


Figure 3 Cell body shipping package and attached pipings

(2) Attachments

Name	Part No.	Q'ty
O-ring (P65) Material Byton	950	2 pcs. (one of them is installed but the other is spare)
Permeate passage material	951	3 pcs. (two of them are spares)

The main body and attached parts are packaged together before shipping.

3. Cares When Installing the Test Cell

(1) Install the test cell near the power supply for the pump unit (for example, 200V, 3-phase).

(2) Install the test cell in the place where liquid leakage, if any, does not cause any adverse influence.

(3) Do not install the test cell in unstable place.

(4) Do not install the test cell in the place where shock or vibration may affect.

(5) The test cell is not provided with the temperature adjusting mechanism. Use the pump unit provided with a temperature adjusting mechanism in the place where room temperature is stable and specific temperature can be obtained.

4. Operation

4.1 Installation of Plain Membrane and Assembling of Cell

(1) Remove the Victoria coupling to separate the port, body, and plate. However, there is no need to disconnect the high-pressure hose from the cell.

(2) Thoroughly clean the port, body, and plate with pure water.

(3) Fit the plate, permeate passage material, plain membrane (ø75 mm), and O-ring in succession to the body (Figure 4). At this time ascertain that the O-ring is free from damage. Be careful so as not to damage the membrane surface.

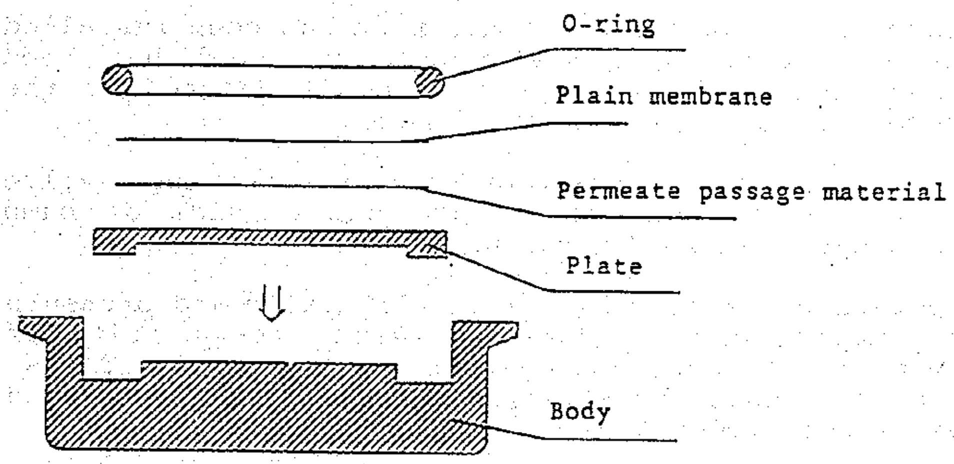


Figure 4

(4) After the plain membrane has been set on the body in Step (3) above, put the port on the body, and connect the port with the body, using the Victoria coupling. At this time sufficiently tighten the knob of Victorias coupling by hand.
As a result the cell is assembled as shown in Figure 5.

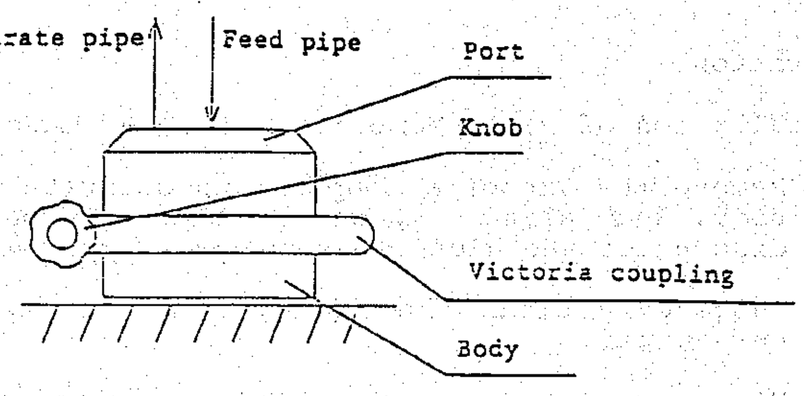


Figure 5

4.2 Operation Procedure

(1) Ascertain that the plain membrane has been installed as stated in item 4.1 above, the cell has been assembled, and the cell has been connected to the pump unit and high-pressure hose.

(2) Ascertain that the pressure adjusting valve installed at the concentrate outlet side of pump unit has been fully opened.

(3) Operating the flow rate adjusting valve and pressure adjusting valve, slowly increase the quantity of feed water and pressure up to specific levels. Figure 6 shows the relation between quantity of feed water and membrane surface flow speed.

Notes:
(1) Do not raise the pressure above 70 kgf/cm^2.

(2) So as to ensure safety during operation, use the protective cover, and take due care.

(3) The cell is not provided with the temperature adjusting mechanism. Hence, the liquid temperature must be kept constant with the aid of temperature adjusting mechanism of pump unit or the temperature adjusting mechanism of feed tank.

(4) The permeate flows out from the tube at the permeate outlet tube. The permeate begins to flow out after pressurizing for a while since the air remains at the permeate side for the initial stage of operation. The quantity of permeate may fluctuate while the air remains.
Unless the parts have been cleaned sufficiently, quality of permeate is degraded, resulting in improper performance of membrane. Therefore due care must be taken.

* It is recommended to start measurement or sampling after about 10 ml of permeate is sent.

(5) The outlet side of permeate outlet tube must be lower than the plain membrane.

(6) After completion of test gradually reduce the quantity of feed water and pressure of pump unit, and after stopping the unit ascertain that the inner pressure of cell has been lowered down to zero. And then disassemble the cell.
Disassemble the cell in the reverse order of procedure stated in item 4.1.

(7) After disassembling thoroughly clean the parts with detergent and pure water, and then proceed to the next test.

* If the permeate passage material is contaminated, the required quality of permeate cannot be obtained. Usually, replace the permeate passage material once per 30 tests, although the replacement frequency varies depending on the quality of liquid to be treated.
The permeate passage materials for the cell can be supplied by Nitto Denko Corporation.

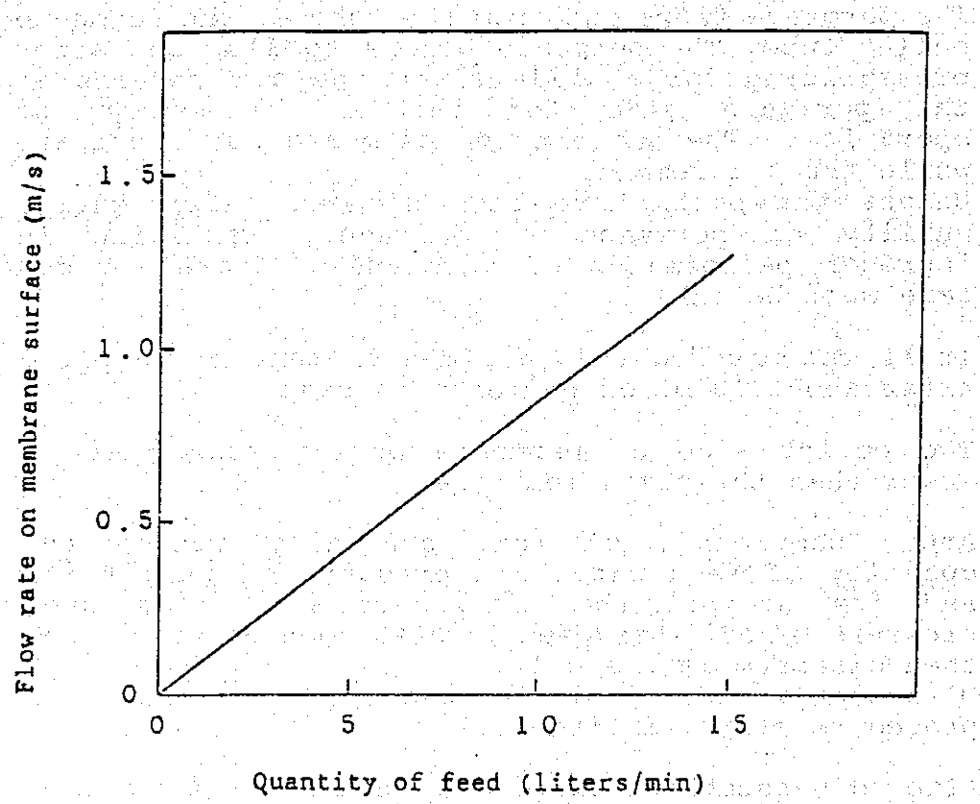


Figure 6

4.3 Calculation of Membrane Performance

The permeate flux (flux) and solute rejection (Rej) are calculated in the following procedure.

(1) The test liquid concentration Co (ppm) in the tank during test is measured.

(2) Approx. 10 minutes after start of pressurizing, or after 10 ml of permeate is sent, sampling is started.
If there is much permeate, sampling is started within 10 minutes when the quantity of permeate is stabilized.

(3) It is desirable that the quantity of sample for analysis be about 50 cc. It is allowed, however, to increase the quantity of sample as required.

(4) The sampling quantity V (ml) and the time T (min) are measured.

(5) The concentration C (ppm) of sampling liquid is measured.

(6) The quantity of concentrate Ct (ppm) discharged from the concentrate outlet of pump unit is measured.

(7) The flux and solute rejection (Rej) are calculated by using the following formula:

$$\text{Flux} = \frac{0.45 \cdot f \cdot V}{T} = (m^3/m^2\text{day at } 25^\circ C)$$

(where f is flux temperature conversion coefficient*)

$$\text{Rej} = \{ 1 - \frac{2 \cdot C}{C_0 + C_t} \} \times 100 \ (\%)$$

* The flux temperature conversion coefficient is shown in Table 2.
The temperature conversion is based on viscosity coefficient of water. It may vary insignificantly depending on test liquids.

Table 2 Flux conversion coefficient (f)

(25°C conversion)

T (℃)	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
10	1.448	1.444	1.448	1.436	1.432	1.428	1.424	1.421	1.417	1.413
11	1.409	1.405	1.402	1.398	1.394	1.391	1.387	1.383	1.380	1.376
12	1.372	1.369	1.365	1.361	1.358	1.354	1.351	1.347	1.344	1.340
13	1.337	1.333	1.330	1.326	1.323	1.319	1.316	1.313	1.309	1.306
14	1.302	1.299	1.295	1.292	1.289	1.286	1.283	1.279	1.276	1.273
15	1.270	1.266	1.263	1.260	1.257	1.254	1.250	1.247	1.244	1.241
16	1.230	1.235	1.232	1.229	1.226	1.223	1.220	1.216	1.213	1.210
17	1.207	1.204	1.201	1.199	1.196	1.193	1.190	1.187	1.184	1.181
18	1.178	1.175	1.172	1.169	1.167	1.164	1.161	1.158	1.155	1.153
19	1.150	1.147	1.144	1.142	1.139	1.136	1.133	1.131	1.128	1.125
20	1.123	1.120	1.117	1.115	1.112	1.109	1.107	1.104	1.101	1.099
21	1.096	1.094	1.091	1.089	1.086	1.083	1.081	1.078	1.076	1.073
22	1.071	1.068	1.066	1.063	1.061	1.059	1.056	1.054	1.051	1.049
23	1.046	1.044	1.042	1.039	1.037	1.035	1.032	1.030	1.027	1.025
24	1.023	1.020	1.018	1.016	1.014	1.011	1.009	1.007	1.005	1.002
25	1.000	0.998	0.996	0.993	0.991	0.989	0.987	0.984	0.982	0.980
26	0.978	0.976	0.974	0.972	0.969	0.967	0.965	0.963	0.961	0.959
27	0.957	0.955	0.953	0.950	0.948	0.946	0.944	0.942	0.940	0.938
28	0.936	0.934	0.932	0.930	0.928	0.926	0.924	0.922	0.920	0.918
29	0.916	0.914	0.912	0.910	0.908	0.906	0.905	0.903	0.901	0.899
30	0.897	0.895	0.893	0.891	0.889	0.888	0.886	0.884	0.882	0.880
31	0.878	0.875	0.875	0.873	0.871	0.869	0.867	0.866	0.864	0.862
32	0.860	0.859	0.857	0.855	0.853	0.851	0.850	0.848	0.846	0.845
33	0.843	0.841	0.839	0.838	0.836	0.834	0.833	0.831	0.829	0.828
34	0.826	0.824	0.823	0.821	0.819	0.818	0.816	0.814	0.813	0.811
35	0.810	0.808	0.806	0.805	0.803	0.802	0.800	0.798	0.797	0.795
36	0.794	0.792	0.791	0.789	0.787	0.786	0.784	0.783	0.781	0.780
37	0.778	0.777	0.775	0.774	0.772	0.771	0.769	0.768	0.766	0.765
38	0.763	0.762	0.760	0.759	0.758	0.756	0.755	0.753	0.752	0.750
39	0.749	0.747	0.745	0.745	0.743	0.742	0.740	0.739	0.738	0.736
40	0.735	0.733	0.732	0.731	0.729	0.728	0.727	0.725	0.724	0.723
41	0.721	0.720	0.719	0.717	0.716	0.715	0.713	0.712	0.711	0.709
42	0.708	0.707	0.705	0.704	0.703	0.702	0.700	0.699	0.698	0.696
43	0.695	0.694	0.693	0.691	0.690	0.689	0.688	0.686	0.685	0.684
44	0.683	0.681	0.680	0.679	0.678	0.677	0.675	0.674	0.673	0.672
45	0.671	0.669	0.668	0.667	0.666	0.665	0.663	0.662	0.661	0.660
46	0.659	0.658	0.656	0.655	0.654	0.653	0.652	0.651	0.650	0.648
47	0.647	0.646	0.645	0.644	0.643	0.642	0.641	0.640	0.638	0.637
48	0.636	0.635	0.634	0.633	0.632	0.631	0.630	0.629	0.628	0.626
49	0.625	0.624	0.623	0.622	0.621	0.620	0.619	0.618	0.617	0.616
50	0.615	0.614	0.613	0.612	0.611	0.610	0.609	0.608	0.607	0.606

4.4 Troubleshooting

When any failure is found in operation of the cell, execute the corrective action shown in Table 3.

Table 3 Troubleshooting

Item	Failure	Causes	Corrective action
Flux	Reduction	Pressure drop 1. Pressure adjusting valve adjusted improperly 2. Pump discharge pressure too low	1. Adjust the pressure adjusting valve. 2. Repair the pump.
		Reduction of membrane surface flow speed 1. Flow adjusting valve adjusted improperly 2. Pump discharge flow rate too low	1. Adjust the flow rate adjusting valve. 2. Repair the pump.
		Permeate side clogging	1. Clean or replace the permeate passage material. 2. Clean or replace the permeate tube.
		Membrane contamination	Replace the membrane.
		Excessive concentration of liquid	Lower the concentration rate.
Rejection	Reduction	Pressure drop 1. Pressure adjusting valve adjusted improperly 2. Pump discharge pressure too low	1. Adjust the pressure adjusting valve. 2. Repair the pump.
		Reduction of membrane surface flow speed 1. Flow adjusting valve adjusted improperly 2. Pump discharge flow rate too low	1. Adjust the flow rate adjusting valve. 2. Repair the pump.
		Permeate side contamination	1. Clean the permeate side. 2. Replace the permeate passage material. 3. Replace the permeate tube.
		Leak from O-ring seal	Replace O-ring. 1. Replace the membrane. 2. Replica the membrane.
		Membrane contamination	Replace the membrane.
Others	Liquid leakage	Leak from O-ring seal	Replace O-ring.
		Leak from piping	1. Redo piping installation. 2. Replace the broken piping part.

Appendix NITTO Membranes

1. Typical reverse osmosis membranes

	Rejection (%)	Flux $(m^3/m^2.d)$	Range of pH	Max. operating pressure (kgf/cm^2)	Max. operating temperature (°C)	Residual chlorine (ppm)
NTR - 759HR	≥99[1]	≥1.0[1]	2 to 10	30	40	1.0 or less
NTR - 729HF	≥90[2]	≥1.7[2]	2 to 10	30	40	1.0 or less
NTR - 7450	50	≥1.8[3]	2 to 13	30	40	100 or less
NTR - 7410	10	≥3.5	2 to 13	30	40	100 or less

Inspection conditions
1) 0.15% NaCl, 15 kgf/cm^2, pH6 to 7
2) 0.15% NaCl, 15 kgf/cm^2, pH6 to 7
3) 0.2% NaCl, 5 kgf/cm^2, pH6 to 7
4) 0.2% NaCl, 10 kgf/cm^2, pH6 to 7

2. Ultrafiltration Membranes

	Cut-off molecular weighty (nominal)	Flux $(m^3/m^2.d)$	Range of pH	Max. operating pressure (kgf/cm^2)	Max. operating temperature (°C)	Residual chlorine (ppm)
NTU - 3150	50000	≥5[1]	2 to 12	10	40	50
NTU - 2120	20000	≥2[1]	2 to 12	5	40	10

Inspection conditions
1: Pure water, 2 kgf/cm^2

OPERATION INSTRUCTION FOR NITTO REVERSE OSMOSIS COMPOSITE MEMBRANES (NTR-7250, 7197, 7199)

So as to ensure the best use of NITTO reverse osmosis composite membranes the following requirements must be observed.

1. The glossy surface of the plain membrane is front side. Its rear side is nonwoven fabric. A thin transparent film is inserted between membranes so as to protect their surfaces. Before use remove the film.

2. Do not rub or damage the membrane surface.

3. The plain membrane is dry membrane. Set it in the test cell, and apply pressure without delay. With NTR-7250, in no case attempt to immerse the plain membrane in water and to use it after wetting.

4. In some cases the satisfactory performance cannot be obtained just after start of test. It is necessary to check the quality of permeate periodically. Generally, stable performance can be obtained after 30 to 50 ml permeate is passed.

5. If once used and removed test cell is used again, performance is degraded due to damage of O-ring contact part. Therefore do not use once used and removed membrane.

6. If oil or surfactant is mixed with feed liquid through the test cell or piping, the membrane performance may be degraded. The performance of NTR-7197 and NTR-7199 is degraded due to contact with water containing residual chlorine, such as city water.

7. Hard substance such as metal chip contained in the feed liquid may damage the membrane surface, resulting in degradation of its performance.

8. If the following failure is found on the membrane which has been removed from the test cell and cleaned with water after test, the membrane may be malfunctioning.

When damage is found on the membrane surface with the aid of magnifying glass.
When the membrane surface is partially colored in dark color after the membrane is immersed in 0.05% water solution of cation dye (for example, Sumitomo Chemical's Sumiacryl Red) for about 5 minutes and then washed in water, although coloring varies depending on liquids to be treated.

Appendix 7.1.1-2

Expectable RO Performance Based on Saudi Arabia Seawater

Expectable RO performance based on Saudi Arabia Seawater

1. Summary

Expectable RO performance for Spiral membrane elements (Toray, Nitto Denko) and Hollow fine fiber membrane elements (Toyobo) were conducted based on Saudi Arabia Seawater contents in order to simulate RO-Plant performance before conducting actual operation.

2. Calculated Condition

2.1 Specification of the RO membrane element

Manufacturer	Type of element	Type of membrane	Number of element
Toray	Spiral	SU-820	2
Nitto Denko	Spiral	70SWC-S8	2
Toyobo	Hollow fine fiber	HM8155EI	2

2.2 Raw Seawater Content applied for Simulation

		mg/l	mg/l as $CaCO_3$
Cation	Na^{+}	12688	27583
	K^{+}	494	632
	Ca^{++}	505	1263
	Mg^{++}	1545	6358
	Total Cation		35835
Anion	M-alk		129
	Cl^{-}	23000	32440
	Br^{-}	80	50
	SO_4^{-}	3030	3156
	Total Anion		35775

T.D.S = 46843 mg/l
Salinity = 41.54 gm/kg

3. Result

Estimated performance were shown in Table 1 - Table 11 and Fig.1 - Fig.6.Tab

Table 1 Expected RO Performance of Test Plant
Recovery(%), Working Pressure (Kg/cm^2) vs Permeate(ppm)

Element:NITTO DENKO NTR- 70SWC-S8 x 2
Temperature:25(°C) Feed TDS=46843 pH=7.0

			Product Flow Rate(m^3/h)		
Recovery	Item	Unit	0.79	1.0	1.2
18 %	Feed Brine Pressure Permeate	m3/h m3/h Kg/cm2 ppm	4.4 3.6 56.7/56.5 180.0	5.6** 4.6 62.8/62.5 142.8	6.7** 5.5 67.8/67.4 118.8
20 %	Feed Brine Pressure Permeate	m3/h m3/h Kg/cm2 ppm	4.0 3.2 56.4/56.2 183.3	5.0** 4.0 63.0/62.7 144.3	6.0** 4.8 69.1/68.8 120.5
23 %	Feed Brine Pressure Permeate	m3/h m3/h Kg/cm2 ppm	3.4 2.7 59.2/59.1 187.2	4.4 3.4 64.4/64.2 147.6	5.2** 4.0 69.5/69.2 122.8
25 %	Feed Brine Pressure Permeate	m3/h m3/h Kg/cm2 ppm	***	4.0 3.0 65.7/65.5 150.1	4.8** 3.6 70.9/70.6 124.8
27 %	Feed Brine Pressure Permeate	m3/h m3/h Kg/cm2 ppm	***	3.7 2.7 66.0/65.8 151.9	4.4 3.2 72.3/72.1 127.0
30 %	Feed Brine Pressure Permeate	m3/h m3/h Kg/cm2 ppm	***	***	4.0 2.8 72.8/72.7

Remarks
** :Feed flow is biger than the Pilot Plant feed capacity
*** :Brine flow rate is less than minimun flow rate of element

Table 2 Expected RO Performance of Test Plant
Woeking Pressure vs Permeate(m^3/d)

Feed TDS=46,843(ppm)
Module :TOYOBO Element: HM8155EI x 2

Feed Water (m^3/d)	Temperature (°C)	Permeate(m^3/d) Working Pressure (Kg/cm^2) 56	60	65	70
55	25	15.4	17.5	20.0	22.4
	30	15.9	18.1	20.7	23.2
	35	16.3	18.6	21.3	23.8
60	25	15.8	18.1	20.7	23.2
	30	16.4	18.8	21.6	24.1
	35	16.9	19.3	22.2	24.9
65	25	16.3	18.6	21.3	23.9
	30	16.9	19.3	22.2	25.0
	35	17.4	19.9	23.0	25.8
67	25	16.4	18.7	21.5	24.2
	30	17.0	19.5	22.5	25.3
	35	17.5	20.2	23.3	26.2

Table 3 Expected RO Performance of Test Plant
Permeate(ppm as TDS)

Feed TDS=46,843(ppm)
Module : TOYOBO Module Type : HM8155EI

Feed Water (m^3/d)	Temperature (°C)	Permeate(ppm as TDS) Working Pressure (Kg/cm^2) 56	60	65	70
55	25	362	323	289	265
	30	386	344	309	285
	35	410	366	330	305
60	25	346	307	273	250
	30	368	327	291	268
	35	389	347	310	285
65	25	333	294	261	237
	30	353	313	278	253
	35	373	331	294	269
67	25	328	290	256	233
	30	348	303	272	248
	35	368	325	289	264

Table 4 Expected RO Performance of Test Plant
Working Pressure(Kg/cm2) and Permeate(m3/d)

Feed TDS=46,843 (ppm)
Element:TORAY SU - 820 x 2

		Permeate(m^3/d)			
Feed water (m^3/d)	Temperature (°C)	Working Pressure (Kg/cm²)			
		56	60	65	70
55	25	13.52	15.82	18.55	20.83
	30	14.36	16.81	19.68	22.08
	35	15.10	17.68	20.65	23.15
60	25	14.09	16.52	19.41	21.84
	30	15.02	17.63	20.70	23.27
	35	15.87	18.63	21.83	24.52
65	25	14.61	17.16	20.21	22.77
	30	15.64	18.38	21.63	24.37
	35	16.59	19.51	22.92	25.80
67	25	14.81	17.40	20.51	23.11
	30	15.87	18.67	21.99	24.78
	35	16.86	19.84	23.34	26.28

Table 5 Expected RO Performance of Test Plant
Working Pressure(Kg/cm2) vs Permeate(ppm as TDS)

Feed TDS=46,843 (ppm)
Element:TORAY SU - 820 x 2

		Permeate(ppm as TDS)			
Feed water (m^3/d)	Temperature (°C)	Working Pressure (Kg/cm²)			
		56	60	65	70
55	25	667.74	594.67	534.72	508.96
	30	852.75	762.97	691.40	662.64
	35	1099.43	988.80	903.55	872.33
60	25	623.02	552.47	494.07	468.18
	30	792.06	705.33	635.38	606.00
	35	1016.49	909.56	825.92	793.32
65	25	585.71	517.45	460.55	434.72
	30	741.62	657.68	589.34	559.68
	35	947.80	844.25	762.29	728.84
67	25	572.45	505.05	448.73	422.96
	30	723.74	640.85	573.16	543.44
	35	923.52	821.25	739.96	706.28

Table 6 Expected RO Performance of Test Plant
Recovery(%), Working Pressure (Kg/cm^2) vs Permeate(m^3/d)

Feed TDS=46,843 (ppm)
Element:TORAY SU - 820 x 2

		Permeate(m^3/d)			
Recovery (%)	Temperature (°C)	Working Pressure (Kg/cm^2)			
		56	60	65	70
25	25	13.30	17.93	24.01	29.41
	30	15.02	20.61	27.88	34.32
	35	16.99	23.61	32.29	39.85
30	25	10.64	15.10	20.89	26.08
	30	11.85	17.20	24.12	30.36
	35	13.10	19.52	27.80	35.32
35	25	7.63	12.12	17.72	22.78
	30	8.07	13.55	20.30	26.40
	35	8.30	15.06	23.18	30.53

Table 7 Expected RO Performance of Test Plant
Temperature(°C), Revovery(%) vs Permeate(ppm)

Feed TDS=46,843 (ppm)
Element:TORAY SU - 820 x 2

		Permeate(ppm as TDS)			
Recovery (%)	Temperature (°C)	Working Pressure (Kg/cm^2)			
		56	60	65	70
25	25	686.10	479.39	337.5	269.84
	30	792.06	541.26	376.38	299.69
	35	911.97	613.88	421.36	337.19
30	25	982.85	642.68	434.16	338.92
	30	1154.72	734.65	488.16	377.11
	35	1370.03	843.46	549.86	420.02
35	25	1626.53	919.37	578.02	434.20
	30	2042.41	1076.24	656.43	486.05
	35	2657.07	1269.39	748.39	545.44

Table 8 Expected RO Performance of Test Plant
Recovery(%), Working Pressure (Kg/cm^2) VS Permeate(m^3/d)

Feed TDS=46,843(ppm)
Module : TOYOBO Element: HM8155EI x 2

		Permeate(m^3/d)			
Recovery (%)	Temperature (°C)	Working Pressure (Kg/cm^2)			
		56	60	65	70
25	25	16.3	19.6	23.5	27.4
	30	17.2	20.8	25.2	29.4
	35	18.0	21.9	26.7	31.2
30	25	14.7	18.1	22.2	26.1
	30	15.5	19.3	23.7	28.1
	35	16.1	20.2	25.1	29.8
35	25	12.7	16.6	20.6	24.5
	30	13.3	17.3	21.9	26.4
	35	13.7	18.1	23.1	28.0

Table 9 Expected RO Performance of Test Plant
Temperature(°C), Recovery(%) VS Permeate(ppm)

Feed TDS=46,843(ppm)
Module : TOYOBO Element: HM8155EI x 2

		Permeate(ppm as TDS)			
Recovery (%)	Temperature (°C)	Working Pressure (Kg/cm^2)			
		56	60	65	70
25	25	332	273	225	192
	30	342	280	230	196
	35	354	288	235	200
30	25	384	307	248	209
	30	397	315	253	213
	35	411	324	259	217
35	25	465	356	279	231
	30	484	367	286	236
	35	506	379	293	241

Table 10 Recovery(%).Working Pressure(Kg/cm2) vs
Flux Conversion Coefficient
Element:TORAY SU - 820 x 2

		Flux Conversion Coefficient			
Recovery (%)	Temperature (°C)	Working Pressure (Kg/cm^2)			
		56	60	65	70
25	23	0.942	0.937	0.934	0.931
	24	0.971	0.968	0.966	0.965
	25	1.000	1.000	1.000	1.000
	26	1.025	1.028	1.030	1.032
	27	1.051	1.057	1.061	1.064
	28	1.077	1.087	1.094	1.098
	29	1.105	1.117	1.127	1.132
	30	1.132	1.148	1.161	1.167
	31	1.159	1.180	1.195	1.203
	32	1.188	1.213	1.231	1.240
	33	1.217	1.247	1.268	1.277
	34	1.247	1.281	1.306	1.316
	35	1.277	1.315	1.345	1.355
	36	1.307	1.352	1.385	1.395
30	23	0.948	0.940	0.935	0.933
	24	0.975	0.970	0.967	0.966
	25	1.000	1.000	1.000	1.000
	26	1.023	1.026	1.029	1.031
	27	1.044	1.054	1.059	1.063
	28	1.067	1.081	1.090	1.096
	29	1.090	1.109	1.122	1.130
	30	1.113	1.138	1.155	1.165
	31	1.136	1.167	1.188	1.201
	32	1.160	1.198	1.223	1.237
	33	1.182	1.228	1.258	1.275
	34	1.207	1.259	1.293	1.314
	35	1.229	1.292	1.331	1.355
	36	1.254	1.324	1.369	1.396
35	23	0.965	0.973	0.938	0.934
	24	0.983	0.973	0.969	0.967
	25	1.000	1.000	1.000	1.000
	26	1.013	1.023	1.028	1.030
	27	1.025	1.046	1.056	1.061
	28	1.037	1.070	1.085	1.093
	29	1.048	1.094	1.115	1.126
	30	1.058	1.118	1.146	1.159
	31	1.067	1.143	1.177	1.193
	32	1.075	1.167	1.209	1.229
	33	1.081	1.192	1.241	1.265
	34	1.085	1.217	1.274	1.302
	35	1.087	1.243	1.308	1.340
	36	1.089	1.268	1.343	1.380

Table 11 Recovery(%) , Working Pressure(Kg/cm^2) VS Flux Conversion Coefficient
Module : TOYOBO Element: HM8155EI

		Flux Conversion Coefficient			
Recovery (%)	Temperature (°C)	Working Pressure (Kg/cm^2)			
		56	60	65	70
25	23	0.965	0.971	0.970	0.969
	24	0.985	0.986	0.985	0.985
	25	1.000	1.000	1.000	1.000
	26	1.013	1.013	1.015	1.015
	27	1.025	1.027	1.030	1.030
	28	1.037	1.040	1.044	1.045
	29	1.048	1.053	1.058	1.060
	30	1.059	1.065	1.071	1.074
	31	1.070	1.077	1.084	1.088
	32	1.081	1.089	1.098	1.102
	33	1.090	1.101	1.110	1.116
	34	1.100	1.112	1.122	1.128
	35	1.109	1.122	1.134	1.141
	36	1.118	1.133	1.145	1.154
30	23	0.966	0.972	0.970	0.969
	24	0.986	0.986	0.985	0.985
	25	1.000	1.000	1.000	1.000
	26	1.012	1.014	1.015	1.016
	27	1.024	1.026	1.029	1.031
	28	1.035	1.039	1.043	1.046
	29	1.046	1.051	1.057	1.060
	30	1.056	1.063	1.071	1.075
	31	1.067	1.075	1.083	1.089
	32	1.076	1.087	1.096	1.103
	33	1.085	1.097	1.109	1.116
	34	1.093	1.107	1.120	1.130
	35	1.102	1.118	1.132	1.142
	36	1.110	1.127	1.143	1.155
35	23	0.967	0.973	0.971	0.968
	24	0.986	0.987	0.986	0.985
	25	1.000	1.000	1.000	1.000
	26	1.011	1.013	1.014	1.015
	27	1.021	1.025	1.028	1.030
	28	1.031	1.038	1.042	1.044
	29	1.041	1.049	1.055	1.059
	30	1.050	1.061	1.068	1.073
	31	1.059	1.072	1.081	1.087
	32	1.068	1.082	1.093	1.100
	33	1.075	1.091	1.105	1.114
	34	1.081	1.101	1.117	1.127
	35	1.089	1.110	1.128	1.139
	36	1.094	1.190	1.138	1.152

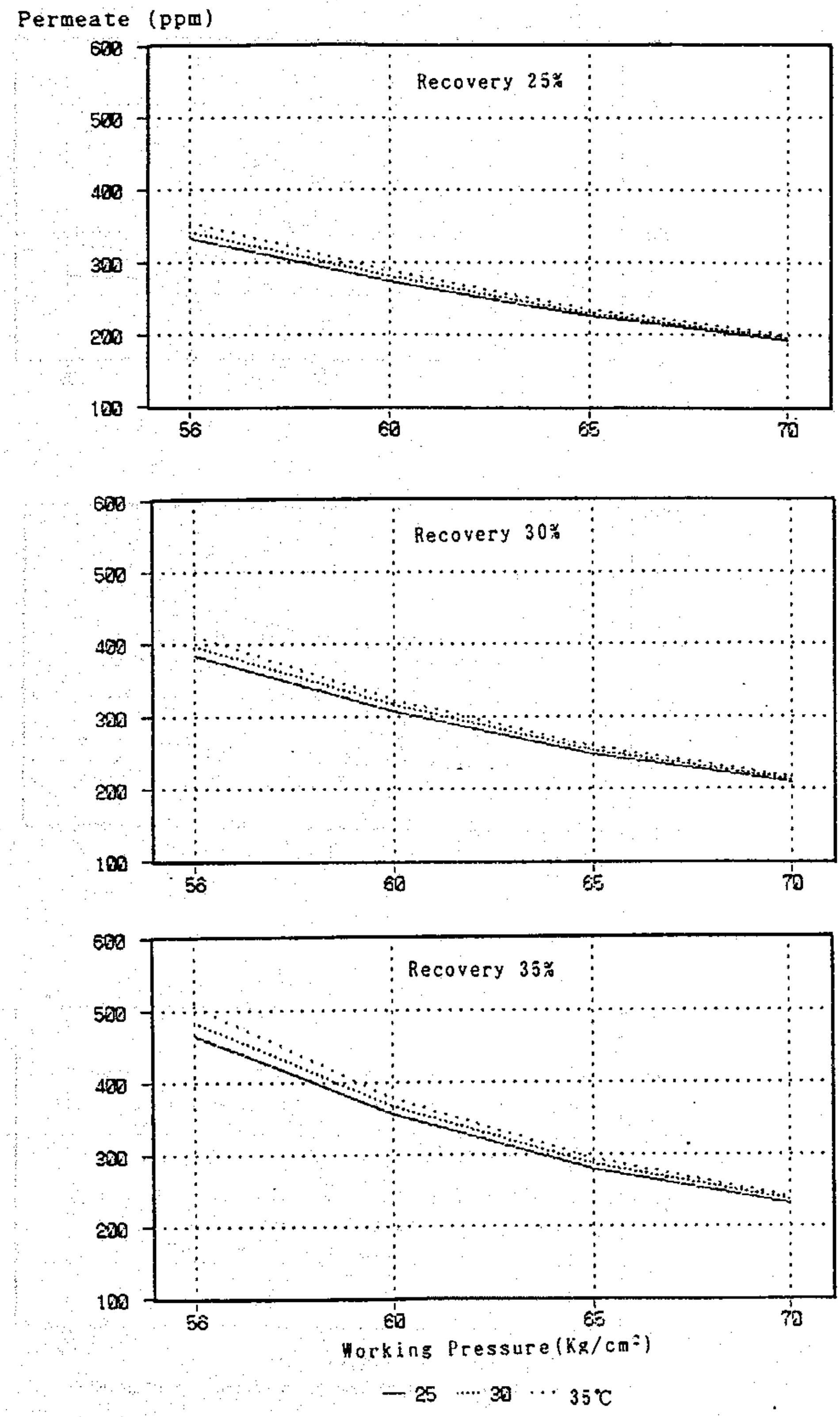


Fig.1 Expected RO Element Performance of Test Plant
Working Pressure.Temperature vs Permeate(ppm)
Element:TOYOBO HM8155EI x 2

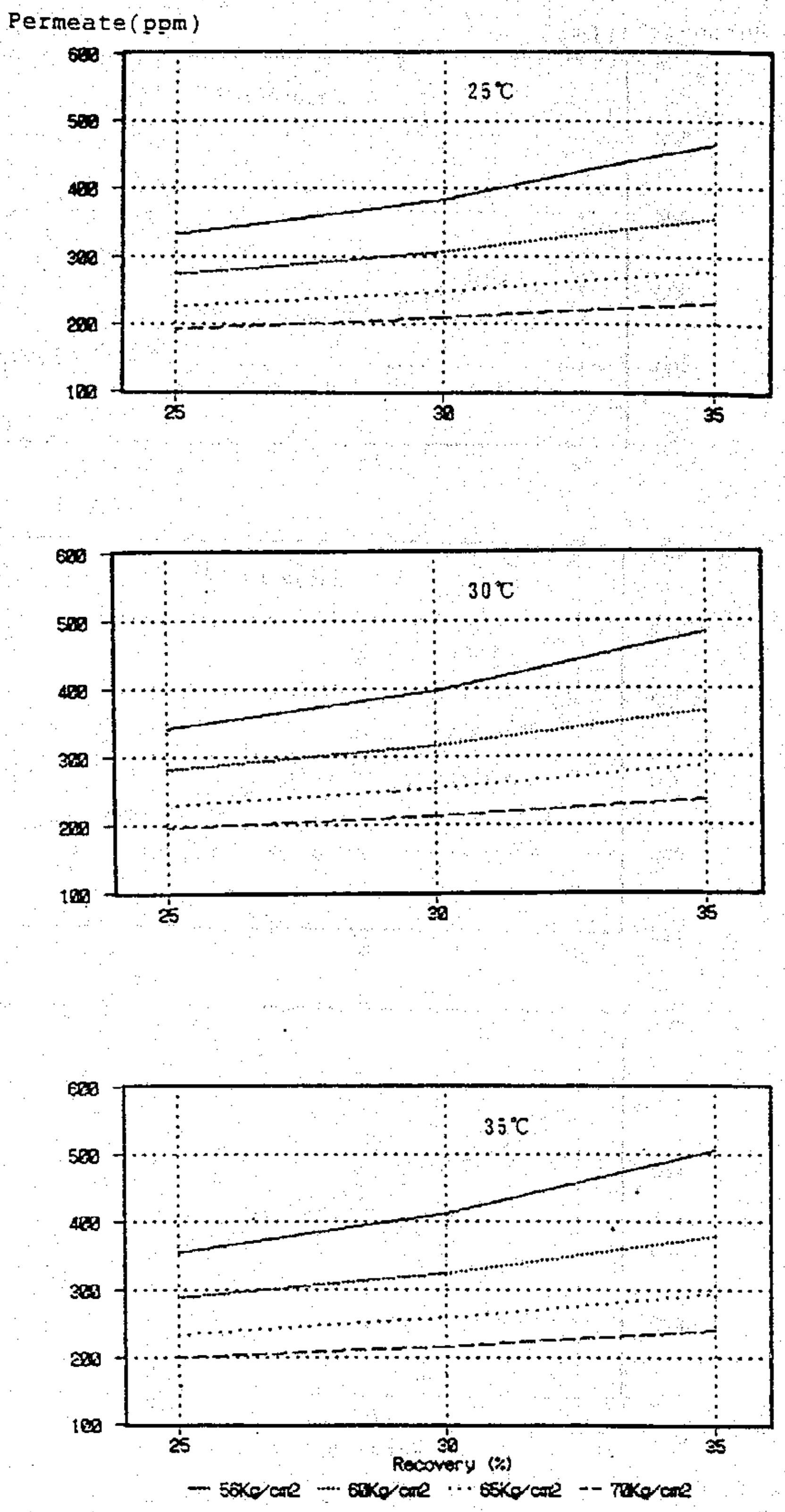


Fig. 2 Expected RO Element Performance of Test Plant
Recovery(%),Working Pressure vs Permeate(ppm)
Element:TOYOBO HM8155EI x 2

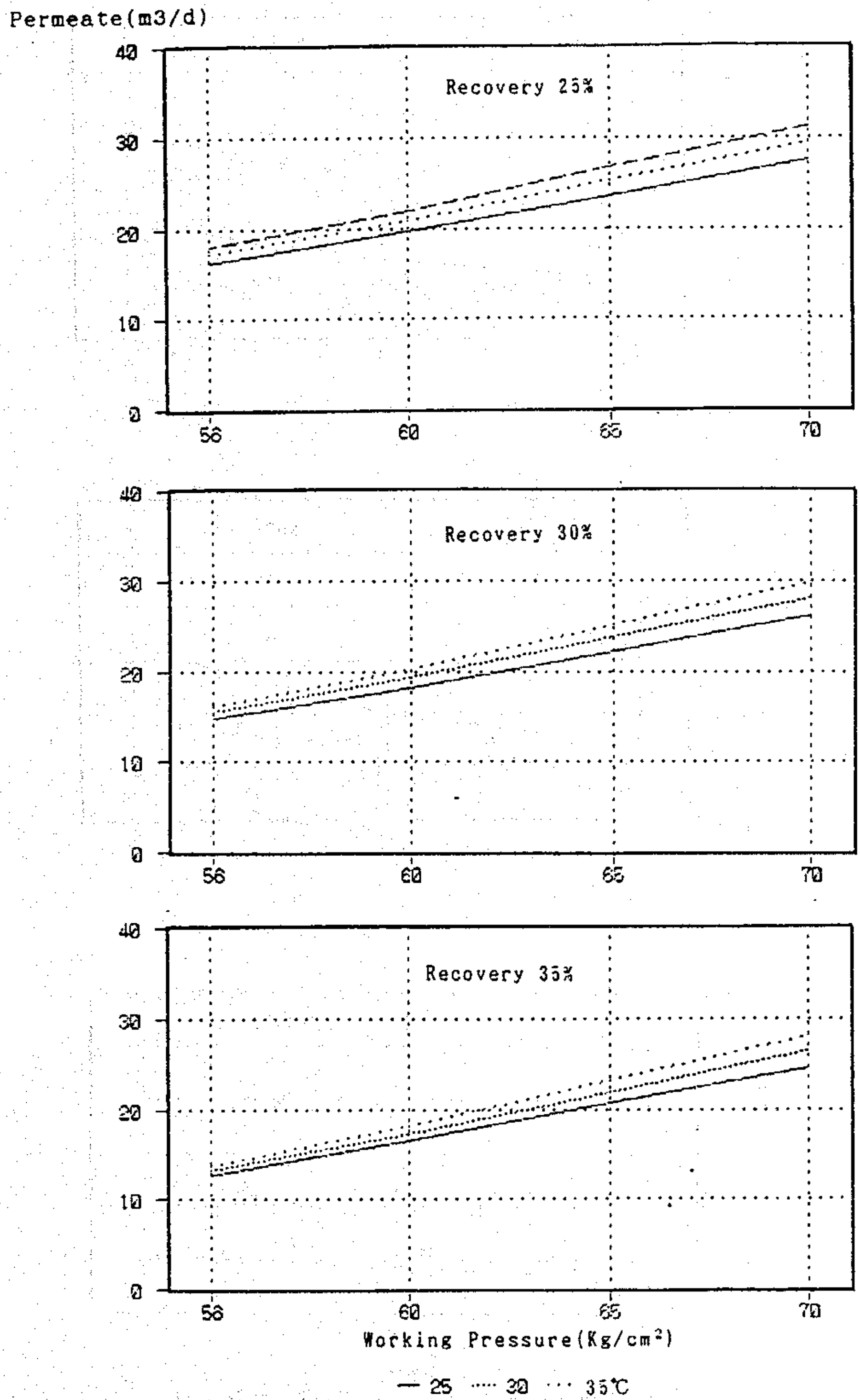


Fig. 3 Expected RO Element Performance of Test Plant
Working Pressure.Temperature vs Permeate(m^3/d)
Element:TOYOBO HM8155EI x 2

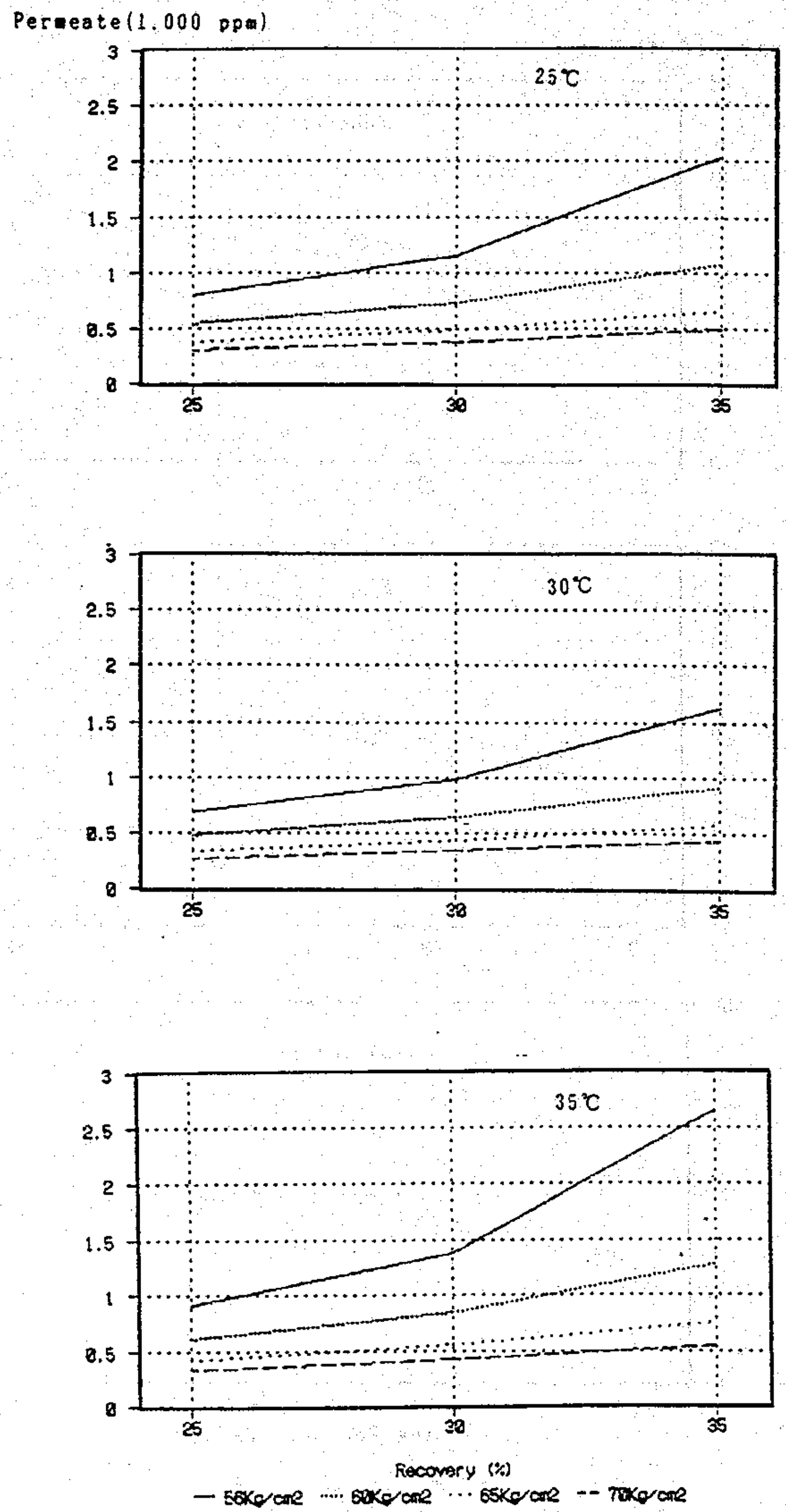


Fig. 4 Expected RO Element Performance of Test Plant
Recovery(%), Working Pressure vs Permeate(ppm)
Element: TORAY SU-820 x 2

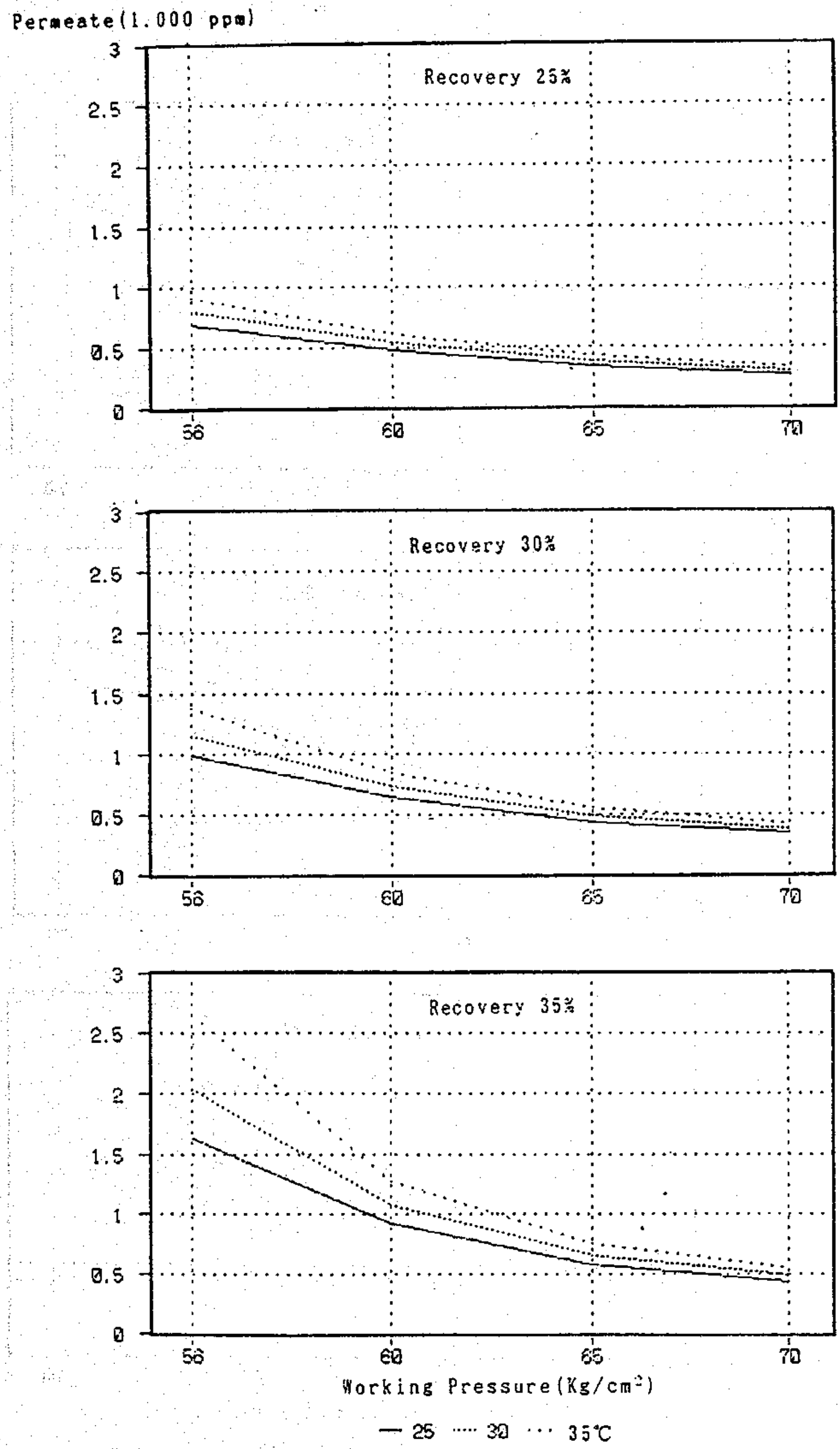


Fig. 5 Expected RO Element Performance of Test Plant
Working Pressure.Temperature vs Permeate(ppm)
Element:TORAY SU-320 x 2

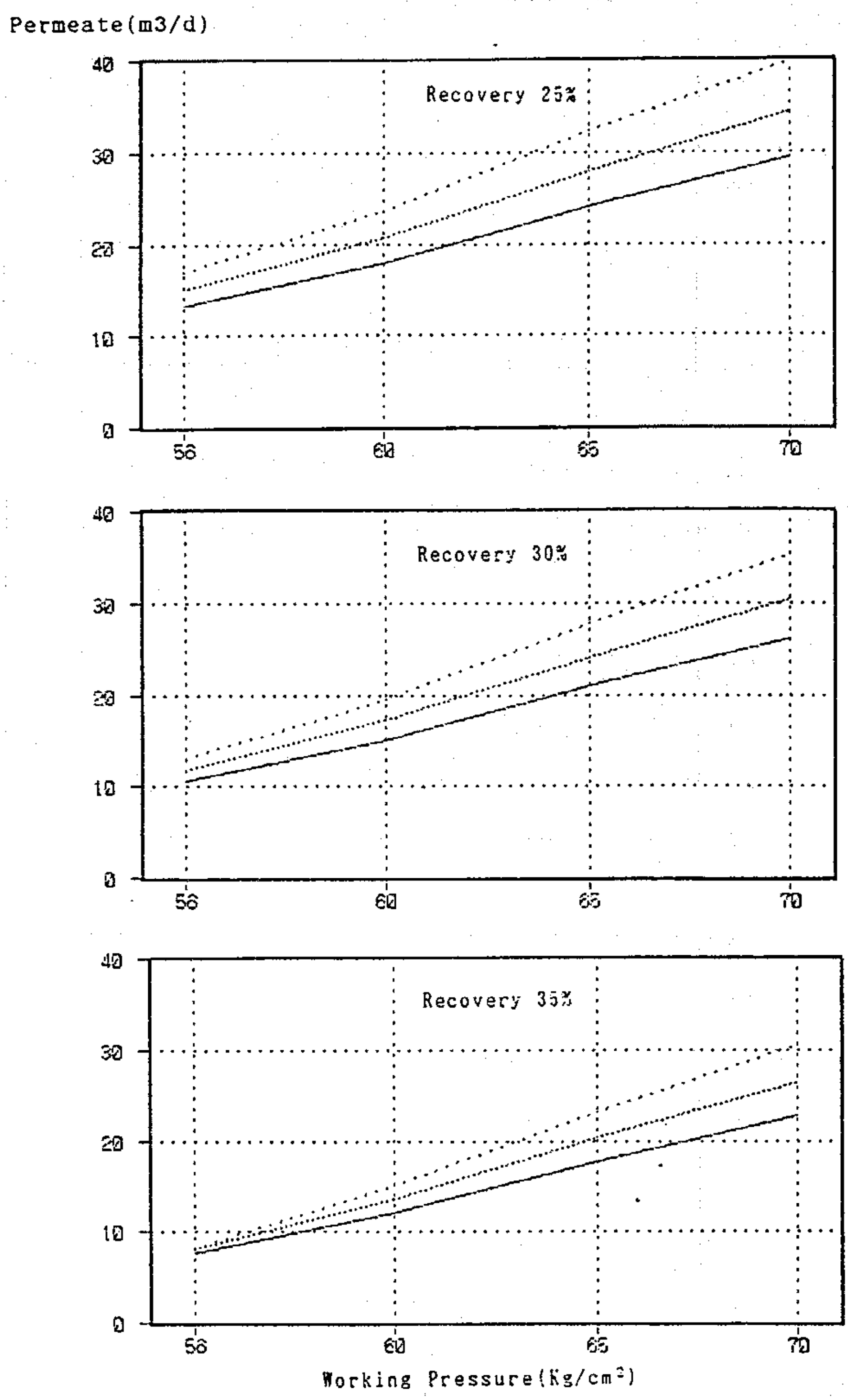


Fig. 6 Expected RO Element Performance of Test Plant
Working Pressure Temperature vs Permeate(m^3/d)
Element:TORAY SU-820 x 2