No. 7

サウディ・アラビア王国

海水淡水化技術協力計画調査
最終報告書
（付属資料）

平成7年2月

国際協力事業団

サウディ・アラビア王国海水淡水化公団

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学 会 発 表 論 文
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BAHRAIN 5TH - 9TH NOVEMBER 1994

Water in the Gulf Region toward integrated management

PROCEEDINGS

VOLUME1 - ARABIC PAPERS

VOLUME 2 - ENGLISH PAPERS

P.O.BOX 20018, MANAMA, BAHRAIN
TEL.: (0973) 522010, FAX.: (0973) 533035

(Appendix 5.1.2)

مؤتمر الخليج الثاني للمياه

البحـــرين ٥ - ٩ نـوفمـــبر ١٩٩٤

الماء في الخليـج،
نحـو إدارة متكاملة

وثائـــق المؤتمـــر

المجلـد الأول ـ الاوراق العربيـة
المجلـد الثاني ـ الاوراق الانجليزيـة

جمعيـة علـوم وتقنيـة الميـاه
ص . ب : ٢٠٠١٨ ، المنامـــة ، البحـــرين
هاتف : ٥٢٢٠١٠ (٠٩٧٣) ، فاكس : ٥٣٣٠٣٥ (٠٩٧٣)

(Appendix 5.1.2)

LABORATORY TESTING OF ANTISCALANT THRESHOLD EFFECTIVENESS

BY

Mohammad Abdul-Kareem Al-Sofi(i), Tadatsugu Hamada(ii), Yoshihiro Tanaka(ii), Saad Abdullah Al-Sulami(iii).

(i) Research Technical Advisor, SWCC, (ii) JICA Researchers,[1] And (iii) Research Chemist, SWCC.

ABSTRACT

This paper reports laboratory test results carried out to study antiscalant threshold effectiveness. The primary objective of these tests were to establish some reference points to be used as a base for initial evaluation and selection of antiscalants for further testing in a single heat exchanger tube testing. These results are intended to be used for evaluation and selection of antiscalants for MSF Pilot unit.

These bench top tests indicate Magnesium hydroxide precipitation is not time dependent unlike calcium carbonate in the presence of antiscalant in brine solution at pH of 8-9. They also indicate that most antiscalants are effective for up to 20 minutes at 95°C with up to 2 parts per million concentration. While at higher temperature of 110°C this effectiveness dropped down to less than 10 minutes. Furthermore, no major difference was noted on effectiveness at 95°C for a range of antiscalant concentration of 1-2 ppm.

INTRODUCTION

In seawater desalination predominant scales are of calcium combining with either carbonate or sulfate, and magnesium combining with hydroxide. Calcium forms hard scale when it combines with sulfate, but this reaction is of appreciable magnitude only at temperatures of 121°C or more. Calcium sulfate scale can therefore be avoided if operating temperature is maintained below the said value (< 121°C). On the other hand calcium and magnesium form softer scales with carbonate and hydroxide (respectively) at lower temperatures and brine concentration of 65000 ppm (or less). In distillation process where temperatures are maintained below 121°C, $CaCO_3$ and $Mg(OH)_2$ forma-

1 JICA Researchers working at Al-Jubail, Saline Water Conversion Corporation (SWCC) Research & Development Center (RDC) under cooperation agreement between SWCC and Japan International Corporation Agency (JICA).

tions are controlled by either chelation or depletion. In depletion process carbonate is decomposed down to CO_2 through reaction with acid e.g. H_2SO_4 or HCl. In this process, seawater make up pH drops down to 7.8 or less after CO_2 removal in the decarbonator. Multi Stage Flash (MSF) evaporators which are in operation in Gulf Cooperation Council (GCC) states are being mostly operated with additive treatment at top brine temperatures well below the said value (TBT < 121^{0}C). Further limiting factors of TBT are the capabilities of available additives [1].

EXPERIMENTAL SETUP AND PROCEDURE

1. Reagents Preparations

(a) *Sodium carbonate solution:*

53 grams of Na_2CO_3 powder was weighed and dissolved in 1L of deionized water to prepare IN solution.

(b) *Stock Solutions of antiscalants:*

0.5 gram of each antiscalants were weighed accurately and dissolved in 500 ml of deionized water in order to give 1000 ppm stock solutions.

(c) *Artificial Brine:*

(i) Chemicals used for preparation & mixing ratio:

- Chemical A: NaCl
- Chemical B: INSTANT OCEAN (a registered commercial name of mixture of salts)
- Mixing ratio should be adjusted based on the following ratio: NaCl/INSTANT OCEAN = 1.375

(ii) In order to prepare artificial brine with a concentration equals 1.4 times that of seawater, approximately 8.8 grams of NaCl and 6.4 grams of INSTANT OCEAN were dissolved in unfiltered seawater. M-Alkalinity of final solution was adjusted to 180 ppm by dissolving more salts or by diluting with seawater.

2. Instruments For Analysis & Measurements

(a) pH meter (Fisher brand Model 825 MP) equipped with glass reference electrode to measure pH of solutions.

(b) Automatic Titrator (Fisher brand Model 465) to measure M-Alkalinity.

(c) Atomic Absorption Spectrometer (Varian Model AA-975) for Ca and Mg analysis.

3. Experimental Apparatus

(a) *Low temperatre experimental apparatus:*

As shown in Figure 1, the apparatus consists of a three neck flask (1L capacity) equipped with a condenser and a thermometer. Heating mantle equipped with a stirrer was used to heat up the brine solution, and a vacuum pump was used in order to create vacuum above the brine surface for flashing to take place.

(b) *High temperature apparatus:*

As shown in Figure 2, the apparatus consists of a reaction vessel that can withstand high pressure and temperatures. The vessel is equipped with a heating coil and a stirrer. Temperature and stirring speed can be controlled from a control unit.

4. Test Conditions

(a) Test temperatures	:	95 & 110°C
(b) Brine M-Alkalinity (M-Alk)	:	180 ppm
(c) Concentration of antiscalant	:	2 ppm (or less)
(d) Retention times	:	5, 10, 15, 20, 30 & 40 minutes

5. Test Procedure

500 ml of artificial brine was measured accurately and spiked with 1 ml of antiscalant stock solution in order to make 2 ppm of antiscalant in the brine final solu-

tion. The brine was charged to the reaction vessel or flask and it was heated to the desired temperature under refluxing. When the solution reached the required temperature, it was kept refluxing for 15 min to reach equilibrium and to observe any possibility of scale formation. Because there was no precipitation in the presence of antiscalant, 10 ml of lN Na_2CO_3 was added to break the supersaturation point and to form the scale. The moment at which Na_2CO_3 was added was considered to be T = 0. Successive samples (25 ml each) were drown from solution at time intervals of 5, 10, 15, 20, 30 and 40 minutes. The samples were filtered through 0.45 micron filter paper and filtrate was analysed for Ca, Mg and M-Alk.

RESULTS AND DISCUSSION

Scale formation behavior was studied in laboratory at temperatures similar to actual TBT's (95 & 110°C). Figure 3 shows results of tests carried out on calcium and magnesium presence in solution as a function of change in solution M-Alkalinity at 110°C. This Figure clearly demonstrates the dependence of Calcium concentration on M-Alkalinity in brine solution unlike Magnesium. These phenomena are further verified by the results of additional testing of magnesium and calcium ratios versus time in a brine solution heated up to 110°C. Figure 4 & 5 show changes in magnesium and calcium concentration ratios denoted by (f) for final over initial (i) as function of time at 110°C in the presence of 2 parts per million of different antiscalants in a brine solution having salts concentration of 1.4 times gulf seawater (GSW TDS <61000 ppm). After having verified the fact that $CaCO_3$ scale formation is time dependent further laboratory tests were carried out. To study this time dependance, at 95 and 110°C in the presence of different antiscalants in brine solution (1.4xGSW). Figures 6 & 7 show laboratory test results for different antiscalants at 2ppm concentration and at 95 & 110°C respectively. In addition, brine samples at the above two temperatures were also tested in the absence of antiscalant for $CaCO_3$ measurement against time. These points are denoted by a solid squares and referred to by the letter (B) for blank in Figures 6 & 7. It can be seen from Figure 6 that at 95°C most antiscalants have almost the same threshold effect for up to 15 minutes. Thereafter, they start to show some variations in their effectiveness between 15-30 minutes at 95°C. However, results at 110°C indicate this variation in effectiveness much faster as can be seen in Figure 7. Figure 7 also shows that loss of effectiveness of almost all antiscalants start after only 10 minutes at 110°C compared to 30 minutes at 95°C which can be seen from Figure 6. Figures 8 to 11 show results of antiscalant concentration optimization laboratory tests on the most outstanding antiscalant of those tested (at 95°C) and reported in Figures 3 to 7.

The first pair (Figures 8 & 9) are on a totally synthetic brine of 1.4xGSW TDS. These two Figures show that effectiveness is almost proportionally related to antiscalant concentration. Yet when brine solution was prepared by salt addition to filtered GSW there was a change in behavior which can be seen in Figures 10 & 11 where there is an indication of an optimum dose rate specially as for longer elapsed time of retentions.

Further experimental laboratory and mini module of single tube heat exchanger testing are still underway. Nevertheless the above results could be used to explain some of the earlier reported observations on actual operating plants. In particular the existence of an optimum dose rate plus observed slugging and scaling in flash chambers and demisters [2 & 3].

CONCLUSION

Laboratory experimental results shown in Figures 3-11 can help in making the following observations and recommendations.

1. Magnesium hydroxide separation is pH dependent and time independent.

2. Calcium carbonate separation is time, temperature and antiscalant concentration dependent.

3. At antiscalant dose rates of up to 2 ppm there are quite few brand name antiscalants which are effective for as long as 20 minutes at 95°C and brine concentration of 1.4 GSW TDS.

4. At antiscalant dose rate of 2 ppm there appears to be only few which could be considered to be effective at 110°C and brine concentration of 1.4 GSW TDS.

5. It seems that to maintain an acceptable threshold effect at 110°C either brine concentration needs to be lowered drastically, antiscalant dose rate optimized, or a second antiscalant injection point near the brine heater needs to be considered so that effectiveness time is further elongated beyond the first 10 minutes.

6. To verify these results further tests are required on mini module, (of single tube heat exchanger) pilot units and most importantly actual trial tests on large plants specially where total residence time is 15 minutes or more (up to 30-40).

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2. Al-Sofi, Mohammad Abdul-Kareem, Al-Zahrani, S. G., And Al-Hussain, M. A.: "Optimum Operation and Anti Scalant Dose Rate"; proceedings of 3rd world conference on Desalination & Water-Re use; Canne, France; Sept. 1987.

3. Al-Sofi, Mohammad Abdul Kareem, Al-Hussain, M. A., Al-Omran, A. A. And Farran, K. M.; "A Full Decade of Operating Experience on Al-Khobar phase II MSF Evaporators"; proceedings of 6th world congress on Desalination & Water Re use; Yokohama, Japan; Nov. 1993.

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(Appendix 5.1.2)

Figure 1 : Low Temperature Test Equipment

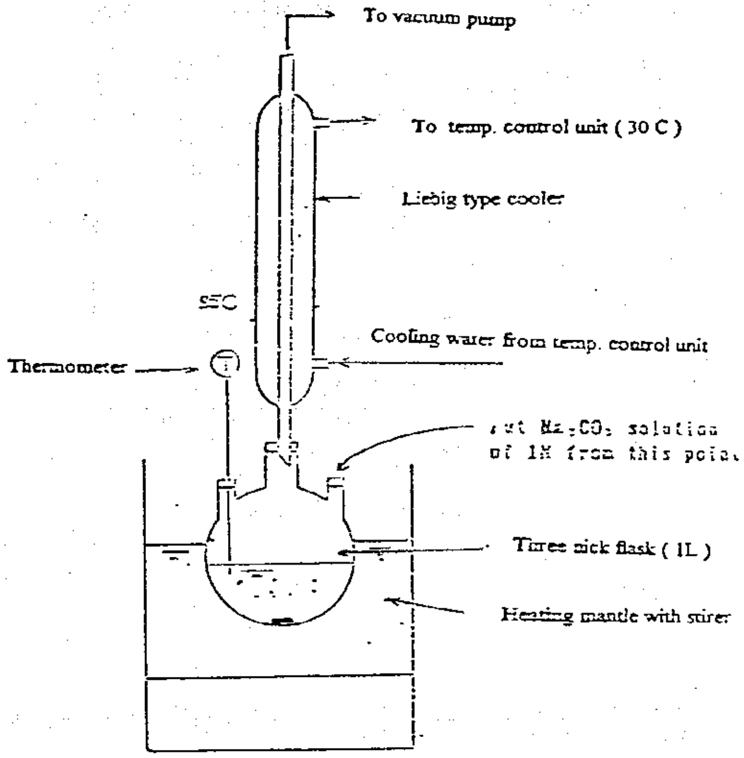
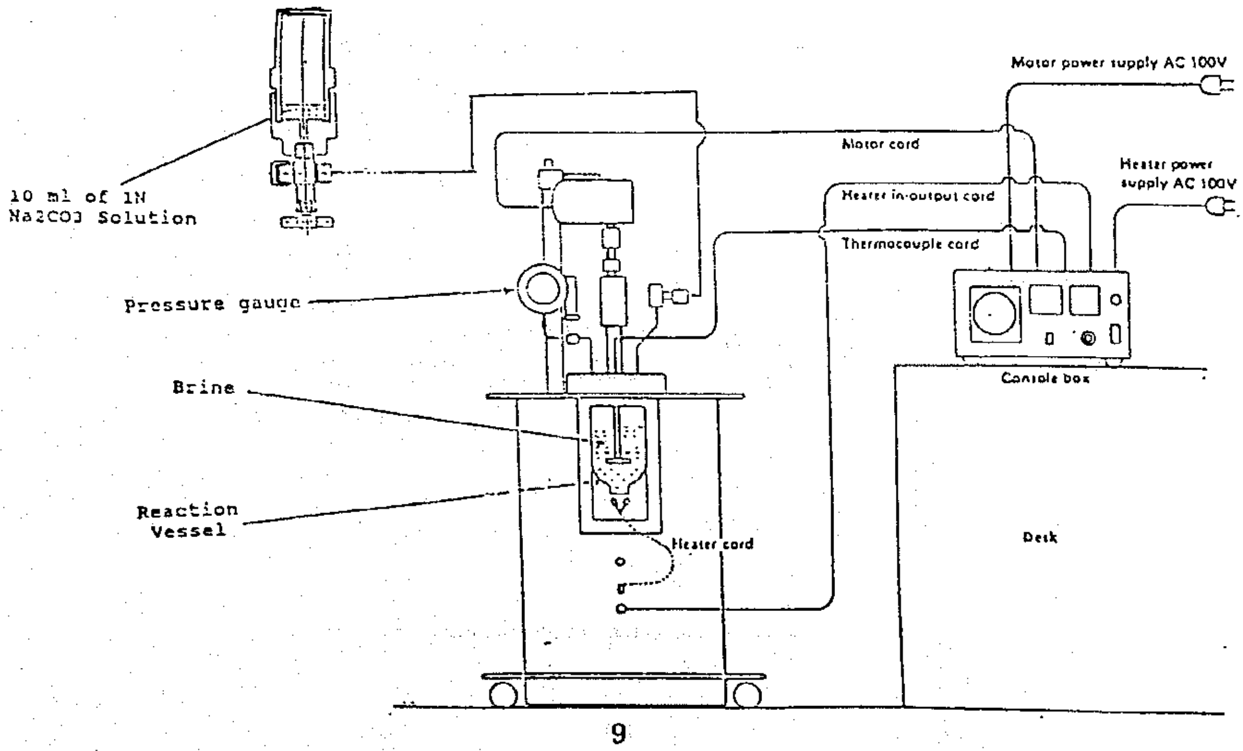


Figure 2 : High Temperature Test Equipment



(Appendix 5.1.2)

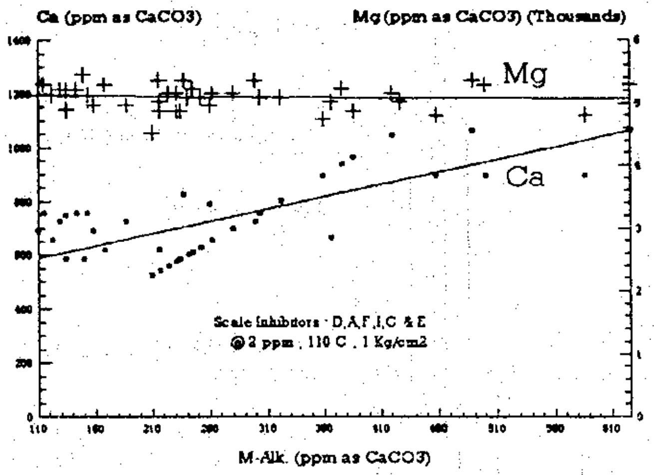


Figure 3 : Relationship Between M-Alkalinity and Ca & Mg Concentrations

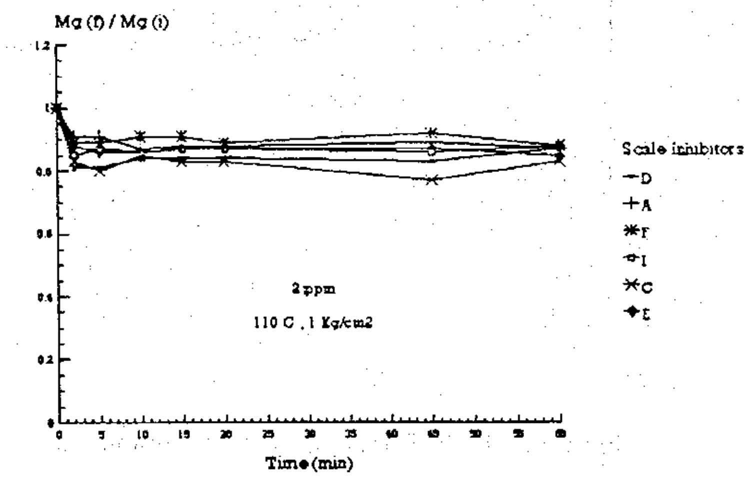


Figure 4 : Changes of Threshold Effect Mg(f)/Mg(i) With Retintion Time

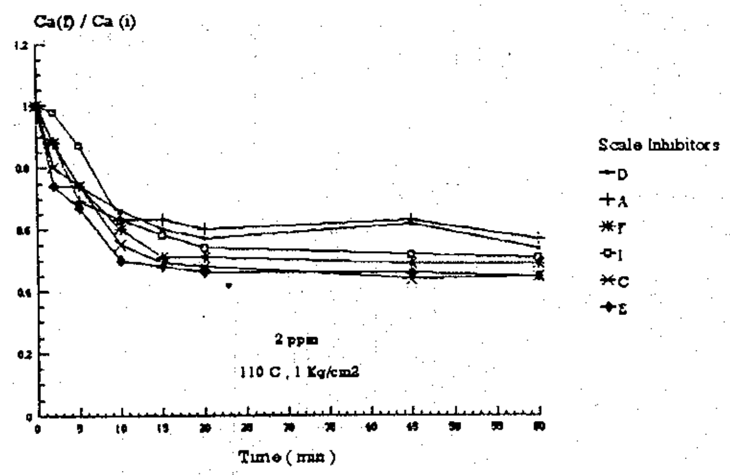


Figure 5 : Changes of Threshold Effect Ca(f)/Ca(i) With Retintion Time

(Appendix 5.1.2)

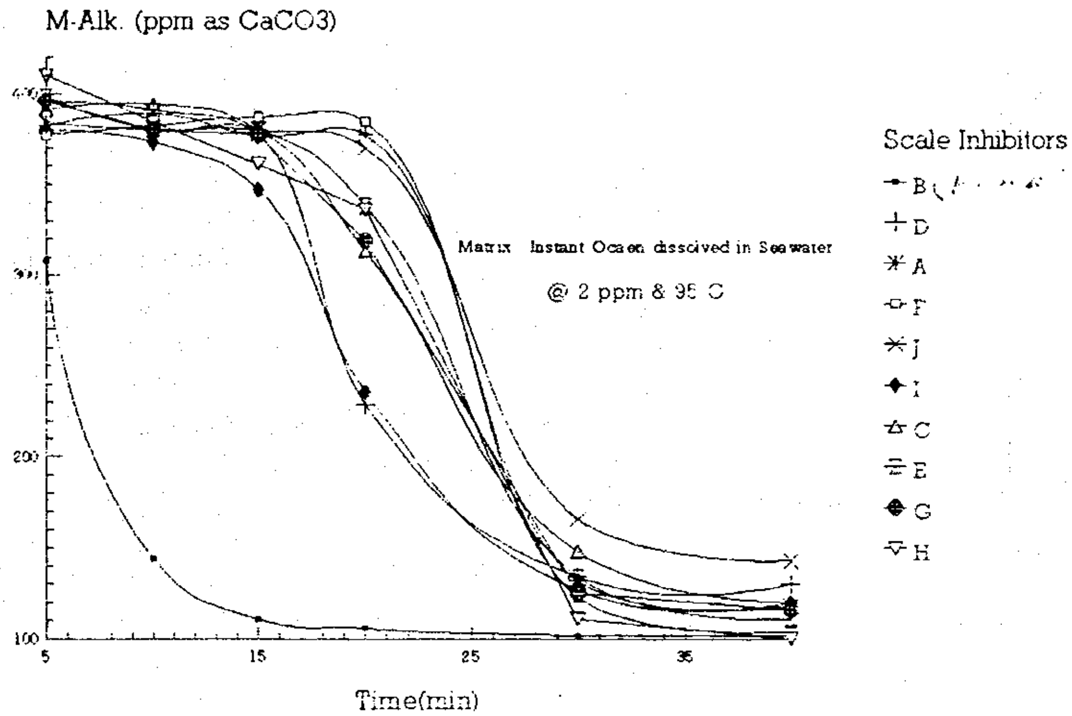


Figure 6 : Threshold Effect of Scale Inhibitors

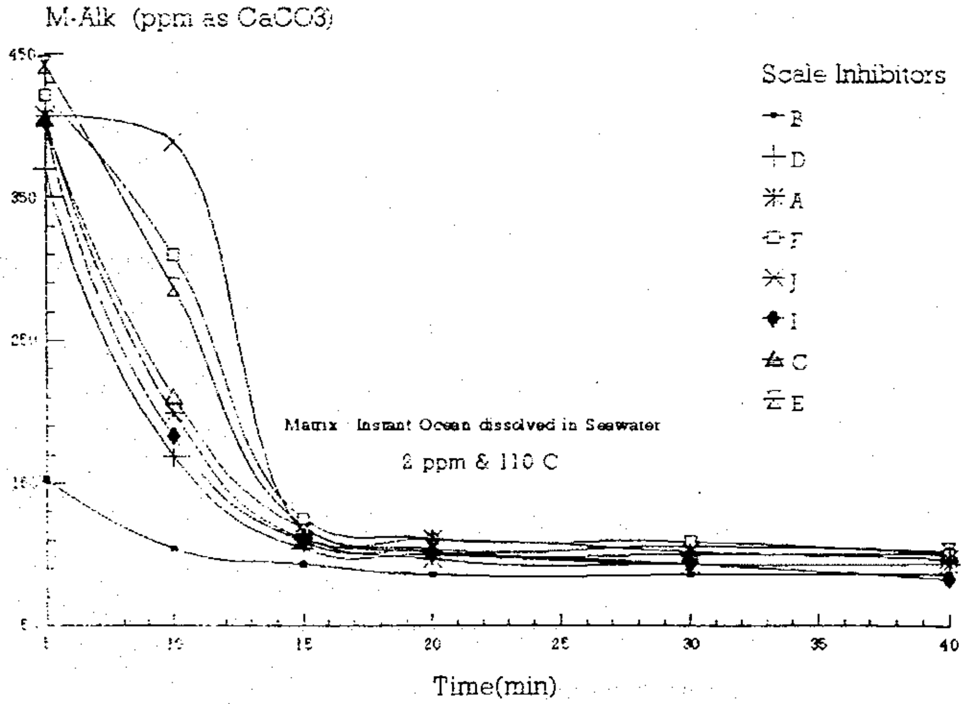


Figure 7 : Threshold Effect of Scale Inhibitors

(Appendix 5.1.2)

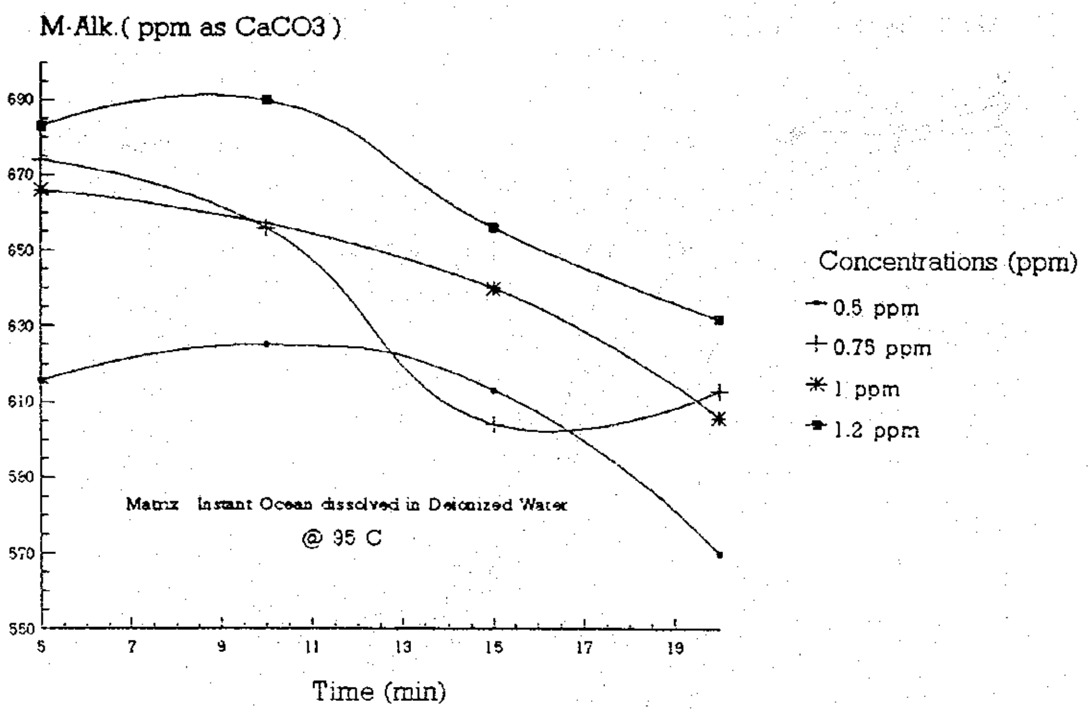


Figure 8 : Optimizing The Concentration of (F)

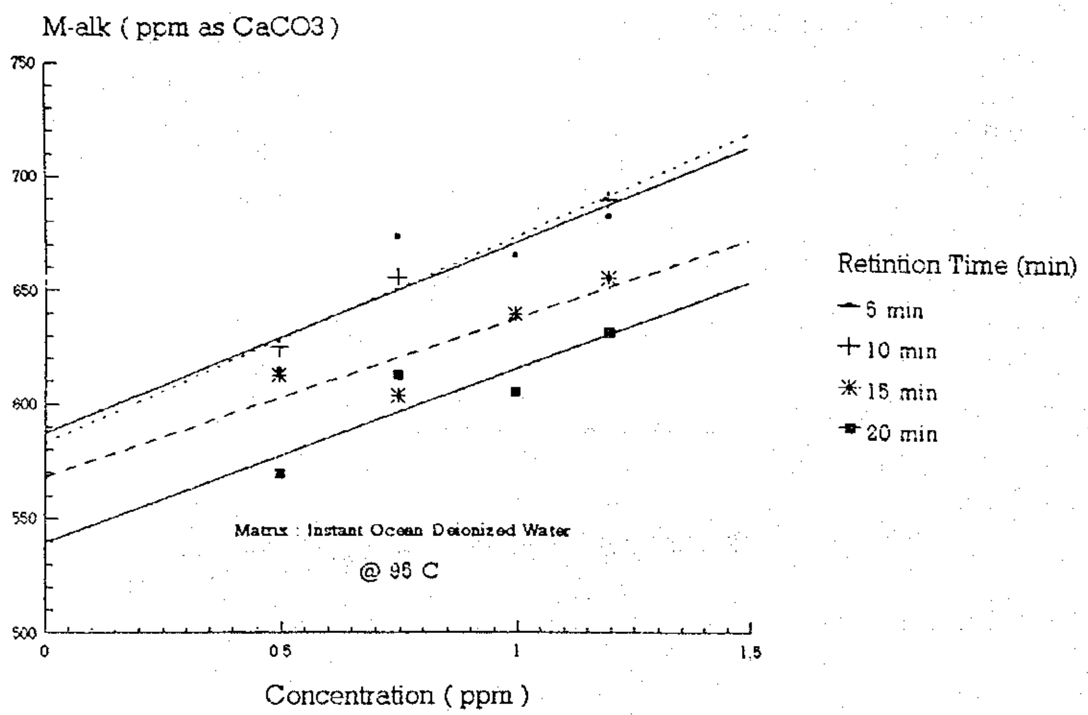


Figure 9 : Optimizing The Concentration of (F)

(Appendix 5.1.2)

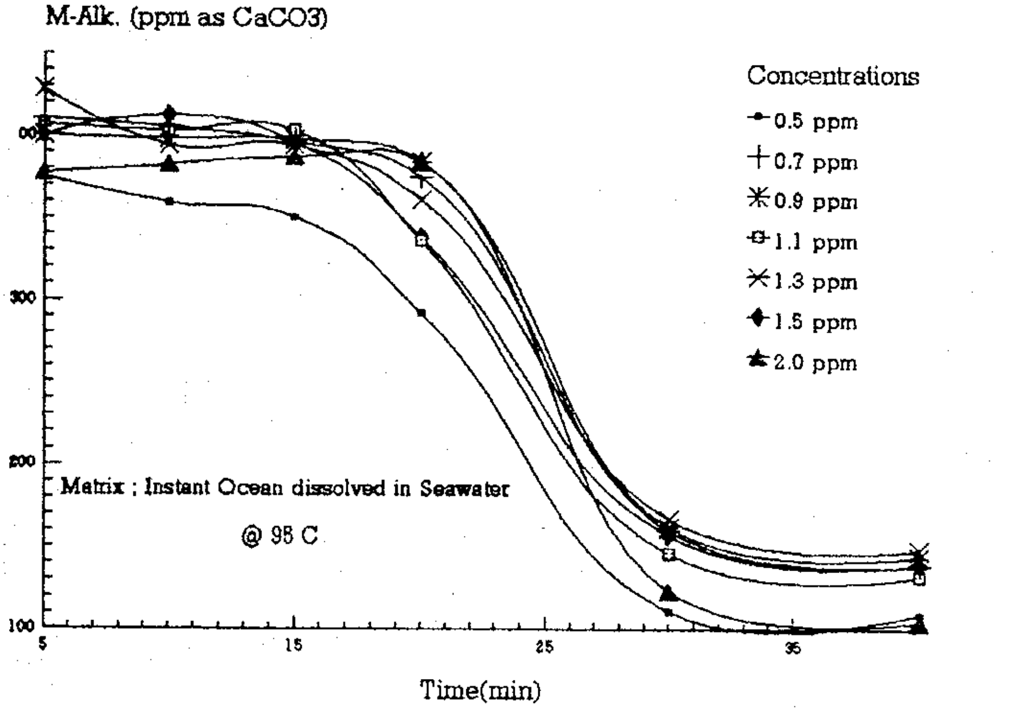


Figure 10 : Optimizing The Concentration of (F)

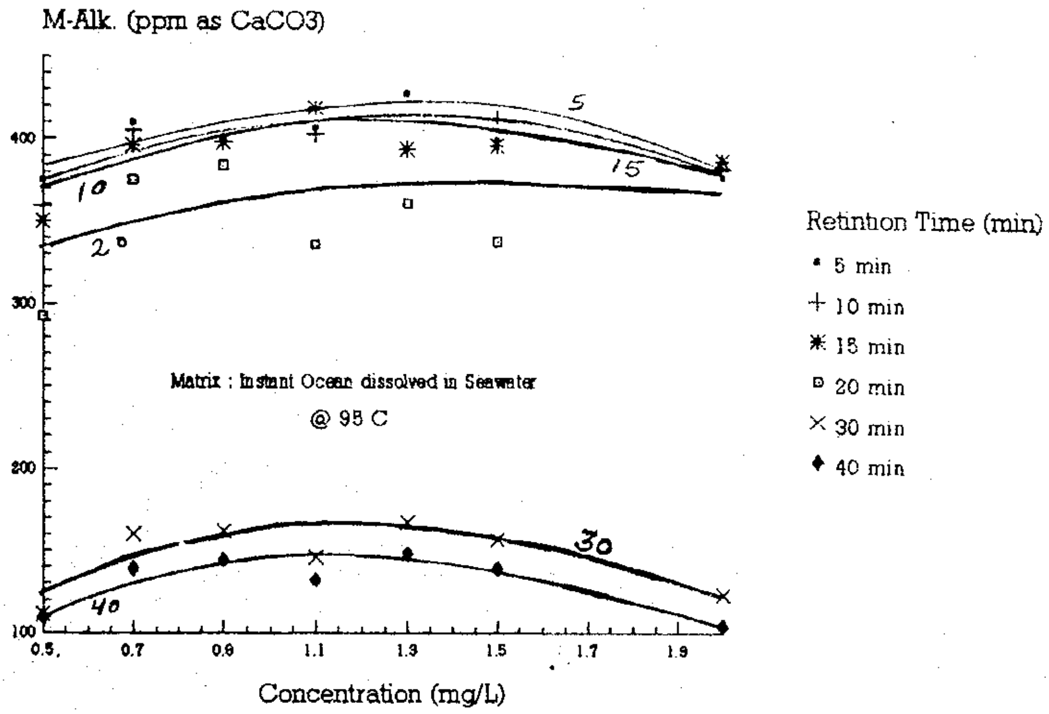


Figure 11 : Optimizing The Concentration of (F)

付属資料 5.3.1

ＭＳＦテストプラント運転説明書

(Appendix 5.3.1)

OPERATION MANUAL
CHAPTER 1
START-UP AND SHUT-DOWN PROCEDURE

1.1 GENERAL GUIDANCE

These instructions are intended to guide qualified personnel in the operation of the desalination plant. They are not intended to cover every possible contingency in the complex desalting process.

Operators should be thoroughly familiar with the layout of equipment, instruments and control devices.
Piping and instrument diagrams should be studied for the arrangement of instrumentations, piping and valves.
They should also be familiar with the access way to the plant equipment, valves, control devices etc..
The desalination plant should not be operated beyond the specified top brine temperature and heating steam temperature. Higher temperature than those will cause rapid scale formation that obliges to shutdown for acid cleaning and scale removal.

Operators should pay careful attention to the process conditions of temperatures, pressures and flows. The various alarm systems should warn the operators of any condition which might lead to disruption of the desalination plant.

During operation, various components of the plant are interdependent due to the critical heat-to-fluid flow balance. For example, an increase of recycle brine flow will require more heat at the brine heater to keep the top brine temperature. If the heat input is kept constant, the top brine temperature lowers, resulting in a decrease of vapor flashing off in the first stage, and the level of flashing brine in the stage will rise. This will adversely affect the heat balance in the second and all succeeding evaporator stages, causing a chain reaction throughout the plant. Those changes will eventually work out into a new balance condition, but many other adjustments would be required to make the new balance satisfactory.

1.1 GENERAL GUIDANCE (cont'd)

Often, over-controlling and over-adjusting will magnify the original problem instead of correcting it. The plant operators should make simple adjustments in small increasing and/or decreasing, allowing ample time to settle for the new conditions to achieve.

The manufacturer's instructions on boiler, pumps, motors, pneumatic, electric and manual operated valves, instruments and other components of the desalination plant are also given in the other part of this manual.
Any operating precaution in those part must be observed on the operation of the desalination plant.

1.1.1 Outline of Description

In this chapter each operation procedure is described in the following manner.

a. Block diagram which gives the idea of operation sequence.

b. Step-by-step procedure which details the indivisual actions required for operation with the tag numbers of the equipment and the indications appeared on the instruments.

Followings are the explanations of the form and the symbols used in the description of step-by-step procedure.

a. Explanation of Columns and Symbols

(1) Tag No. : Identification number of equipment, valve, instrument, switch etc. are indicated.

1.1 GENERAL GUIDANCE (cont'd)

(2) Position : Position of valve, controller, switch and indication of instrument are shown.
Followings are the terms showing the position of controllers.

ADJUST	means to ADJUST by HAND control mode or by shifting the set point when in AUTO control mode.
AUTO	means to put the controller in AUTO control mode.
AUTO SET	means to SET the set point at and put the controller in AUTO control mode.
REMOTE	means to put the controller in REMOTE control mode.

(3) Operation and Judgement : Explanation to the operation, judgement of the condition, supplemental information etc. are described.

(4) Location : Location of equipment, instrument or place of action is indicated.

F : Field (Desalination area)
CP : Control panel in control room

In the step-by-step procedure, the operation of vent, drain and instrument isolation valves are not included except when those require to be in special positions. Common practice shall be applied to those valves i.e. vent and drain valves shall be closed and instrument isolation valves opened during the plant is in service.

1.2 START-UP PROCEDURE

(Appendix 5.3.1)

Start-up OPERATION STEP FLOW CHART		
STEP NO. BR	SYSTEM NAME : BRINE RECIRCULATION SYSTEM	SHEET NO.: BR-ST-1

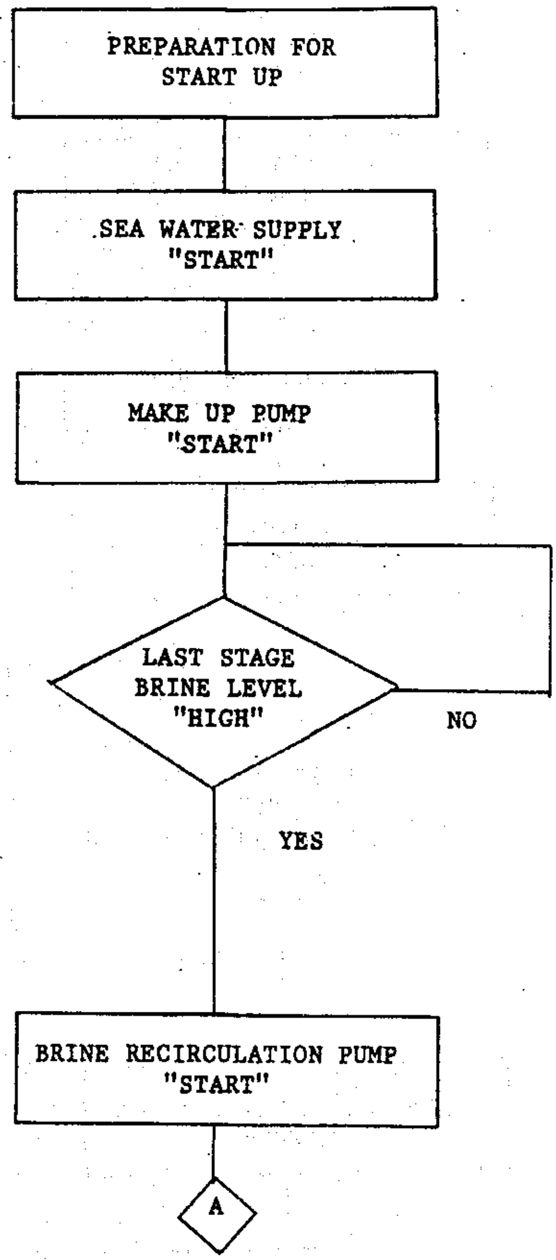
PROCEDURE NO.

1.1

1.2

1.3

1.4



(Appendix 5. 3. 1)

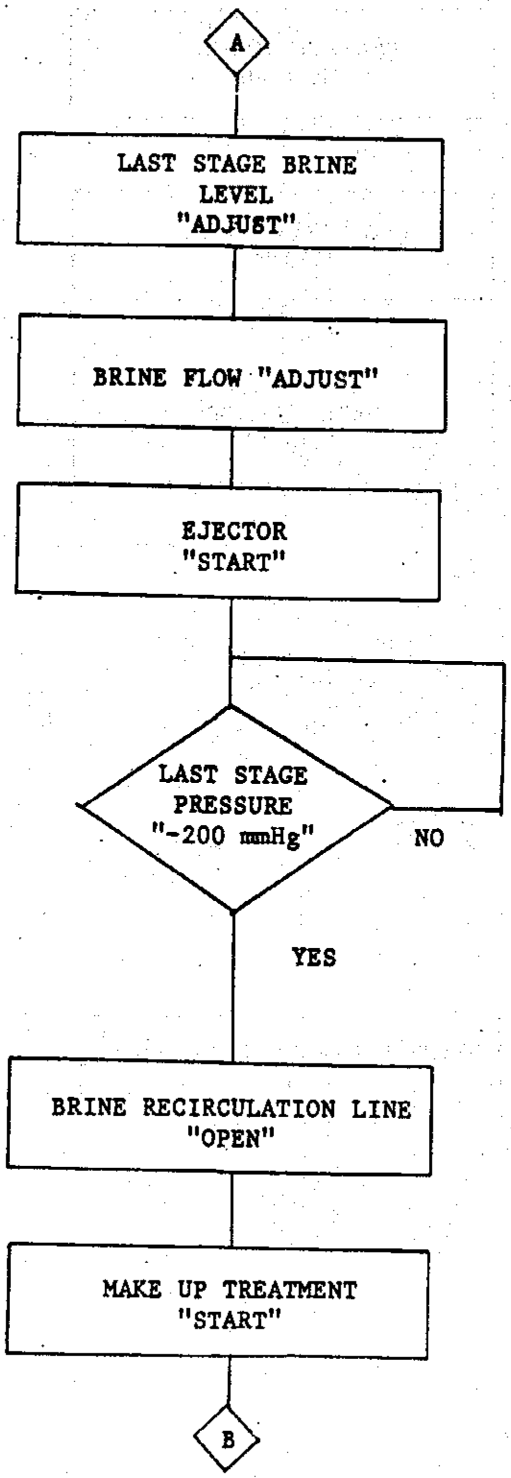
Start-up OPERATION STEP FLOW CHART		
STEP NO. BR	SYSTEM NAME : BRINE RECIRCULATION SYSTEM	SHEET NO.: BR-ST-2

PROCEDURE NO.

1.5

1.6

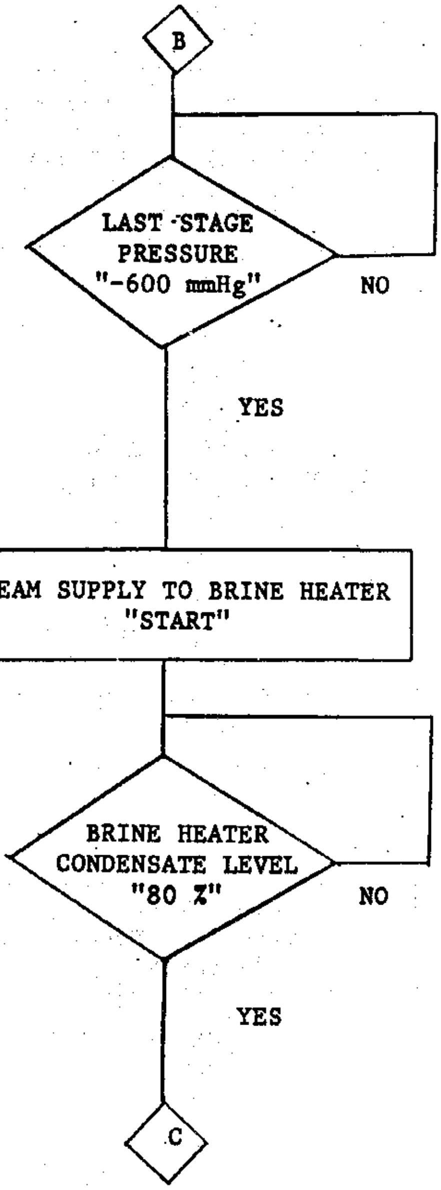
1.7



Start-up OPERATION STEP FLOW CHART		
STEP NO. BR	SYSTEM NAME : BRINE RECIRCULATION SYSTEM	SHEET NO.: BR-ST-3

PROCEDURE NO.

1.8



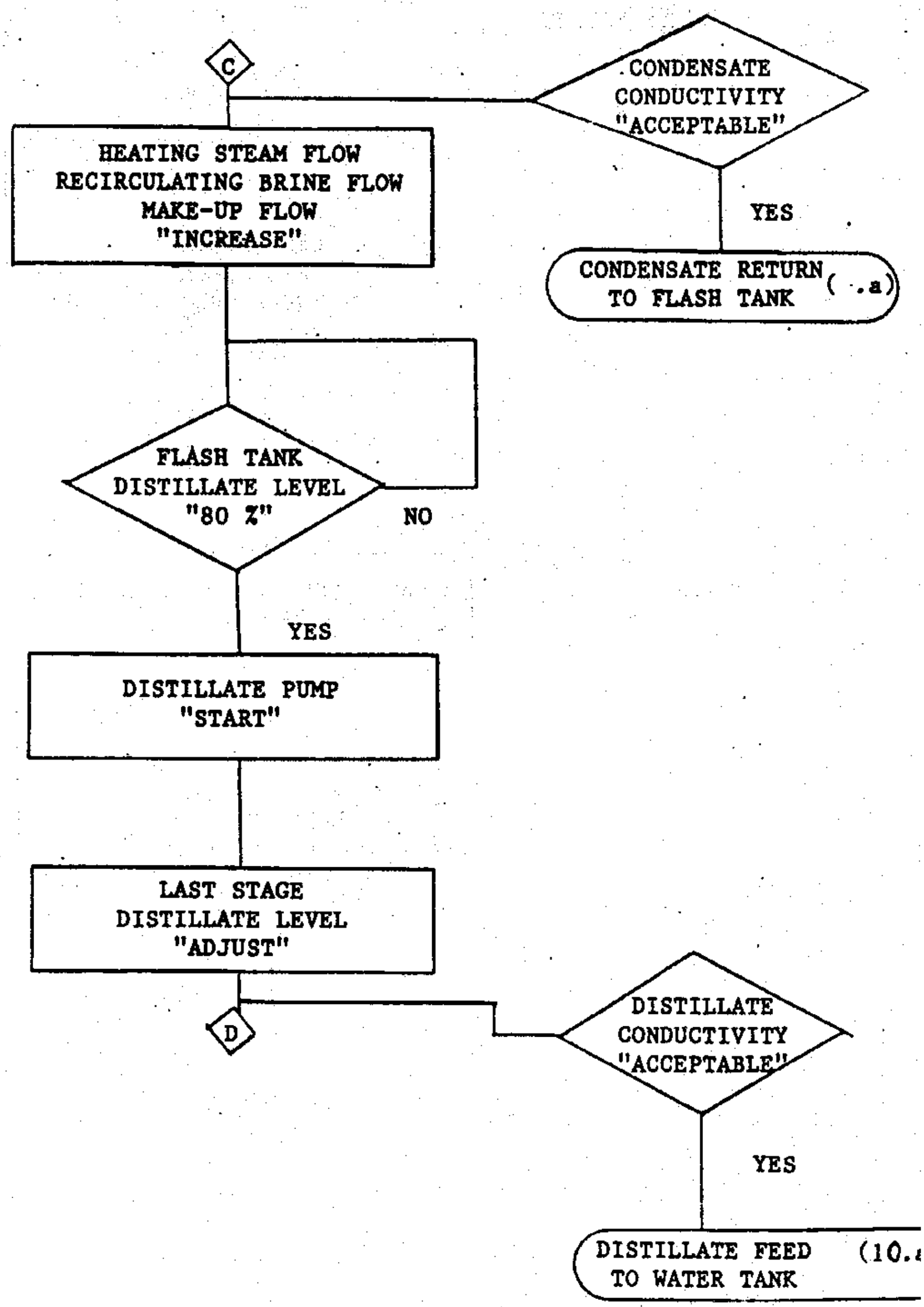
(Appendix 5.3.1)

Start-up OPERATION STEP FLOW CHART		
STEP NO. BR	SYSTEM NAME : BRINE RECIRCULATION SYSTEM	SHEET NO.: BR-ST-4

PROCEDURE NO.

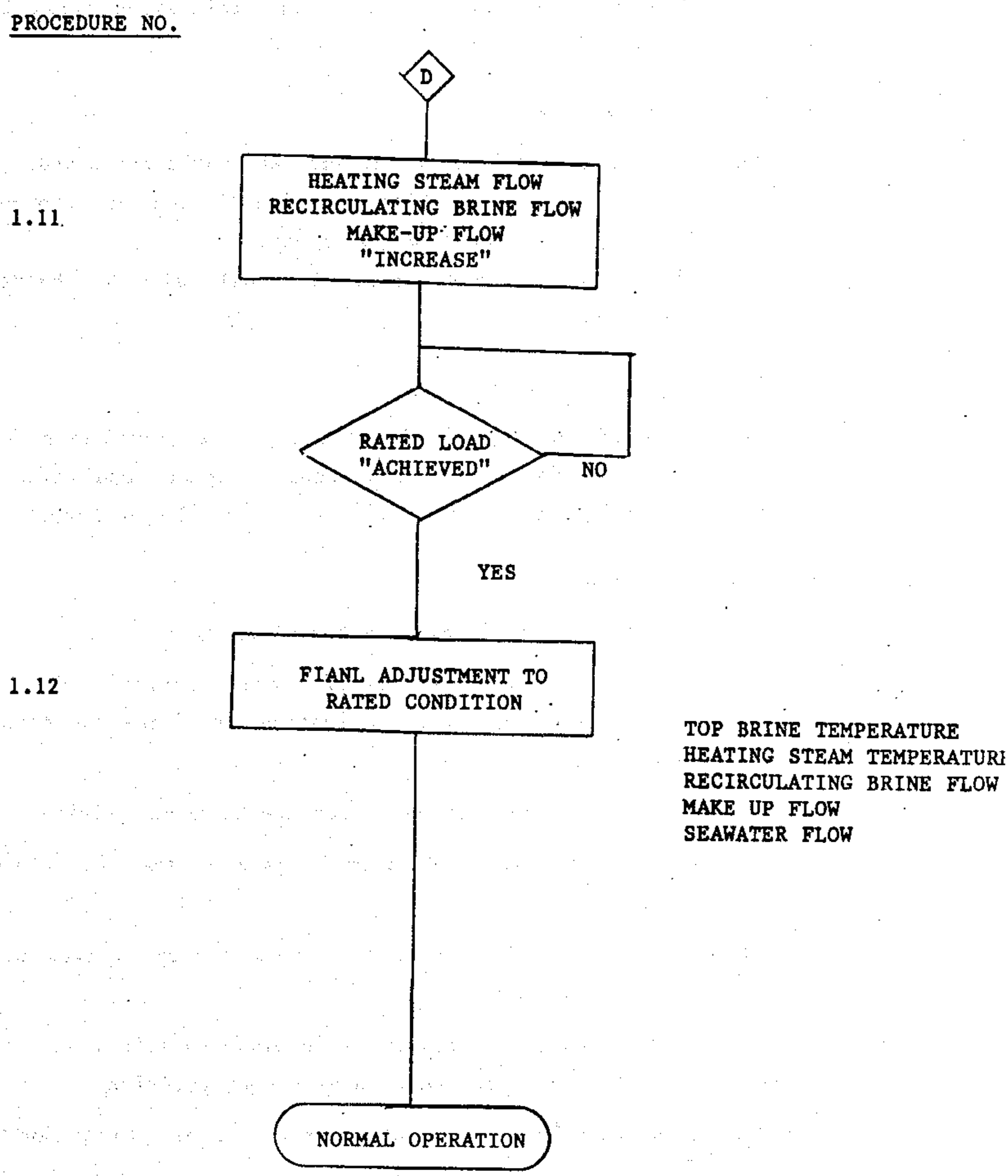
1.9

1.10



(Appendix 5.3.1)

Start-up OPERATION STEP FLOW CHART		
STEP NO. BR	SYSTEM NAME : BRINE RECIRCULATION SYSTEM	SHEET NO.: BR-ST-5



STEP NO.	OPERATION SHEET FOR :	PAGE : 1-1
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	REFERENCE SHEET : BR-ST-1

1.2 PREPARATION FOR START-UP

Each time of desalination unit start-up, followings shall be checked and confirmed.

a. General Inspection

Check and confirm all equipment and pipe works are sound. Leaks and loosened connections, if found, must be informed to maintenance department and be repaired.
Electrical equipment and instruments shall also be checked for their soundness.

b. Lubricating Oil and Grease

Check the lubricating oil level and greasing condition for all rotating machines and any other equipment and devices which require lubrication, refill or renew if necessary.

c. Valve Position

Check the positions of all hand operated valves.

1) Interface isolation valves of seawater, distillate and boiler steam to/from desalination unit are in close posistion.
2) All process pump suction valves are in open position.
3) All process pump discharge valves are in close position.
4) Upstream isolation valves of steam control valves are in close position.
5) All vent and drain valves are in close position.
6) All instrument root valves are in open position.
7) All steam valves around ejectors are in close position.
8) Outlet valves of the chemical tanks are in open position and, discharge valves of the injection pumps are in close position.

STEP NO.	OPERATION SHEET FOR :	PAGE : 1-2
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	REFERENCE SHEET : BR-ST-1

c. Valve Position (cont'd)

9) Isolation valve of service water supply is in open position.

10) All valves on instrument air line are in open position.

d. Operational Chemicals

Prepare, or make up anti-scale, acid, anti-foam and sodium sulphite solutions in the tanks.
The stocks and procurement schedule of the above chemicals for the expected opertion period shall also be confirmed.

e. Review of Previous Operation and Maintenance Reports

Review the reports and confirm all the deficiencies and the damages found in previous operation have been repaired or recovered.

f. Operational Staffs

Shift charge engineer, operators and site operating staffs shall be in positions. Also maintenance staffs (mechanical, electrical and instrumental) shall be ready to assist during start-up.

g. Notification to Other Systems

Start-up of desalination plant shall be notified to the relating system control rooms, and the followings shall be confirmed.

1) Electric power is available to start the desalination unit.

2) Instrument air is available to start the desalination unit.

3) Pressure of seawater header is high enough to start for supplying seawater to the desalination unit.

STEP NO.	OPERATION SHEET FOR :	PAGE : 1-3
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	REFERENCE SHEET : BR-ST-1

g. Notification to Other Systems (cont'd)

4) Boiler steam is available to start the desalination unit.

5) Service water is available to start the desalination unit.

6) Water tank is ready to receive distillate from the desalination unit.

STEP NO.	OPERATION SHEET FOR :	PAGE :
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	1-4
		REFERENCE SHEET : BR-ST-1

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	1.2	SEA WATER SUPPLY "START"	
TRC-102	HAND 30% OPEN	Controller for seawater. discharge valve. (XV-101)	CP
BA-102	30% OPEN	Cooling water valve for Ejector condenser.	F
BV-101	OPEN	Seawater supply valve.	F
	OPEN/CLOSE	Vent valves of heat rejection section water boxes. Open and close after air is expelled.	F
	OPEN/CLOSE	Vent valves of ejector condenser water boxes and piping. Open and close after air is exelled.	F
TRC-102	ADJUST	Controller for XV-101. Adjust the flow rate to 18.4 T/hr.	CP
FR-101	18.4 T/hr	Rejection cooling seawater flow indicator.	CP
BA-102	ADJUST	Cooling water valve for ejector condenser.	F
FI-102	5 T/h	Flow indicator for condenser cooling water.	F

STEP NO.	OPERATION SHEET FOR :	PAGE :
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	1-5
		REFERENCE SHEET : BR-ST-1

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	1.3	MAKE UP PUMP "START"	
FRC-201	HAND	Controller for make up flow control valve (XV-201).	CP
	30 %	Gradually open.	
BA-202 BA-206	OPEN OPEN	Isolation valve for make up deaerator.	F
FRC-301	HAND	Controller for recirculation brine flow control valve (XV-301).	CP
	30 %	Gradually open.	
LICA-202	HAND	Controller for deaerator level control valve (XV-203).	CP
	10 %	Gradually open.	CP
	80 %	Check the deaerator level.	CP
	OPEN	Vent valves for make up pump.	F
	OPEN	Sealing water inlet valve.	F
	START	Push button for make up pump.	CP
BA-209	OPEN	Pump discharge valve open slowly.	F
	CLOSE	Vent valve at pump discharge.	F
LICA-202	AUTO SET 80 %	Controller for deaerator level control valve (XV-203). Adjust deaerator level at 80 % and put into AUTO MODE.	CP

STEP NO.	OPERATION SHEET FOR :	PAGE : 1-6
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	REFERENCE SHEET : BR-ST-1

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	1.4	BRINE RECIRCULATION PUMP "START"	
LICA-507	HAND CLOSE	Controller for last stage brine level control valve (XV-302).	CP
	80 %	Check the last stage brine level rises about 80 %.	
	OPEN	Sealing water isolation valve.	F
	OPEN	Vent valve at pump suction line.	F
	OPEN	Vent valve at pump discharge line.	F
BA-301	OPEN	Isolation valve for pump suction.	F
	OPEN	Sealing water inlet valve.	F
	OPEN	Sealing water strainer isolation valves.	F
LICA-507	HAND 10% OPEN	Controller for last stage brine level control valve (XV-302).	CP
	START	Push button for brine recirculation pump.	CP
BA-303	OPEN	Pump discharge valve. Open slowly.	F
	CLOSE	Vent valve at pump discharge pipe.	F
LICA-507	AUTO SET 80%	Controller for last stage brine level. Control valve (XV-302). Adjust last stage brine level at 80% and put in AUTO MODE.	CP

STEP NO.	OPERATION SHEET FOR :	PAGE :
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	1-7
		REFERENCE SHEET : BR-ST-2

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	1.5	EJECTOR "START"	
BA-414 BA-415	OPEN	Vent valves.	F
		NOTE The opening of this vent valve has been set to give best thermal efficiency. Therefore this valve should always be left opened.	
	OPEN	Drain trap isolation valves on common and ejector steam lines.	F
	OPEN A LITTLE	Drain trap bypass valves on common and ejector steam lines.	F
	CHECK	Steam valve is full open (XV-605).	LCP
SV-603	OPEN	Ejector steam isolation valve. Firstly open a little for warming up the steam pipe. Then open fully when dry steam blows out from the drain trap bypass valves.	F
	CLOSE	Drain trap bypass valves.	F
	OPEN	Isolation valves for strainer.	F
	CLOSE	Bypass valve for strainer.	F
SV-615	OPEN	Drain valve ejector condenser to 6th stage flash box.	F
BA-612 BA-613	OPEN	Isolation valves for ST-603.	F
PI-604	8 Kg/cm^2G	Pressure gauge for ejector steam.	F

STEP NO. BR	OPERATION SHEET FOR : START-UP PROCEDURE OF ONE DESALINATION PLANT	PAGE : 1-8 / REFERENCE SHEET : BR-ST-2

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	1.6	RECIRCULATION LINE "OPEN"	
PR-506	-200 mmHg	Pressure gauge for last stage. After the last stage pressure reaching -200 mmHg, Brine recirculation line can be opened.	F
FRC-301	HAND 30 % OPEN	Controller for recirculating brine flow control valve (XV-301).	CP
BA-304	OPEN	Brine recirculation on line valve. Open slowly. In case of once through operation, this valve shall be kept closed.	F
FRC-301	ADJUST	Controller for recirculating brine flow control valve (XV-301). Adjust the flow to about 4.0 T/hr.	CP
FRC-301	4.0 T/hr	Recirculating brine flow recorder.	CP
		CAUTION When opening brine recirculating line, the last stage brine level may fall quickly even it is controlled in automatic mode. Carefully observe and regulate not to loose the level.	

STEP NO.	OPERATION SHEET FOR :	PAGE :
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	1-9
		REFERENCE SHEET : BR-ST-2

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	1.7	MAKE UP TREATMENT" START" (CHEMICAL CONTROL)	
FrC-201B	AUTO	Anti scale injection pump select switch. Select "AUTO" (or "REMOTE").	CP
BA-807 BA-809	OPEN	Pump suction valve.	F
BA-811	OPEN	Pump discharge valve.	F
	START	Switch for Anti scale injection pump.	CP
	OPEN	Pulsation damper isolation valve.	F
FI-801	CHECK	Anti-scale solution injection rate.	F

STEP NO.	OPERATION SHEET FOR :	PAGE :
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	1-10
		REFERENCE SHEET : BR-ST-2

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	1.7	MAKE UP TREATMENT" START" (ACID CONTROL)	
LIC-201 XV-202	CHECK	Local control.	F
BA-204	OPEN	Decarbonator isolation valve.	F
BA-202	CLOSE	Decarbonator by-pass valve.	F
	START	Decarbonator blower.	CP
FrC-201A	AUTO	Acid injection pump select switch. Select "AUTO".	CP
BA-802 BA-803	OPEN	Pump suction valve.	F
BA-804	OPEN	Pump discharge valve.	F
	START	Switch for acid injection pump.	CP
	OPEN	Pulsation damper isolation valve.	F
FI-802	CHECK	Acid injection rate.	F
	OPEN	PHRA-201 isolation valve.	F

STEP NO.	OPERATION SHEET FOR :	PAGE :
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	1-11
		REFERENCE SHEET : BR-ST-2

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	1.7	MAKE UP TREATMENT "START" (cont'd)	
	OPEN	Anti foam injection isolation valve.	F
HC-804	REMOTE	Anti scale injection pump speed controller.	CP
BA-822 BA-823	OPEN	Pump suction vavle.	F
BA-824	OPEN	Pump discharge valve.	F
	START	Switch for Anti foam injection pump.	CP
FI-804	CHECK	Antifoam solution flow rate.	F
DV-817	OPEN	Sodium sulphite injection isolation valve.	F
HC-803	REMOTE	Sodium sulphite injection pump speed controller.	CP
BA-814 BA-815	OPEN	Pump suction valve.	F
BA-816	OPEN	Pump discharge valve.	F
	START	Switch for Sodium sulphite injection pump.	CP
FI-803	CHECK	Sodium sulphite solution injection rate.	F
		NOTE It is very important that these chemical are throughly mixed and circulated in the recirculating brine before which is heated. To ensure this, chemical injection shall start at early stage after the recirculating brine line is put in service.	

STEP NO.	OPERATION SHEET FOR :	PAGE :
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	1-12
		REFERENCE SHEET : BR-ST-3

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	1.8	STEAM SUPPLY TO BRINE HEATER "START"	
		Reconfirm followings before starting steam supply to brine heater.	
FRC-301	4 T/hr	Recirculating brine flow recorder.	CP
FRC-201	3.62 T/hr	Make up seawater flow controller.	CP
PR-506	-600 mmHg	Pressure gauge for last stage. -600 mmHg or higher vacuum.	CP
SV-610	OPEN	Isolation valve for drain trap downstream the XV-602.	F
SV-611	CLOSE	Bypass valve for drain trap downstream the XV-602.	F
TRCA-303	HAND 20% OPEN	Controller for brine heater outlet brine temperature control valve (XV-602).	CP
PIC-606	AUTO SET 2.0 kg/cm^{2}G	Heating steam pressure controller slowly open by HAND mode until the pressure rises to 2.0 kg/cm^{2}G, then put in AUTO mode.	CP
LIC-601	CHECK	Controller for brine heater condensate level control valve (XV-604).	F
	OPEN	Condensate dump valve.	F
TRCA-303	HAND	Controller for brine heater outlet brine temperature control valve (XV-602). Gradually open to obtain the condensate flow of 300kg/hr.	CP
FR-601	300 kg/h	Flow recorder for condensate.	CP
BA-408 BA-409	OPEN OPEN	Isolation valves for strainer or desuper-heater cooling water line.	F

STEP NO. BR	OPERATION SHEET FOR : START-UP PROCEDURE OF ONE DESALINATION PLANT	PAGE : 1-13 REFERENCE SHEET : BR-ST-3

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	1.8-a	CONDENSATE RETURN TO FLASH TANK The condensate tends to be contaminated because of the rust and dirt in the line when it is started. Then, once the line is flashed out by the steam and the condensate, the conductivity of the condensate start to fall and the indication appears on the condensate conductivity recorder CRA-601.	
CRA-601	less 100 μ℧/cm	Condensate conductivity recorder. confirm indication appears and is steadily falling down.	CP
SV-609	OPEN	Condensate return valve to flash tank. The positions of feed (return) valve and dump valve will change automatically when the conductivity becomes acceptable range.	F

STEP NO.	OPERATION SHEET FOR :	PAGE :
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	1-14
		REFERENCE SHEET : BR-ST-4

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	1.9	INCREASE HEATING STEAM FLOW RECIRCULATING BRINE FLOW MAKE UP SEAWATER FLOW	

After introducing the heating steam to brine heater, recirculating brine start to rise its temperature.
It then requires the adjustments of process flows.
Followings are typical process flow adjustments based on the top brine temperature , which shall generally be observed during start up procedure.

Top Brine Temperature	Recirculating Brine flow	Make up sea Water flow	Condensate (steam) Flow
35 °C	4 T/hr	3.62 T/hr	300 kg/hr
50 °C	4.5 T/hr	3.62 T/hr	300 kg/hr
60 °C	4.8 T/hr	3.62 T/hr	300 kg/hr
80 °C	5 T/hr	3.62 T/hr	300 kg/hr
100 °C	5.5 T/hr	3.62 T/hr	300 kg/hr
110 °C	6 T/hr	3.62 T/hr	330 kg/hr
120 °C	6.58 T/hr	3.62 T/hr	333 kg/hr

STEP NO.	OPERATION SHEET FOR :	PAGE :
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	1-15
		REFERENCE SHEET : BR-ST-4

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	1.10	DISTILLATE PUMP "START"	
		During the heating up of recirculating brine, flash evaporation starts and thus the distillate starts to accumulate in the flash tank. Also condensate is introduced to the tank. Distillate pump shall be started when the distillate level rises to 80 %.	
LIC-401	CHECK	Controller for distillate level control valve (XV-401).	F
	80%	Confirm the level rises to 80 %.	
BA-401	OPEN	Suction valve of distillate pump.	F
	OPEN	Suction vent valve.	F
	OPEN	Discharge vent valve.	F
	OPEN	Sealing water isolation valve.	F
	OPEN	Isolation valves for sealing water strainer.	F
	START	Swtich for distillate pump.	CP
BA-403	OPEN	Discharge valve of distillate pump, Open slowly.	F
	CLOSE	Discharge vent valve.	F
LIC-401	CHECK	Auto at 60 % level.	F

STEP NO.	OPERATION SHEET FOR :	PAGE :
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	1-16
		REFERENCE SHEET : BR-ST-4

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	1.10-a	PRODUCT WATER FEED TO WATER TANK	
		The product water may not be very pure during start up, but it will soon become pure when the evaporation condition is stabilized.	
CRA-401	less 100 μ℧/cm	Distillate conductivity recorder. confirm indication appears and is steadily falling down.	CP
XV-402	AUTO	Three way valve.	CP
		The positions of feed line and dump line will change automatically when the conductivity becomes acceptable range.	

STEP NO.	OPERATION SHEET FOR :	PAGE :
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	1-17
		REFERENCE SHEET : BR-ST-5

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	1.11	<u>INCREASE HEATING STEAM FLOW</u> <u>RECIRCULATING BRINE FLOW</u> <u>MAKE UP SEAWATER FLOW</u> The process flows shall be further increased toward the rated load conditions. The adjustments of various flow rates relating to the top brine temperature shall be referred to step 1-9 in this procedure.	

STEP NO.	OPERATION SHEET FOR :	PAGE :
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	1-18
		REFERENCE SHEET : BR-ST-5

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	1.12	FINAL ADJUSTMENT TO RATED CONDITION	
		When the rated production is achieved, check whether process conditions are steady and nearly equal to those shown on the heat and mass balance diagram. Put the controllers in AUTO mode.	
FR-401	1,100 kg/hr	By Product water flow recorder, check the flow rate is 1,100 kg/hr and constant.	CP
LIC-401	AUTO SET 50%	By Distillate level controller, check the level is constant, then gradually lower the set point to 50 % (normal level).	F
FRC-201	AUTO SET 3,620 kg/hr	By Make up seawater flow controller, check the flow rate is 3,620 kg/hr. Put the controller into AUTO mode.	CP
TRC-102	AUTO SET 40 °C	Controller for rejection cooling seawater outlet temperature (XV-101).	CP
FR-101	18.4 T/hr	Rejection cooling seawater flow recorder.	CP
BA-102	ADJUST	Vent and ejector condensers cooling water valve. Adjust the opening of the valve to obtain the flow rate about 5 T/hr.	F
FI-102	5 T/hr	Ejector condensers cooling water flow indicator.	F
FRC-301	6.58 T/hr	By Recirculating brine flow controller, check the flow rate is 6.58 T/hr.	CP
LICA-507	AUTO SET 50%	Last stage brine level controller. Check the level is kept constant. Then gradually lower the set point to 50 % (normal level).	CP

STEP NO.	OPERATION SHEET FOR :	PAGE :
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	1-19
		REFERENCE SHEET : BR-ST-5

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	1.12	FINAL ADJUSTMENT TO RATED CONDITION (cont'd)	
TRCA-303	AUTO SET 120 °C	Brine heater cutlet brine temperature controller. Check the brine temperature is 120 °C or a little below. Put the controller in AUTO mode.	CP
TR-602	127 °C	Heating steam temperature recorder. Check the steam temperature is 127 °C.	CP
LIC-601	AUTO SET 50%	Condensate level controller. Check the level is kept constant.	F
LICA-202	AUTO SET	Deaerator level controller. Check the level is kept constant.	CP
LIC-201	AUTO SET 50 %	Decarbonator level controller. Check the level is kept constant.	F

1.3 SUPPLEMENTAL OPERATION

Ball Cleaning System

STEP NO.	OPERATION SHEET FOR :	PAGE :
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	1-20
		REFERENCE SHEET : -

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
		BALL CLEANING SYSTEM	
		Ball cleaning system shall be operated when the desalination plant is operated steadily.	
		A. FILLING WATER TO THE LINE	
BA-314	OPEN	Drain valve at brine inlet line.	F
	OPEN	Ball injection valve at recovery inlet.	F
BA-308	OPEN	Ball collector outlet valve.	F
BA-309	OPEN	Ball collector inlet valve.	F
	OPEN/CLOSE	Ball collector vent valve.	F
	ON-LINE	3 way valve at ball collector outlet.	F
	CLOSE	Brine inlet and outlet valves.	F
BA-306 BA-307	OPEN	Ball collection valve at the ball strainer. Slowly open the valve.	F
GV-312	OPEN	Hot brine return valve.	F
	OPEN/CLOSE	Ball collector vent valve. Carefully open the vent valve to expel the air in the pipe between the ball strainer and the ball collector, then close. CAUTION As hot brine may come out at the collector vent outlet pipe, venting operation shall be done very carefully. Do not touch nor., stand at the vent pipe outlet.	F
BA-306 BA-307	CLOSE	Ball collector valve at the ball collector.	

(Appendix 5.3.1)

STEP NO.	OPERATION SHEET FOR :	PAGE :
BR	START-UP PROCEDURE OF ONE DESALINATION PLANT	1-21
		REFERENCE SHEET : -

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
		B. CLEANING OPERATION	
-	CATCH	Ball strainer positon.	F
	OPEN	Ball collector vent valve.	F
	OPEN	Ball collector lid. Open the collector lid. Put the sponge balls in the collector basket. Squeeze the balls in the water to expel the air. Check that the all balls are sunk in the water.	F
	CLOSE	Ball collector lid. Confirm that the all clips of the lid are fastened tightly.	F
BA-313 BA-309	OPEN	Ball collector inlet line valve. Open a little to fulfil the water in the collector. (The collector vent valve is left opened.)	F
	CLOSE	Ball collector vent valve.	
	OPEN	Ball collector inlet valve. Open fully.	F
	OPEN	Ball collector outlet valve.	F
BA-308	CLOSE	Brine inlet and outlet valves.	F
	OPEN	Ball collector valves.	F
		Repeat above cycle if necessary.	

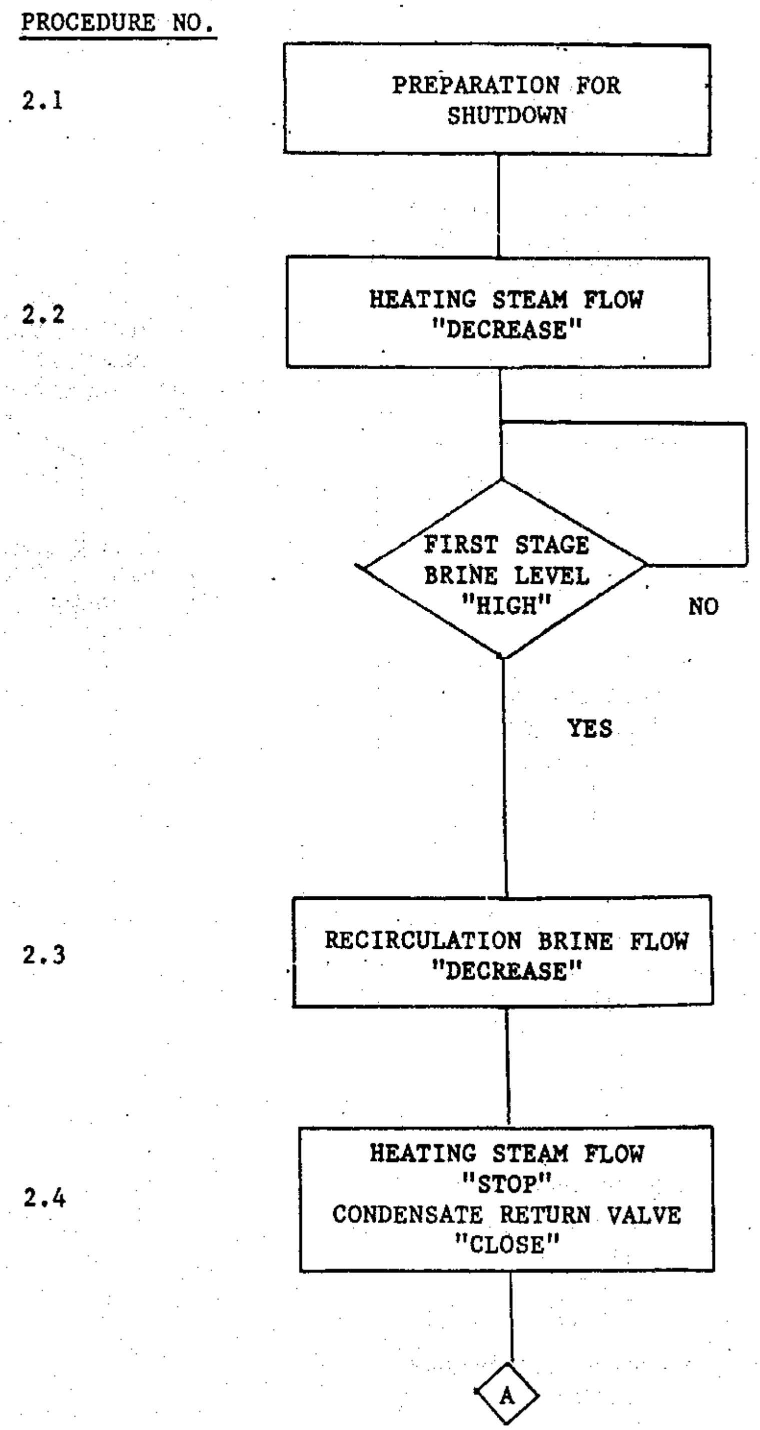
(Appendix 5.3.1)

1.4 SHUTDOWN PROCEDURE

(Appendix 5.3.1)

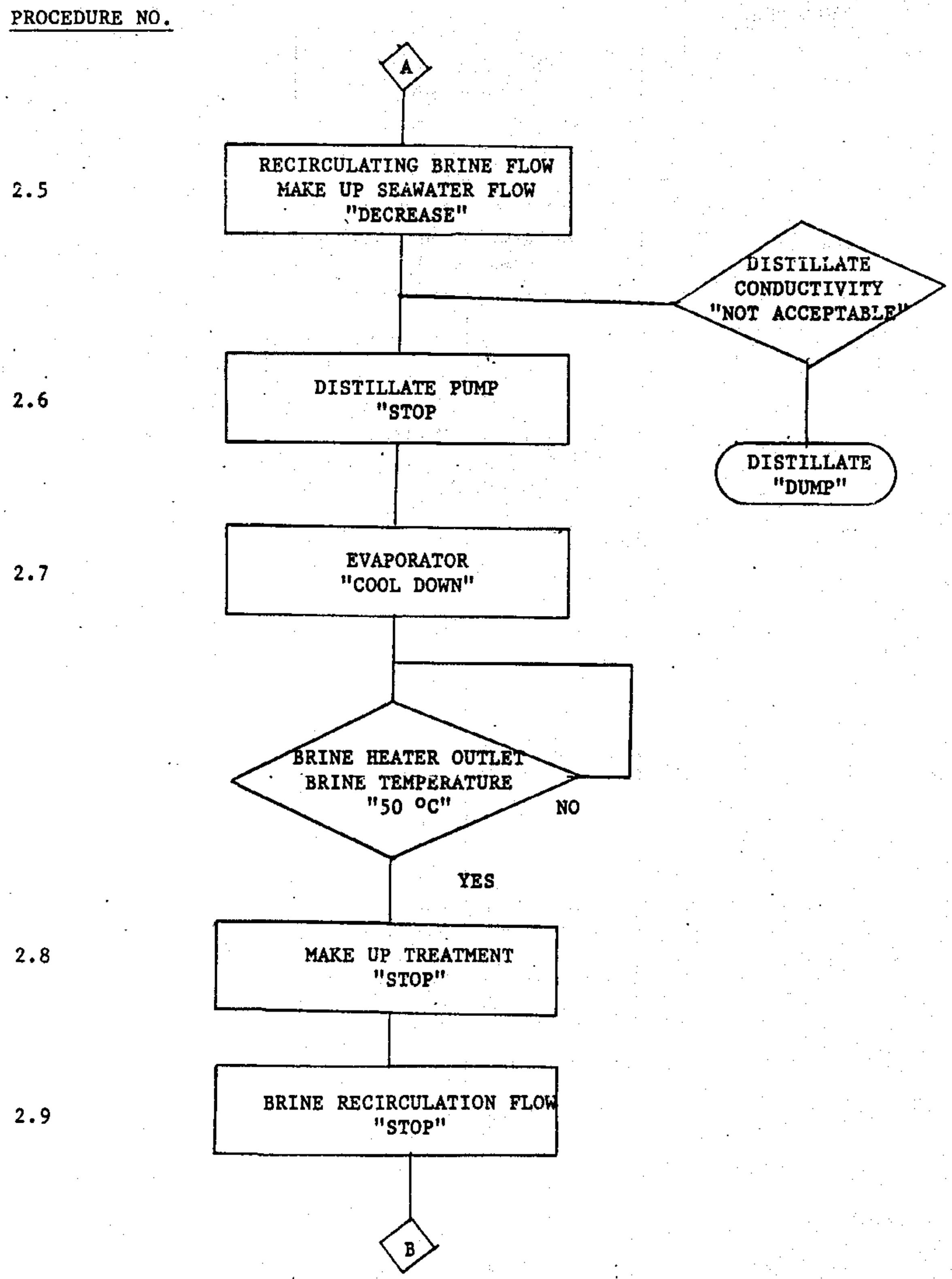
SHUTDOWN OPERATION STEP FLOW CHART

STEP NO.	SYSTEM NAME :	SHEET NO.:
BR	BRINE RECIRCULATION SYSTEM	BR-SH-1



(Appendix 5. 3. 1)

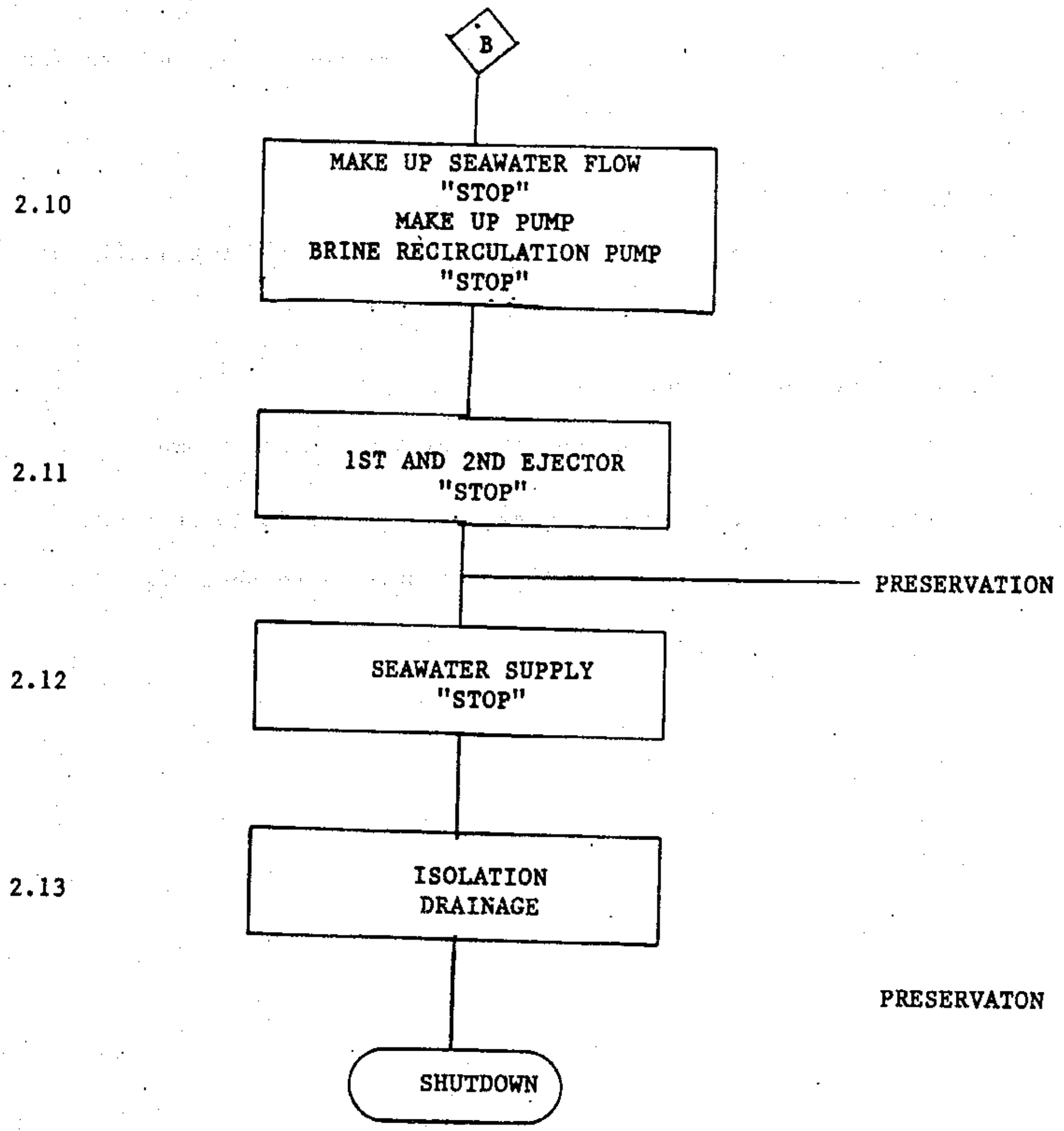
SHUTDOWN OPERATION STEP FLOW CHART		
STEP NO. BR	SYSTEM NAME : BRINE RECIRCULATION SYSTEM	SHEET NO.: BR-SH-2



SHUTDOWN OPERATION STEP FLOW CHART

STEP NO.	SYSTEM NAME :	SHEET NO.:
BR	BRINE RECIRCULATION SYSTEM	BR-SH-3

PROCEDURE NO.



NOTE

For preservation method and procedure, see SECTION 3 MAINTENANCE

STEP NO.	OPERATION SHEET FOR :	PAGE : 2-1
BR	NORMAL SHUTDOWN	REFERENCE SHEET : BR-SH-1

2.1 PREPARATION FOR SHUTDOWN

Followings shall be confirmed before starting any action for shutdown.

a. Operation staffs

Shift charge engineer, operator and site operating staffs are in their positions.

b. Notification to other systems

Inform followings to the relating system control rooms.

(1) Boiler steam supply to desalination unit is to shut off.

(2) Seawater supply to desalination unit is to shut off.

STEP NO.	OPERATION SHEET FOR :	PAGE : 2-2
BR	NORMAL SHUTDOWN	REFERENCE SHEET : BR-SH-1

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	2.1	PREPARATION FOR SHUTDOWN (cont'd)	
		Following controller shall be changed this operation mode from "AUTO" to "MANUAL".	
FRC-201	HAND	Controller for make up seawater flow control valve (XV-201).	CP
TRCA-303	HAND	Controller for recirculating brine temperature control valve (XV-602).	CP
FRC-301	HAND	Controller for recirculating brine flow control valve (XV-301).	CP
TRC-102	HAND	Controller for rejection cooling seawater temperature control valve (XV-101).	CP
	2.2	HEATING STEAM FLOW "DECREASE"	
TRCA-303	HAND	Controller for brine heater outlet brine temperature control Valve (XV-602). Reduce opening by 10 % every 6 minutes.	CP

STEP NO.	OPERATION SHEET FOR :	PAGE : 2-3
BR	NORMAL SHUTDOWN	REFERENCE SHEET : BR-SH-1

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	2.3	RECIRCULATING BRINE FLOW "DECREASE"	
		1st stage brine level rises as the top brine temperature falls. Recirculating brine flow shall be reduced not to rise the level excessively.	
FRC-301	HAND	Controller for recirculation brine flow control valve (XV-301).	CP
		Reduce the flow rate when first stage brine level high.	F
		NOTE	
		1st stage brine level shall carefully be watched during the shutdown. Good controlling by the recirculating brine flow keeps pure product water until the evaporation ceases completely.	

STEP NO.	OPERATION SHEET FOR :	PAGE : 2-4
BR	NORMAL SHUTDOWN	REFERENCE SHEET : BR-SH-1

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	2.4	HEATING STEAM FLOW "STOP" CONDENSATE RETURN VALVE "CLOSE" When the brine heater outlet brine temprature control valve (XV-602) comes to close position by manual step-by-step operation, the controller for heating steam pressure control valve (XV-601) shall also put in HAND mode and close valve fully. Then, at plant site, close the upstream isolation valve for XV-601.	
TRCA-303	HAND CLOSE	Controller for XV-602.	CP
PIC-606	HAND CLOSE	Controller for XV-601.	CP
SV-608	CLOSE	Isolation valve for XV-601.	F
		When the condensate flow becomes zero, close condensate level control valve XV-604 and close the condensate return valve.	F
FR-601	0 m^3/hr	Condensate flow recorder.	CP
LIC-601	HAND CLOSE	Controller for cordensate level control valve (XV-604). Put the controller in HAND mode, lower level below 50 % if necessary, and close fully.	F
SV-609	CLOSE	Condensate return valve.	F

STEP NO. BR	OPERATION SHEET FOR : NORMAL SHUTDOWN	PAGE : 2-5 REFERENCE SHEET : BR-SH-2

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	2.5	RECIRCULATING BRINE FLOW "DECREASE" MAKE UP SEAWATER FLOW "DECREASE" Recirculating brine flow shall further be reduced as the top brine temperature falls to make the brine level not too high. Also the make up seawater flow shall be reduced roughly step-by-step as product flow reduces.	

STEP NO.	OPERATION SHEET FOR :	PAGE : 2-6
BR	NORMAL SHUTDOWN	REFERENCE SHEET : BR-SH-2

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	2.6	DISTILLATE PUMP "STOP"	
FR-401	0 m^3/hr	Distillate flow recorder.	CP
LICA-507	HAND CLOSE	Controller for distilalte level control valve (XV-601). Put the controller in HAND mode, lower the level if necessary, and close fully.	CP
BA-403	CLOSE	Distillate pump discharge valve.	F
	STOP	Switch for distillate pump.	CP
	CLOSE	Isolation valve for service water to distillate pump.	F
		NOTE During shutdown, the conductivity of distillate may exceed acceptable level because of unstable brine level. The stream of distillate will be automatically changed to dump line when the conductivity rises to unacceptable level.	

STEP NO.	OPERATION SHEET FOR :	PAGE : 2-7
BR	NORMAL SHUTDOWN	REFERENCE SHEET : BR-SH-2

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	2.7	COOLING DOWN OF EVAPORATOR After stopping distillate pump, recirculating brine and make up seawater shall be continued until the highest system temperature presented by brine heater outlet temperature falls 50 °C or below. Keep the following flow rate as minimum. Recirculating brine 4 T/hr Make up seawter 3.62 T/hr	

STEP NO.	OPERATION SHEET FOR :	PAGE : 2-8
BR	NORMAL SHUTDOWN	REFERENCE SHEET : BR-SH-2

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	2.8	MAKE UP TREATMENT "STOP"	
		Stop injection of chemicals when the top brine temperature falls to 50 °C.	
	STOP	Switch for anti-scale injection pump.	CP
	STOP	Switch for antifoam injection pump.	LCP
	STOP	Switch for sodium sulphite injection pump.	LCP
	CLOSE	Anti foam injection isolation valve.	F
	CLOSE	Sodium sulphite injection isolation valve.	F
	CLOSE	Anti scale injection pump discharge valve.	F
	CLOSE	Anti foam injection pump discharge valve.	F
	CLOSE	Sodium sulphite injection pump discharge (53V-649)	F
		In case of acid control, the word "Anti scale" should be read as "Acid".	

STEP NO.	OPERATION SHEET FOR :	PAGE : 2-9
BR	NORMAL SHUTDOWN	REFERENCE SHEET : BR-SH-2

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	2.9	BRINE RECIRCULATION FLOW "STOP"	
FRC-301	HAND 10 % OPEN	Controller for recirculating brine flow control valve (XV-301). Reduce opening to 10 %.	CP
BA-304	CLOSE	On line valve.	F
	2.10	MAKE UP SEAWATER FLOW "STOP" MAKE UP PUMP, BRINE RECIRUCLATION PUMP "STOP"	
FRC-201	HAND CLOSE	Controller for make up flow control valve. (XV-201).	CP
LICA-202	HAND CLOSE	Controller for deaerator level control valve (XV-203).	CP
BA-209	CLOSE	Discharge valve of make up pump.	F
	STOP	Switch for make up pump.	CP
LICA-507	AUTO SET 20%	Controller for last stage brine level control valve (XV-302). Gradually lower the set point to 20 %, then put the controller in HAND mode and close fully.	CP
BA-303	CLOSE	Discharge valve of the brine recirculation pump.	F
	STOP	Switch for brine recirculation pump.	CP
	CLOSE	Isolation valve of pump sealing water.	F

STEP NO.	OPERATION SHEET FOR :	PAGE : 2-10
BR	NORMAL SHUTDOWN	REFERENCE SHEET : BR-SH-3

RECORD NO. OR VALVE NO.	POSITION OR SET POINT	OPERATION	LOCATION
	2.11	1ST AND 2ND STAGE EJECTOR "STOP"	
SV-603	CLOSE	Steam valve of ejector.	F
	CLOSE	Switch for ejector steam shut-off valve (XV-605).	CP
	2.12	SEAWATER SUPPLY "STOP"	
BV-101	CLOSE	Seawater supply valve.	
	2.13	ISOLATION AND DRAINAGE	
SV-603 SV-608	CLOSE	Steam isolation valve.	F
	CLOSE	Service water isolation valve.	F
		NOTE When the draining is required for maintenance work, open vent and drain valves of the required part of the equipment and pipes. During maintenance work, the unit shall also electrically be isolated. Ask electrical staffs before starting the works. Proper preservation method is required after the plant is shutdown. Details shall be referred to Section 3. MAINTENANCE MANUAL.	

(Appendix 5.3.1)

SECTION 2
OPERATION MANUAL
CHAPTER 2
ROUTINE CHECK LIST

2.1 INTRODUCTION

Good maintenance of the Desalination Plant will result in longer plant life and more economic production of high purity water.
Therefore, evaporator and auxiliary equipment, all instruments and controls and all rotary equipment such as pumps and motors shall be well maintained.

In this section, the routine and specific check works which are required during normal operation are given.

Daily patrol shall be made to see the general condition of the equipment.
Any unusual observations shall be recorded and necessary countermeasure shall be taken immediately, or depending on the cases shall be scheduled for the next shut down.
Daily patrol shall includes following checks :

(1) Check operating condition of rotating machines such as pump, motor, mixer for noise and vibration.

(2) Check pumps for proper effluent from gland, lubricating oil level and temperature of the bearings.

(3) Check for loosen connections, leaks at pipe joints, instrument connections etc.

(4) Check valves for leakage.

(5) Check and clean glass gauges and indicator for legibility, looseness and cracks.

(6) Check structural members and exposed metal parts for damage.

(7) Check electrical cables and instrument leads for fraying, worn or damage.

(Appendix 5.3.1)

2.2 ROUTINE CHECK SCHEDULE

These tables summarized in this section are general guidance for periodical inspection which are required for stable and safe operation of the plant equipment.

1.5 EMERGENCY OPERATION

1.5.1 INTRODUCTION

It should be understood that the steady operation of desalination plant is entirely dependent upon the heat and mass, or temperature and pressure balance of the whole desalination process. And this is fully supported by the good functions of the equipment and control system.
Therefore sudden trip of any major stream or equipment will greatly affect the balance in the process and, eventually, the desalination plant may not continue its operation.

Emergency operation is in every case the essence and quick form of normal shut down procedure, with the exception of the steps on which the failure or trip occurs.

In principle, the operator shall reduce or stop steam supply to brine heater as a primitive action to avoid over shooting of the top brine temperature. Thereafter take necessary and quick actions for shut down in accordance with the normal shut down procedure.

It may be aware from the above explanation that the operators should fully study and understand the procedure of normal shut down.

CAUTION

1. When the steam supply is stopped by closing the control valve, followed by or after ceasing the recirculating brine flow, the isolation valve shall also be closed as the control valve may have some leak.

2. If water hammering occurs in the evaporator during and/or after any case of emergency operation, open air vent valves on water boxes of evaporator and brine heater to break uneven pressure locally appeared in the system.

1.5 EMERGENCY OPERATION PROCEDURE

1.5.2 Power Supply Failure

Destination : Treatment after abnormal shut down.

All pumps stop. Heating steam pressure control valve closes. Ejector steam shut off valve closes. Vacuum in evaporator breaks.

(1) Put all controllers on the panel in manual mode and close them all.
(When the control power and the instrument air remain alive.)

(2-1) Close all pump discharge valves.

(2-2) Close isolation valve on boiler steam line.

(2-3) Close isolation valves on seawater lines.

(2-4) Put all other valves in the position of normal shut down.

(3) Wait for recovery of power supply.

(4) Cool down the evaporator.

(5) Re-start or shut down.

1.5 EMERGENCY OPERATION PROCEDURE

1.5.3 Seawater Supply Failure

Destination : Quick shut down.

Ejector steam shut off valve closes.

(1-1) Close brine temperature control valve. Close heating steam pressure control valve.

(1-2) Close make up flow control valve.

(1-3) Close brine level control valve to keep brine level in the last stage.

(2) Reduce recirculating brine flow.

(3-1) Close condensate level control valve.

(3-2) Close distillate level control valve and stop distillate pump.

(4-1) Close recirculating brine flow control valve.

(4-2) Close brine level control valve and stop brine recirculation pump.

1.5 EMERGENCY OPERATION PROCEDURE

1.5.3 Seawater Supply Failure (cont'd)

(5-1) Close all pump discharge valves.

(5-2) Close isolation valve on boiler steam line.

(6) Stop anti scale chemical injection pump, (or acid injection pump) antifoam injection pump and sodium sulphite injection pump.

(7-1) Close isolation valves on seawater line.

(7-2) Put all other valves in the position of normal shut down.

(8) Wait for recovery of seawater supply.

(9) Cool down the evaporator.

(10) Re-start or shut down.

(Appendix 5.3.1)

1.5 EMERGENCY OPERATION PROCEDURE

1.5.4 Instrument Air Supply Failure

Destination : Quick shut down without control system.

Heating steam pressure control valve closes. Brine temperature control valve closes. Ejector steam shut off valve closes.

(1) Stop brine recirculation pump.
Stop distillate pump.
Stop make up pump.

(2) Close the make up flow control valve.

(3-1) Close all pump discharge valves.

(3-2) Close isolation valve on boiler steam line.

(4) Stop and scale chemical injection pump, (or acid injection pump) anti-foam injection pump and sodium sulphite injection pump.

(5-1) Close isolation valves on seawater line.

(5-2) Put all other valves in the position of normal shut down.

1.5 EMERGENCY OPERATION PROCEDURE

1.5.4 Instrument Air Supply Failure (cont'd)

(6) Wait for recovery of instrument air supply.

(7) Cool down the evaporator.

(8) Re-start or shut down.

NOTE

Action of control valves on failure of instrument air supply is summarized in clause 1.6 in this chapter.

1.5 EMERGENCY OPERATION PROCEDURE

1.5.5 Boiler Steam Supply Failure

The situation is considered almost the same as normal shut down except that boiler steam (for brine heater and ejector) is cut off suddenly and at once.

Destination : Normal shut down.

(1) Reduce recirculating brine flow not to rise the level in evaporator.

Follow normal shut down procedure.

1.5 EMERGENCY OPERATION PROCEDURE

1.5.6 In-plant Equipment Failure

Trip of Pump

Same procedure as 1.5.4.

1.6 CONTROL VALVE ACTION ON AIR FAILURE

The position of each control valve on instrument air failure are as follows.

Definitions

Open : the valve opens when the air supply fails.

Close : the valve closes when air supply fails.

Lock : the valve keeps its opening when the air supply fails.

Free : the valve has no determinate action nor be locked when the air supply fails, may open or close slowly.

Control valve	Tag No.	Action on air failure
Heating steam pressure control valve.	XV-601	Close
Brine temperature control valve.	XV-602	Close
Ejector steam shut off valve.	XV-605	Close
Condensate level control valve.	XV-604	Close
Seawater temperature control valve.	XV-101	Open
Make up flow control valve.	XV-201	Close
Recirculating brine flow control valve.	XV-301	Open
Brine level control valve	XV-302	Close
Distillate level control valve.	XV-401	Close
Distillate conductivity control valve. (dump line)	XV-402	(Open)
Deaerator level control valve.	XV-203	Close

1.7 COOLING DOWN OF EVAPORATOR

When the desalination plant is stopped suddenly resulted from any failure or trip, the temperature gradient through the stages of the evaporator will soon be broken and the evaporator is saturated with vapour and brine of high temperature.
This will make re-start of the plant difficult because the ejector system has to evacuate enormous quantity of vapour which generates from hot brine as the vacuum rises.
Therefore the cooling down of the evaporator become necessary.
Cooling down of the evaporator is simply a few steps of the normal start up procedure.
After recovering the failure or trip, carry out the cooling down as follows.

(1) Start seawater supply to rejection section condenser.

(2) Start make up pump.

(3) Start make up seawater supply to the brine line.

(4) Start brine recirculation pump.

(5) Circulate the brine while supplying make up and discharging blowdown until the brine temperature measured at any point of recirculating brine line falls below 50 °C.

NOTE

If the situation allows, hot brine remaining in the evaporator may be drained through drain valves and by operating blowdown line before starting make up seawater supply.

(Appendix 5. 3. 1)

ROUTINE CHECK. LIST	SYSTEM NO. BR	SYSTEM NAME :	PAGE : CL1

INSPECTION OBJECT	INSPECTION ITEM	INSPECTION FREQUENCY	REMARKS *SET POINT *ALARM POINT *TRIP POINT *OTHERS
Evaporator	1. Check distillate reflash in each stage.	Daily	a) Flash tank distillate level 250 mm
	2. Check brine level in each stage.		b) Last stage brine level (Alarm) : 50 mm (Low)
	3. Inspect gauges and indicators for legibility , loseness and cracks.		
	4. Check for leakage from connections of pipes.		
Brine Heater	1. Check condensate level in the hotwell.	Daily	a) Brine heater condensate level 250 mm
	2. Check for leakage from connections of pipes.	Daily	
Ejector Condenser	1. Check for leakage from connections of pipes.	Daily	

(Appendix 5. 3. 1)

ROUTINE CHECK. LIST	SYSTEM NO. BR	SYSTEM NAME :	PAGE : CL2

INSPECTION OBJECT	INSPECTION ITEM	INSPECTION FREQUENCY	REMARKS *SET POINT *OTHERS *ALARM POINT *TRIP POINT
<u>Ball Cleaning System</u>			
<u>Ball Strainer</u>	1. Check for pressure drop.	Daily	
<u>Ball Collector</u>	1. Check for leakage from pipe connection.	Daily	
<u>Horizontal Pump</u>	1. Check lubricating oil level. Top up when lowered.	Daily	
	2. Check delivery pressure.	Daily	
	3. Check effluent from gland.	Daily	
	4. Check noise.	Daily	
	5. Check vibration (by hand).	Daily	
	6. Check bearing temperature (by hand).	Daily	
	7. Check leakage from pipe connections.	Daily	

ROUTINE CHECK. LIST	SYSTEM NO. BR	SYSTEM NAME :	PAGE : CL4

INSPECTION OBJECT	INSPECTION ITEM	INSPECTION FREQUENCY	REMARKS *SET POINT *OTHERS *ALARM POINT *TRIP POINT
Electric Motors			
	1. Check noise use noise feeling stic when abnormality is suspected.	Daily	
	2. Check bearing and Frame temperature (by hand, or and by thermometer when abnormality is suspected).	Daily	
	3. Check oil level of bearing housing (where oil lubrication is applied).	Daily	
	4. Check vibration (by hand).	Daily	
	5. Check current and voltage.	Daily	

ROUTINE CHECK LIST	SYSTEM NO. BR	SYSTEM NAME :	PAGE : CL5

INSPECTION OBJECT	INSPECTION ITEM	INSPECTION FREQUENCY	REMARKS *SET POINT *OTHERS *ALARM POINT *TRIP POINT
<u>Chemical Injection</u>			
<u>Pump</u>			
	1. Check noise.	Daily	
	2. Check vibration.	Daily	
	3. Check leakage from pipe connection.	Daily	
<u>Strainer</u>			
	1. Check prssure after strainer.	Daily	
<u>Tank and Agitator</u>			
<u>Tank</u>	1. Check for leakage.	Daily	
<u>Agitator</u>	1. Check vibration (by hand).	Daily	

(Appendix 5.3.1)

LOG SHEET (1)

Unit No. ________ Data / /

Item	Tag No.	Unit	Time											
Seawater reject.out temp.	TR - 102	℃												
Top brine temp.	TR - 303	℃												
Last stage vacuum	PR - 506	cmHgV												
Decarbonator out PH	PHR - 201													
Recirc brine PH	PHR - 301													
Make up DO2	DOR - 201	ppb												
Brine DO2	DOR - 301	ppb												
Condensate conductivity	CR - 601	μ υ / cm												
Product conductivity	CR - 401	μ υ / cm												
Seawater to reject. flow	FR - 101	m^3 / hr												
Make up flow	FR - 201	m^3 / hr												
Recirc. brine flow	FR - 301	m^3 / hr												
Seawater reject. out temp.	TIC - 102	℃												
Top brine temp.	TIC - 303	℃												
Heating steam press.	PIC - 606	kg/cm²G												
Make up flow	FIC - 201	m^3 / hr												
Ratio control for acid inject.	Fr - 201	%												
Ratio control for anti scale inject.	Fr - 202	%												
Recirc brine flow	FIC - 301	m^3 / hr												
Deaerator level	LIC - 202													
Last stage brine level	LIC - 507													
Supply steam press.	PI - 605	kg/cm²G												
Seawater temp.	TR - 101	℃												
Make up temp. (Deaerator)	TR - 201	℃												
Recirc. brine temp.	TR - 301	℃												
Brine heater inlet brine temp.	TR - 302	℃												
Brine heater shell temp.	TR - 602	℃												
Anti scale inject. pump speed														
Acid inject. pump speed														
Sodium inject. pump speed														
Antifoam inject. pump speed														

(Appendix 5.3.1)

LOG SHEET (2)

Unit No. ________ Data / /

Item	Tag No.	Unit	Time											
Heating steam temp.	TI - 601	℃												
Brine heater shell press.	PI - 603	kg/cm^2G												
Brine heater condensate level	LIC - 601													
Brine heater outlet brine temp.	TI - 309	℃												
Brine heater outlet brine press.	PI - 303	kg/cm^2G												
Brine heater inlet brine temp.	TI - 308	℃												
Brine heater inlet brine press.	PI - 302	kg/cm^2G												
Vapour temp. 1st st.	TI - 501	℃												
Vapour temp. 2st st.	TI - 502	℃												
Vapour temp. 3st st.	TI - 503	℃												
Vapour temp. 4st st.	TI - 504	℃												
Vapour temp. 5st st.	TI - 505	℃												
Vapour temp. last st.	TI - 506	℃												
1st st.press.	PI - 501	kg/cm^2G												
Recirc. brine temp ST 1/2	TI - 307	℃												
Recirc. brine temp ST 2/3	TI - 306	℃												
Recirc. brine temp ST 3/4	TI - 305	℃												
Recirc. brine temp ST 4 inlet	TI - 304	℃												
Seawater temp ST 5 outlet	TI - 106	℃												
Seawater temp ST 5/6	TI - 105	℃												
Seawater temp ST 6 inlet	TI - 104	℃												
Ejector steam press.	PI - 604	kg/cm^2G												
E/C inlet S.W. press	PI -102	kg/cm^2G												
E/C outlet S.W. temp.	TI - 103	℃												
Decarbonator level	LIC - 201													
Flash tank level	LIC - 401													
Flash tank press.	PI - 401	mm HgV												

LOG SHEET (3)

Unit No. __________ Data / /

Item	Tag No.	Unit	Time											
S.W. supply press.	PI - 101	kg/cm^2G												
Brine recirc. pump discharge press.	PI - 301	kg/cm^2G												
Make up pump discharge press.	PI - 201	kg/cm^2G												
Distillate pump discharge press.	PI - 402	kg/cm^2G												
Antiform tank level	LI - 804													
Antiform flow	FI - 804	l/hr												
Antiform pump disch. press.	PI - 804	kg/cm^2G												
Antiscale tank level	LI - 801													
Antiscale flow	FI - 801	l/hr												
Antiscale pump disch. press.	PI - 801	kg/cm^2G												
Sodium tank level	LI - 803													
Sodium flow	FI - 803	l/hr												
sodium pump disch. press.	PI - 803	kg/cm^2G												
Acid tank level	LI - 802													
Acid flow	FI - 802	l/hr												
Acid pump disch. press	PI - 802	kg/cm^2G												
Acid cleaning tank level	LI - 805													
Acid cleaning pump disch. press.	PI -805	kg/cm^2G												
Air tank press.	PI - 001	kg/cm^2G												
Water tank level	LI - 402													
Oil tank level	LI - 901													

(Appendix 5. 3. 1)

LOG SHEET (4) (Boiler)

Unit No. ________ Data / /

Item	Tag No.	Unit	Time											
Oil press.		kg/cm²G												
Oil temp		℃												
Oil flow		l/hr												
Oil pump press.		kg/cm²G												
Heated oil temp.		℃												
Boiler pressure		kg/cm²G												
Water boost pump press.		kg/cm²G												
Softner inlet press.		kg/cm²G												
Feed water flow		m^3/hr												
Blow water flow		m^3/hr												

(Appendix 5.3.1)

LOG SHEET ( ) Unit No. ________ Data   /   /

Item	Tag No.	Unit	Time											

2.3 CHECK DURING NORMAL OPERATION

2.3.1 Data Reading

The readings of panel instruments and local instruments shall be logged periodically on log sheets.

The logged data shall be served for checking of plant production, thermal performance and operating conditions of the equipment.

When readings are not usual, such condition should be confirmed by the readings of related line or equipment condition or by using other calibrated instrument and appropriate countermeasure should be taken to recover it.

Recommended form of the plant log sheet is attached herewith.

2.3. CHECK DURING NORMAL OPERATION

2.3.2 Functional Checks

Control room operators must take note of any changes in operating conditions.

Local operators shall also make regular patrols over the entire desalination plant and report any abnormality when found.

LOOK	-	for leak, smoke, discoloration, deposition, water accumulations, steam escape, etc.
LISTEN	-	for sound, noise and squealing, etc.
FEEL	-	for heat, vibration, etc.
SMELL	-	for scent of burning or leaking.

A periodical functional checks shall be carried out by analyzing operational data obtained at the control panel and also local instruments. If any abnormal function is noted, immediate corrective action shall be taken to avoid consequent damages and a possible shut down. In case of disturbance in operation, refer to "TROUBLE SHOOTING" in this section and take correct action immediately.

Following items shall be checked daily and occasionally.

2.3 CHECK DURING NORMAL OPERATION

2.3.2 Functional Checks (cont'd)

a. Brine Concentration

The concentration of recirculating brine is one of the most important factor in designing and operating of seawater desalination plant.
The concentration shall preferably be confirmed by water analysis in the terms of total dissolved solids or of specific scale forming components. However, when the seawater concentration is observed steady and constant by regular analysis, this can easily checked through the mass balance of the plant operation using the following formula.

$$CR = \frac{Wmu \times Rmu \ (Wbr \times Rbr - Wd \times Rd)}{(Wmu \times Rmu - Wd \times Rd) \times Wbr \times Rbr}$$

$$Cbr = CR \times Csw$$

Where,

CR	:	Concentration ratio = Cbr/Csw (——)
Cbr	:	Concentration of recirculating brine (ppm)
Csw	:	Concentration of seawater (ppm)
Wmu	:	Make-up water flow rate (m^3/hr)
Wbr	:	Recirculating brine flow rate (m^3/hr)
Wd	:	Product water flow rate (m^3/hr)
Rmu	:	Density of make-up water (kg/m^3)
Rbr	:	Density of recirculating brine (kg/m^3)
Rd	:	Density of product water (kg/m^3)

Cbr shall not be more than 58,500 ppm as total dissolved solids (TDS).
Unacceptable level of concentration will cause precipitation of non-alkaline scale in the tubes of brine heater and heat recovery section.

2.3 CHECK DURING NORMAL OPERATION

2.3.2 Functional Checks (cont'd)

b. Chemical Injection Rate

For anti scale chemical, anti foam chemical and sodium sulphite, the following calculation can be applied for checking of consumption and injection rate.
The injection rates of the chemicals indicated in the heat and mass balance diagram are to be considered as standard dosage.
The injection rates may be optimised while observing the effects of the chemicals.

(1) Consumption

W = Q x C

W (kg/hr) : Consumption rate of chemical

Q (m^3/hr) : Consumption of chemical solution obtained from :

a. descent of tank level
b. pump capacity by stroke indicator

C (kg/hr) : Concentration of chemical solution actually made.

(2) Injection Rate

R = (W / Wmu) x 1000

R (ppm) : Injection rate of chemical

W (kg/hr) : Consumption rate of chemical

Wmu (m^3/hr) : Average make up seawater flow rate.

2.3 CHECK DURING NORMAL OPERATION

2.3.2 Functional Check (cont'd)

c. Water Production

Water production is checked from the operating condition using the following equation.

$$Wdc = \frac{Wbr}{Wbr'} \times \frac{Tmax - Tr}{Tmax' - Tr'} \times Wd' \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where

Wbr : Measured recirculating brine flow rate (m^3/hr)

Wbr' : Design recirculating brine flow rate (m^3/hr)

Tmax : Measured top brine temperature (°C)

Tmax' : Design top brine temperature (°C)

Tr : Measured last stage brine temperature (°C)

Tr' : Design last stage brine temperature (°C)

Wd' : Design product water flow rate (m^3/hr)

Wdc : Calculated product water flow rate (m^3/hr)

2.3 CHECK DURING NORMAL OPERATION

2.3.2 Functional Check (cont'd)

c. Water Production (cont'd)

Another calculation is made by the equation below :

$$Wdc = \frac{2Cpbm\ (Tmax - Tr)}{2Lm + Cpbm\ (Tmax - Tr)} \times Wbr \times \frac{Rbr}{Rd} \quad .....(2)$$

Where

Cpbm	:	Specific heat of recirculating brine at mean temperature (Tmax + Tr)/2	(kcal/kg)
Lm	:	Latent heat of vapour at mean temperature (Tmax + Tr)/2	(kcal/kg)
Rd	:	Density of product water	(kg/m^3)
Rbr	:	Density of recirculating brine	(kg/m^3)
Wdc	:	Calculated product flow rate	(m^3/hr)

2.3 CHECK DURING NORMAL OPERATION

2.3.2 Functional Check (cont'd)

d. Gained Output Ratio

Gained output ratio (GOR) is calculated by the following formula.

(1) As Plant Performance

$$GOR = \frac{Wd}{Ws}$$

$$Ws = Wc \times Rc + Wse$$

(2) As Evaporator Performance

$$GOR = \frac{Wd}{Wc \times Rc}$$

Where	Ws	:	Steam for desalination plant	(kg/hr)
	Wc	:	Condensate flow rate	(m^3/hr)
	Rc	:	Density of condensate	(kg/m^3)
	Wse	:	Steam for ejector	(kg/hr)

The daily transition of GOR shall be watched carefully. If abrupt decrease is found, anti scale chemical feed system must be checked for its operation.

2.4 WATER ANALYSIS

2.4.1 General

The desalination plant has been designed based on the results of chemical analysis of seawater. The change in chemical compositions of the seawater will affect qualitative and quantitative plant production and sometimes will affect plant material resistivity. Therefore, if unacceptable level of components is found, the plant operation must be re-adjusted in order not to cause troubles and to keep reliable production or keep the plant safe.

The scale precipitation which greatly affect the performance of the plant is depending on the concentrations of scale components such as Ca^{++}, Mg^{++}, SO_4^{--} and strength of alkalinity.
The tendency of the precipitation is also affected by the amount of total dissolved solid content.

In addition, the electrical conductivity of the product water and the condensate return may be measured for checking of the reliability of the plant inistalled instruments.

2.4.2 Guidance of Water Analysis

The following table shows general guidance of chemical analysis for good operation of the desalination plant. Excessive deviations from the normal values will predict contamination of streams or unsatisfactory operation of the plant. In such case proper countermeasure should be taken immediately.

NOTE

Measurment of electrical conductivity is very useful as it represents the content of chloride ion or total dissolved solids, and is instant and simple.
Typical relation curve of electrical conductivity and total dissolved solids for seawater is attached in this chapter. However, it is recomended to make calibration curve from the actual seawater at the site.

2.4 Water Analysis

2.4.2 Guidance of Water Analysis (Cont'd)

RECOMMENDED INTERVALS FOR WATER ANALYSIS

Item	Fluid	Seawater Brine	Recycle Water	Product
pH	Biweekly	Weekly		
Conductivity		Daily	Daily	Daily
M-Alkalinity		Biweekly		
Chloride Ion		Biweekly	Weekly	
Sulfate Ion	Biweekly			
Total Hardness		Biweekly		
Residual Chlorine	As needed			
Hydrogen sulphide		Seasonally		
Ammonia	Seasonally			

2.4 WATER ANALYSIS

2.4.2 Guidance of Water Analysis (Cont'd)

Following data given in the specification is taken into consideration in designing the desalination plant.

	Unit	Data	Normal Seawater*
pH	-	8.2	
Turbidity	NTU		
Electrical conductivity	umho/cm		
Total alkalinity as $CaCO_3$	ppm		
M-alkalinity as $CaCO_3$	ppm		
Total hardness as $CaCO_3$	ppm		
Total dissolved solid at 100 ^{o}C	ppm	45,000	35,174
Suspended solid	ppm		
Calcium	ppm		408
Magnesium	ppm		1,297
Sodium	ppm		10,768
Potasium	ppm		388
Iron	ppm		1.3
Copper	ppm		
Chloride	ppm	25,000	19,360
Sulphate	ppm		2702
Bicarbonate as $CaCO_3$	ppm		116
Carbonate as $CaCO_3$	ppm		
Nitrate nitrogen	ppm		
Silicate as SiO_2	ppm		
Total sulphide as H_2S	ppm		
Free CO_2	ppm		
Oil content			

2.4 WATER ANALYSIS

2.4.2 Guidance of Water Analysis (Cont'd)

NOTE

* : "Normal seawater" as prepared by the Hydrographic Laboratories of Copenhagen, Denmark.